2015 Transducers – 2015 18th International Conference on Solid-State Sensors, Actuators and Microsystems

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Pages 1-767

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MONDAY PROGRAM

Sunday, June 21

07:30	**Short Course Registration** (Hilton Anchorage)
08:00 - 12:00	**Short Courses** (Hilton Anchorage)
09:30 - 18:00	**International Contest of Application in Nano-Micro Technology (iCAN)**
14:00 - 19:00	**Conference Registration / Check-In Opens**
17:00 - 19:00	**Welcome Reception**

Monday, June 22

07:00	**Registration/Check-In Continues**
07:00 - 08:15	**Continental Breakfast & Exhibit Inspection**
08:15 - 08:45	**Welcome Address -** Conference Chair: Thomas Kenny, Ph.D., *Stanford University, USA* **Technical Program Introduction -** Technical Program Chair: Victor Bright, Ph.D., *University of Colorado, Boulder, USA*
08:45 - 09:00	**IEEE Electron Devices Society Fellows Recognition** **IEEE Electron Devices Society Robert Bosch Micro and Nano Electro Mechanical Systems Award Recipients –** **Roger T. Howe, Ph.D.,** *Stanford University, USA* **Yu-Chong Tai, Ph.D.,** *California Institute of Technology, USA* The Robert Bosch Micro and Nano Electro Mechanical Systems Award was established by the IEEE Electron Devices Society in 2014 to recognize and honor advances in the invention, design, and/or fabrication of micro- or nano- electromechanical systems and/or devices. The 2015 Bosch Awards will be presented by IEEE EDS President, Albert Wang, Ph.D.
09:00 - 09:40	**PLENARY I** **Chair:** G. Fedder, *Carnegie Mellon University, USA* **M1G.001** **RADIOVOLTAICS: HIGH-EFFICIENCY CONVERSION OF IONIZING RADIATION DIRECTLY TO ELECTRICAL POWER** ..... 1 D. Coso[1], J. Segal[2], J. Hasi[2], C. Kinney[2], S. Chu[1], S. Yee[3], **Arun Majumdar, Ph.D.**[1] [1]*Stanford University, USA,* [2]*SLAC National Accelerator Laboratory, USA, and* [3]*Georgia Institute of Technology, USA*
09:40 - 10:20	**PLENARY II** **Chair:** P.M. Sarro, *Delft University of Technology, THE NETHERLANDS* **M1G.002** **E-HEALTH: FROM SENSORS TO SYSTEMS** ..... 3 Giovanni De Micheli, Ph.D. *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND*
10:20 - 11:00	**Break & Exhibit Inspection**
11:00 - 11:40	**PLENARY III** **Chair:** S. Konishi, *Ritsumeikan University, JAPAN* **M1G.003** **THE FUTURE LIFE SUPPORTED BY INTERACTIVE HUMANOID** ..... 7 Hiroshi Ishiguro, Ph.D. *Osaka University, JAPAN and ATR Hiroshi Ishiguro Laboratories, JAPAN*
11:40 - 11:50	**Transducers 2017 Conference Presentation**
11:50 - 12:00	**Final Announcements**
12:00 - 13:30	**Lunch on Own & Exhibit Inspection**
13:30 - 15:30	**Poster/Oral Session M3P** Poster/Oral presentations are listed by topic category with their assigned number starting on page 64.
15:30 - 16:00	**Break & Exhibit Inspection**

MONDAY PROGRAM

Session M4A
Inertial Sensors

TIKAHTNU A

Session Co-Chairs:
F. Laermer, *Robert Bosch GmbH Stuttgart, GERMANY*

T. Tsuchiya, *Kyoto University, JAPAN*

16:00 - 16:15

M4A.001

CMOS INTEGRATED POLY-SiGeMEMS ACCELEROMETER ABOVE 0.18 µM TECHNOLOGY

A. Ray Chaudhuri [1,2], P. Helin[1], R. van den Hoven[3], S. Severi[1], X. Rottenberg[1], R.F. Yazicioglu[1], A. Witvrouw[4], L.A. Francis[2], and H.A.C. Tilmans[1]
[1]*imec, BELGIUM,* [2]*Université Catholique de Louvain, BELGIUM,* [3]*Holst Centre/Imec, THE NETHERLANDS, and* [4]*KULeuven, BELGIUM*
.....11

The paper demonstrates the very first CMOS integrated monolithic MEMS Accelerometer with SiGeMEMS technology combined with TSMC 0.18 µm CMOS technology. The developed SiGeMEMS technology shows ability to integrate above any standard foundry process. This allows us to build the smallest form-factor surface micromachined accelerometer. The accelerometer dimension is one of the smallest of its kind for the consumer application.

Session M4B
Electrostatic Power MEMS

TIKAHTNU B

Session Co-Chairs:
D. Arnold, *University of Florida, USA*

P. Mitcheson, *Imperial College London, UK*

16:00 - 16:15

M4B.001

INVITED SPEAKER

ELECTRET BASED VIBRATION ENERGY HARVESTER FOR SENSOR NETWORK

Y. Suzuki
University of Tokyo, JAPAN
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Energy harvesting is an enabling technology for wireless sensor network and low-power-consumption wearable devices. Among various energy sources in the environment, structural vibration and human motion are most abundantly distributed. Since kinetic energy of the vibration is mainly located in the low-frequency range, electrostatic induction generator using electrets attracts much attention. In this talk, recent advances of electret materials, charging methods, and device technologies are reviewed, and rich opportunity of MEMS technologies for further developments will be discussed.

Session M4C
Medical Measurements & Instrumentation

TIKAHTNU CD

Session Co-Chairs:
S. Konishi, *Ritsumeikan University, JAPAN*

S. Tatic-Lucic, *Lehigh University, USA*

16:00 - 16:15

M4C.001

INVITED SPEAKER

INERTIAL-BASED CONTROL SYSTEM CONCEPTS FOR THE TREATMENT OF MOVEMENT DISORDERS

H. Cagnan[1], P. Brown[1], D. Bourget[2], and T. Denison[2]
[1]*Nuffield Department of Clinical Neurosciences, University of Oxford, UK and* [2]*Medtronic Neuromodulation, USA*
.....70

The emergence of micropower inertial sensors is enabling opportunities for embedding sensors both within medical implants and in distributed peripheral instrumentation. Inertial sensing inside the body got its start with rate-responsive cardiac pacing. Building on that concept, accelerometers were adapted for use in the first adaptive neuromodulation system, which provides real-time posture and activity feedback to a spinal cord stimulator implanted for the treatment of chronic pain. This paper provides a survey of new technology concepts being explored for neurological disorders, including both the neuroscience basis for the algorithms and the technical hurdles that remain for their implementation.

Session M4D
Tactile, Fluidic & Implantable Devices

TIKAHTNU EF

Session Co-Chairs:
C. Livermore, *Northeastern University, USA*

P. Woias, *University of Freiburg - IMTEK, GERMANY*

16:00 - 16:15

M4D.001

FLIPPED CMOS-DIAPHRAGM CAPACITIVE TACTILE SENSOR SURFACE MOUNTABLE ON FLEXIBLE AND STRETCHABLE BUS LINE

S. Asano[1], M. Muroyama[1], T. Bartley[1], T. Kojima[1], T. Nakayama[2], U. Yamaguchi[2], H. Yamada[2], Y. Nonomura[3], Y. Hata[3], H. Funabashi[3], and S. Tanaka[1]
[1]*Tohoku University, JAPAN,* [2]*Toyota Motor Corporation, JAPAN, and* [3]*Toyota Central R&D Labs., Inc., JAPAN*
.....97

We have developed a configuration for a MEMS-CMOS integrated tactile sensor on a flexible and stretchable wire for covering a robot body. A sensing diaphragm is made on a CMOS wafer by backside etching. The CMOS wafer is flip-bonded to a low-temperature cofired ceramics (LTCC) via wafer and electrically connected using Au-Au bonding, which also formed differential capacitive gaps. The flexible and stretchable wire, which was fabricated by metal etching and laser cut, was tested for reliability.

Session M4E
LF Resonant Systems & Sensors

TUBUGHNENQ

Session Co-Chairs:
J. Hsieh, *Asia Pacific Microsystems, TAIWAN*

M. Ziaei-Moayyed, *iSono Health, USA*

16:00 - 16:15

M4E.001

ZERO QUIESCENT POWER VLF MECHANICAL COMMUNICATION RECEIVER

R. Liu, J. Naghsh Nilchi, Y. Lin, T.L. Naing, and C.T.-C. Nguyen
University of California, Berkeley, USA
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A first-in-kind all-mechanical communication receiver front-end employing resonant micromechanical switch (i.e., resoswitch) technology has detected and demodulated frequency shift keyed (FSK) information signals as low as -60dBm at an LF frequency of 20kHz suitable for extremely long-range communications, all while consuming zero quiescent power when in standby.

MONDAY PROGRAM

Session M4A Inertial Sensors	Session M4B Electrostatic Power MEMS	Session M4C Medical Measurements & Instrumentation	Session M4D Tactile, Fluidic & Implantable Devices	Session M4E LF Resonant Systems & Sensors
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
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16:15 - 16:30

M4A.002

SUBSTRATE-DECOUPLED SILICON DISK RESONATORS HAVING DEGENERATE GYROSCOPIC MODES WITH Q IN EXCESS OF 1-MILLION

R. Mirjalili[1], H. Wen[1], D.E. Serrano[2], and F. Ayazi[1,2]
[1]*Georgia Institute of Technology, USA and*
[2]*Qualtré Inc., USA*

.....15

We present a center-supported solid disk resonator in <100> single-crystalline-silicon (SCS) that uses a novel substrate decoupling structure to achieve ultra low dissipation gyroscopic modes with small frequency split. The secondary bulk acoustic wave (BAW) elliptic modes (m=3) of a 2mm diameter substrate-decoupled disk resonator exhibit Q of ~1.3M with 40ppm frequency split (as fabricated) at 2.745MHz. Pressure and temperature behavior of the Q is in very close agreement with FEM predictions.

INVITED CONTINUED

INVITED CONTINUED

M4D.002

MICROFABRICATED PLGA/PVA-BASED COMPLETELY BIODEGRADABLE PASSIVE RF PRESSURE SENSORS

M. Luo[1], W. Shen[2], and M.G. Allen[2]
[1]*Georgia Institute of Technology, USA and*
[2]*University of Pennsylvania, USA*

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We report a microfabricated, completely biodegradable passive RF pressure sensor with rapid degradation rate. The sensor utilizes a "shell-core" dielectric structure consisting of poly(lactic-co-glycolic) acid and poly(vinyl alcohol) to achieve rapid degradation. Zn is chosen as the biodegradable electrical conductor. The fabricated sensor was characterized wirelessly in a long-term immersion test in vitro. Full functionality and an in vitro degradation lifetime of 25 days were demonstrated.

M4E.002

A SINGLE-CHIP OSCILLATOR BASED ON A DEEP-SUBMICRON GAP CMOS-MEMS RESONATOR ARRAY WITH HIGH-STIFFNESS DRIVING SCHEME

H.-C. Su, M.-H. Li, C.-Y. Chen, and S.-S. Li
National Tsing Hua University, TAIWAN

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This work reports the design of a monolithic oscillator based on a low motional impedance CMOS-MEMS resonator array with high-stiffness driving scheme in a standard 0.35 um CMOS. Combined with polysilicon release process and the proposed "contact-array-assisted" gap spacing design, a tiny equivalent transducer's gap of only 190 nm is successfully attained.

MONDAY PROGRAM

Session M4A Inertial Sensors	Session M4B Electrostatic Power MEMS	Session M4C Medical Measurements & Instrumentation	Session M4D Tactile, Fluidic & Implantable Devices	Session M4E LF Resonant Systems & Sensors
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16:30 - 16:45				
M4A.003	**M4B.003**	**M4C.003**	**M4D.003**	**M4E.003**
AN AUTOMATIC ACCELERATION COMPENSATION SYSTEM FOR A SINGLE-MASS MEMS GYROSCOPE H.D. Gavcar, K. Azgin, S.E. Alper, and T. Akin *Middle East Technical University (METU), TURKEY* .....19 This paper presents the architecture and experimental verification of an automatic acceleration compensation system applied to a single-mass MEMS gyroscope. The proposed method keeps the proof mass of the gyroscope stationary irrespective to the external accelerations, suppressing the g-sensitivity of the gyroscope bias up to 12 times. This is achieved by dedicated acceleration cancellation electrodes, eliminating any degradation of the bias stability and noise performance during compensation.	**LONG TIME POWER ENHANCEMENT OF VERTICAL CAPACITIVE ENERGY HARVESTER USING MAGNETIC REPULSIVE FORCE** T. Takahashi[1], M. Suzuki[1], T. Nishida[2], Y. Yoshikawa[2], and S. Aoyagi[1] [1]*Kansai University, JAPAN and* [2]*ROHM Co. Ltd., JAPAN* .....47 We propose a method of enhancing output power by magnetic repulsive force in a vertical capacitive energy harvester using electret (Fig. 1(b)). Since electrostatic attraction between dielectric mass and electret plate is reduced by magnetic force, the mass velocity is increased, which leads to the sharp current peak and high output power. The device achieved 30 μW (1.5 times compared to that without magnet), which was kept even after 2 million vibration cycles (31 hour).	**REAL TIME MECHANICAL CHARACTERIZATION OF DNA IN LIQUID DURING A RADIOTHERAPY TREATMENT AND ITS THEORETICAL ANALYSIS** G. Perret[1,3], T. Lacornerie[2], F. Manca[3], S. Giordano[3], M. Kumemura[1,4], N. Lafitte[1,4], L. Jalabert[1], E. Lartigau[2], T. Fujii[1,4], F. Cleri[3], H. Fujita[1,4], and D. Collard[1,4] [1]*LIMMS/CNRS-IIS, JAPAN,* [2]*University of Lille 2, FRANCE,* [3]*University of Lille 1, FRANCE, and* [4]*University of Tokyo, JAPAN* .....74 We report the first real-time biomechanical measurement of DNA bundle degradation in stable condition when exposed to a therapeutic radiation beam and a theoretical model to describe DNA damages. The Silicon Nano Tweezers and their new microfluidic system endure the harsh environment of radiation beams and still retain molecular-level accuracy. This result paves the way for both fundamental and clinical studies of DNA degradation under radiation for improved tumor treatment.	**MICRO HYDRAULIC PRESSURE SENSING STENT** A. Bulbul, A. Tandar, A. Patel, and H. Kim *University of Utah, USA* .....105 This paper reports both the novel configuration and the operation principle of a pressure sensing stent that completely incorporates a micro pressure sensor into the stent wire and achieves 75 times amplification in output signals of capacitive sensing via micro-scale hydraulic movement.	**7TH ORDER SHARP-ROLL-OFF BRIDGED MICROMECHANICAL FILTER** J. Naghsh Nilchi, R. Liu, and C.T.-C. Nguyen *University of California, Berkeley, USA* .....137 A 7th-order capacitive-gap transduced 8-MHz micromechanical filter has been demonstrated with a channel-selecting bandwidth of 24kHz (0.3%) and a shape factor of 1.45, which bests the previous mark of 1.86 for a similar frequency MEMS-based filter [1]. This shape factor arises not only from the sheer order of the filter, governed by seven coupled clamped-clamped resonators, but also from strategic bridging of the non-adjacent 1st, 4th, and 7th resonators to generate loss poles that further steepen the roll-off from passband to stopband.

MONDAY PROGRAM

Session M4A
Inertial Sensors

TIKAHTNU A

Session Co-Chairs:
F. Laermer, *Robert Bosch GmbH Stuttgart, GERMANY*

T. Tsuchiya, *Kyoto University, JAPAN*

Session M4B
Electrostatic Power MEMS

TIKAHTNU B

Session Co-Chairs:
D. Arnold, *University of Florida, USA*

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Session M4C
Medical Measurements & Instrumentation

TIKAHTNU CD

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Session M4D
Tactile, Fluidic & Implantable Devices

TIKAHTNU EF

Session Co-Chairs:
C. Livermore, *Northeastern University, USA*

P. Woias, *University of Freiburg - IMTEK, GERMANY*

Session M4E
LF Resonant Systems & Sensors

TUBUGHNENQ

Session Co-Chairs:
J. Hsieh, *Asia Pacific Microsystems, TAIWAN*

M. Ziaei-Moayyed, *iSono Health, USA*

16:45 - 17:00

M4A.004

A DUAL-MODE GYROSCOPE ARCHITECTURE WITH IN-RUN MODE-MATCHING CAPABILITY AND INHERENT BIAS CANCELLATION

A. Norouzpour-Shirazi[1], D.E. Serrano[2], M.F. Zaman[2], G. Casinovi[1], and F. Ayazi[1]
[1]*Georgia Institute of Technology, USA and*
[2]*Qualtré Inc., USA*
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We introduce a novel dual-mode actuation and sensing scheme for readout and calibration of axisymmetric Coriolis resonant gyroscopes. A dual-mode simultaneous actuation and sensing, along with summation and difference functions on the sense outputs is used to demonstrate twofold enhancement of sensitivity and SNR, automatic in-run mode-matching capability, and complete cancellation of bias terms down to sub-10°/hr levels. The proposed scheme enables online scale factor self-calibration.

M4B.004

A SANDWICH-STRUCTURED MEMS ELECTRET POWER GENERATOR FOR MULTI-DIRECTIONAL VIBRATION ENERGY HARVESTING

K. Tao, S.W. Lye, N. Wang, X. Hu, and J.M. Miao
Nanyang Technological University, SINGAPORE
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We design and fabricate a MEMS electret power generator for multi-directional vibration energy harvesting by using two orthogonal vibration degrees of freedom. Sandwich structure is adopted to reduce both vertical pull-in and horizontal damping force with two separate 180 out-of-phase capacitive circuits.

M4C.004

MEMS FOR SINGLE-ISLET ELECTROISLETOGRAM

Y. Liu[1], A. Shapero[1], X. Zhang[1], D. Kang[1], J. Park[1], L. Xu[1], K. Chang[1], H. Lin[2], K. Ferreri[2], and Y.C. Tai[1]
[1]*California Institute of Technology, USA and*
[2]*City of Hope, USA*
.....77

This paper reports the first MEMS device designed for in-vitro measuring of electroisletogram (EIG) of individual rat islet. Using vacuum to hold an islet in proximity to a microelectrode, strong EIG signals in millivolt range are obtained, while the noise is about 100 micro-volt pk-pk. This work proves the feasibility of using MEMS and EIG for high-throughput screening, in contrast to patchclamp measurements, of islets for transplantation to treat diabetes.

M4D.004

PHOTO-SWITCHABLE MICROVALVE IN A REUSABLE LAB-ON-A-DISC

T. Glennon[1], J. Saez[2], M. Czugala[1], L. Florea[1], E. Mcnamara[1], K.J. Fraser[1], J. Ducrée[1], D. Diamond[1], and F. Benito-Lopez[2]
[1]*Dublin City University, IRELAND and*
[2]*CIC microGUNE, SPAIN*
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The abstract describes for the first time the fabrication and the performance of a reversible ionogel microvalve in- situ photopolymerised into a reusable disc platform for fluid control.

M4E.004

STUDY OF BROADBAND PROPAGATION CHARACTERISTIC OF QUASI-FRACTAL PHONONIC CRYSTAL FOR ENHANCED SENSING APPLICATIONS

B. Figeys[1,2], R. Jansen[1], S. Severi[1], B. Nauwelaers[2], H.A.C. Tilmans[1], and X. Rottenberg[1]
[1]*imec, BELGIUM and*
[2]*KU Leuven, BELGIUM*
.....141

We report on BAW resonators with quasi-fractal perforations for increased sensitivity in bio-sensing applications. Fractal perforations increase the surface-to-volume ratio with enhanced sensitivity as a result. Yet higher sensitivities can be obtained by using the resonator at higher resonance frequencies, e.g. higher order modes. We model a device by implementing this phononic crystal as a broadband dispersive transmission line to account for the essential modes of longitudinal resonance.

MONDAY PROGRAM

Session M4A
Inertial Sensors

TIKAHTNU A

Session Co-Chairs:
F. Laermer, *Robert Bosch GmbH Stuttgart, GERMANY*

T. Tsuchiya, *Kyoto University, JAPAN*

Session M4B
Electrostatic Power MEMS

TIKAHTNU B

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P. Mitcheson, *Imperial College London, UK*

Session M4C
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TIKAHTNU CD

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S. Tatic-Lucic, *Lehigh University, USA*

Session M4D
Tactile, Fluidic & Implantable Devices

TIKAHTNU EF

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C. Livermore, *Northeastern University, USA*

P. Woias, *University of Freiburg - IMTEK, GERMANY*

Session M4E
LF Resonant Systems & Sensors

TUBUGHNENQ

Session Co-Chairs:
J. Hsieh, *Asia Pacific Microsystems, TAIWAN*

M. Ziaei-Moayyed, *iSono Health, USA*

17:00 - 17:15

M4A.005

EFFECT OF DIAPHRAGM PERFORATION ON QUALITY FACTOR OF HEMISPHERICAL RESONANCE GYROSCOPE

A. Vafanejad and E.S. Kim
University of Southern California, USA
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In this paper we study the effect of perforation on quality factor of hemispherical resonance devices; FEM study and measurements has been done in order to show the effect of perforation on these resonators.

M4B.005

A SUPER-FLEXIBLE AND LIGHTWEIGHT MEMBRANE FOR ENERGY HARVESTING

M.D. Han, B.C. Yu, X.L. Cheng, B. Meng, and H.X. Zhang
Peking University, CHINA
.....55

An energy harvesting membrane based on contact electrification is presented. This new design includes two highlighted progress. Firstly, the energy harvester is a multi-layer membrane having excellent physical properties such as robust, super-flexible (foldable, rollable), and lightweight (2.7 mg/cm^2). Secondly, this membrane is capable of harvesting multi-type mechanical energy, including different motion styles and various contacted materials.

M4C.005

LONG-TERM ELECTRO-ENCEPHALOGRAM MEASUREMENT USING POLYMER-BASED DRY MICRONEEDLE ELECTRODE

M. Arai[1], Y. Nishinaka[1], and N. Miki[1,2]
[1]*Keio University, JAPAN and* [2]*Japan Science and Technology Agency (JST), JAPAN*
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This paper reports a successful measurement of electroencephalogram (EEG) for hours using polymer-based microneedle electrodes. The tested needles consist of SU-8 needles, a silver film, and a nanoporous parylene protective film. The skin-electrode impedance was low enough for EEG measurement for hours. The acquired EEG signals were found to be as high quality as the standard wet electrode that required skin treatment and uncomfortable pasting of conductive gel.

M4D.005

LEAKAGE-FREE PNEUMATIC MICRO VALVE WITH SEMICIRCULAR FLUID CHAMBER

C.K. Oh[1], J.-Y. Ahn[2], and O.C. Jeong[1]
[1]*Inje University, SOUTH KOREA and* [2]*Chungbuk National University, SOUTH KOREA*
.....

This paper presents the simple and reliable fabrication method of the leakage-free pneumatic valve with the semicircular fluidic chamber. The effectiveness of the proposed valve was verified through the optical observation of the valve pattern and the measurement of the flow rate of the pressurized fluid flow rectified by the fabricated valve. The proposed method provides effective method to overcome drawback of the micro valve with the rectangular-cross-section.

M4E.005

TRANSDUCTION COMPARISON OF A RESONANT TRANSDUCER REALIZED IN A COMMERCIALLY AVAILABLE CMOS-MEMS PLATFORM

C.-Y. Chen[1], M.-H. Li[1], C.-H. Wang[2], and S.-S. Li[1]
[1]*National Tsing Hua University, TAIWAN and* [2]*Industrial Technology Research Institute (ITRI), TAIWAN*
.....145

The CMOS-MEMS platform has become an attractive solution for microsensors monolithically integrated with circuits to enable a single-chip configuration. In this work, we investigate various transduction mechanisms of a resonant transducer, including (i) purely capacitive drive/sense, (ii) capacitive drive/piezo-R sense, and (iii) thermal drive/piezo-R sense, implemented in a commercially available platform (CMOS 0.18um technology) which is mainly developed to accommodate most physical sensors.

MONDAY PROGRAM

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17:15 - 17:30				
M4A.006	**M4B.006**	**M4C.006**	**M4D.006**	**M4E.006**
A NEW THREE AXIS LOW POWER MEMS GYROSCOPE FOR CONSUMER AND INDUSTRIAL APPLICATIONS A.D. Oliver, Y.L. Teo, A. Geisberger, R.F. Steimle, T. Cassagnes, K. Adhikari, D. Sadler, and A. McNeil *Freescale Semiconductor, USA* .....31 This paper is the first publication of a new, commercially available three axis MEMS gyroscope that consumes less power than any other reported device. The power consumption is 20% less than the lowest published competitor or online datasheet at 6.8 mW.	**LIQUID-BASED ELECTROSTATIC ENERGY HARVESTER USING ROTATIONAL MOTION OF FERROFLUID DROPLETS** D. Kim[1], S. Yu[1], B.-G. Kang[2], and K.-S. Yun[1] [1]*Sogang University, SOUTH KOREA and* [2]*LG Electronics Advanced Research Institute, SOUTH KOREA* .....59 We develop a fully liquid-based energy harvester using ferrofluid droplets as a movable dielectric material. The rotational motion of the ferrofluid droplets is actuated by a magnetic field, which causes a capacitance variation that is used to generated electric power. Compared to the previous device, our device is superior in long-term reliability because there is no solid moving part and consequently solid friction in our device.	**DISPOSABLE DIGITAL DRY POWDER MICRO-NEBULIZER DEVICE FOR DRUG STORAGE AND TRIGGERED RELEASE** N. Banerjee, S.S. Pandey, and C.H. Mastrangelo *University of Utah, USA* .....85 This paper presents the fabrication and testing of a novel microfabricated dry powder digital nebulizer device for drug storage and triggered release. The device consists of arrays of 40 µm deep sealed cavities of different volumes containing drug in powder form on a flexible polymer film. Each discrete cavity contains its own micro-heater triggered release mechanism. Approximately 200mJ of heater energy is required to release 1.35µg of powder drug in less than a second.	**LARGE STROKE ELECTROSTATIC ACTUATED PDMS-ON-SILICON MICRO-PUMP** J. Gao, D. Guo, S. Santhanam, and G.K. Fedder *Carnegie Mellon University, USA* .....117 We introduce a large stroke electrostatic micro-pump made from a thin PDMS diaphragm embedded with metal electrodes and bonded over a smoothly curved Si substrate that acts as the counter electrode. The curved substrate significantly reduces actuation voltage, and is fabricated by a new modification to grayscale lithography for Si MEMS. The measured displacement of the diaphragm is greater than 100 µm, giving a displacement volume of 1 µL/stroke, and a pumping rate of 60 µL/min at 1 Hz.	**FABRICATION OF RESONANT SENSORS WITH SIGNIFICANTLY IMPROVED SENSITIVITY THROUGH STRONG MECHANCIAL COUPLING** M.S. Hajhashemi, A. Rasouli, and B. Bahreyni *Simon Fraser University, CANADA* .....149 We are reporting on the first use of strongly coupled resonator arrays to improve the sensitivity of sensor systems to single or multiple inputs. A novel physics-based model is developed to investigate the effect of perturbations on the eigenvalues of resonator arrays, which demonstrates the improvements in sensitivity as the coupling strength between the resonators is increased. The developed theory is employed to design strongly-coupled resonant sensor systems.

MONDAY PROGRAM

Session M4A
Inertial Sensors

TIKAHTNU A

Session Co-Chairs:
F. Laermer, *Robert Bosch GmbH Stuttgart, GERMANY*

T. Tsuchiya, *Kyoto University, JAPAN*

Session M4B
Electrostatic Power MEMS

TIKAHTNU B

Session Co-Chairs:
D. Arnold, *University of Florida, USA*

P. Mitcheson, *Imperial College London, UK*

Session M4C
Medical Measurements & Instrumentation

TIKAHTNU CD

Session Co-Chairs:
S. Konishi, *Ritsumeikan University, JAPAN*

S. Tatic-Lucic, *Lehigh University, USA*

Session M4D
Tactile, Fluidic & Implantable Devices

TIKAHTNU EF

Session Co-Chairs:
C. Livermore, *Northeastern University, USA*

P. Woias, *University of Freiburg - IMTEK, GERMANY*

Session M4E
LF Resonant Systems & Sensors

TUBUGHNENQ

Session Co-Chairs:
J. Hsieh, *Asia Pacific Microsystems, TAIWAN*

M. Ziaei-Moayyed, *iSono Health, USA*

17:30 - 17:45

M4A.007

CONTINUOUS SELF-CALIBRATION CANCELING DRIVE-INDUCED ERRORS IN MEMS VIBRATORY GYROSCOPES

I.P. Prikhodko, C. Merritt, J.A. Gregory, J.A. Geen, J. Chang, J. Bergeron, W. Clark, and M.W. Judy
Analog Devices, Inc., USA
.....35

We report a system for simultaneous rate readout and drift cancellation for MEMS vibratory gyroscopes which demonstrates a five-fold reduction of the output drift without significantly affecting the sensor noise or bandwidth. The drift cancellation is accomplished by periodically reversing polarity of the gyroscope's forcing voltage. This technique may enable high-performance and low-cost MEMS gyroscopes to enter into the market where low-cost fiber optic gyroscopes have traditionally dominated.

M4B.007

A HIGH-EFFICIENCY TRANSPARENT ELECTRIFICATION-BASED GENERATOR FOR HARVESTING DROPLET ENERGY

X.L. Cheng, B. Meng, M.D. Han, H.T. Chen, and H.X. Zhang
Peking University, CHINA
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We present a transparent flexible triboelectric generator for harvesting the energy from droplet effectively. An interdigital-shaped electrode was fabricated on ITO-coated PET film, which made the generator transparent, flexible with hydrophobic surface. Meanwhile, this design allows it to harvest a droplet energy successively. Employed the simple structure and method, high output performance was achieved, while a maximum energy conversion efficiency of about 8.7% was observed.

M4C.007

DEVELOPMENT OF A DISPOSABLE AND FLEXIBLE MICRONEEDLE-FLUIDIC-SYSTEM WITH FINGER DRIVEN DRUG LOADING AND DELIVERY FUNCTIONS

Z. Xiang, H. Wang, G. Pastorin, and C. Lee
National University of Singapore, SINGAPORE
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We will demonstrate a disposable and flexible microneedle-fluidic-system (MFS) which achieves finger driven on-chip drug loading and delivery functions by integrating Polydimethylsiloxane (PDMS) based microfluidic dispensing networks, check valves and micro pump on one device. The drug is delivered by easily squeezing the integrated PDMS micro pump with fingers. The study of inflammation treatment using MFS has been done in vivo for rodents.

M4D.007

FABRICATION OF MICRONEEDLES PRECISELY IMITATING MOSQUITO'S PROBOSCIS BY NANOSCALE TREE DIMENSIONAL LASER LITHOGRAPHY AND ITS CHARACTERIZATION

M. Suzuki, T. Sawa, Y. Terada, T. Takahashi, and S. Aoyagi
Kansai University, JAPAN
.....121

A hollow microneedle imitating mosquito's proboscis is developed using three-dimensional laser lithography, which is divided into two half parts. The tip of each part is three-dimensionally sharpened, and several jagged edges project. The combined halves act as one hollow microneedle, which can draw up human blood by capillary action. The microneedle can puncture an artificial skin without buckling. The resistive force during insertion can be reduced when the two halves are alternately advanced.

M4E.007

A SELF-TEMPERATURE COMPENSATING BAROMETER WITH DUAL DOUBLY-CLAMPED RESONATORS

Z.Y. Luo[1], Y.N. Li[1], B.Y. Xie[1], D.Y. Chen[2], and J.B. Wang[2]
[1]*University of Chinese Academy of Sciences, CHINA and* [2]*Chinese Academy of Sciences, CHINA*
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We have developed a self-temperature compensation method for micro-fabricated pressure sensor featured with dual resonant beams. The two resonant beams have reversed response to the applied pressure, while identical response to temperature, which makes the compensation without external temperature sensing.

MONDAY PROGRAM

Session M4A Inertial Sensors	Session M4B Electrostatic Power MEMS	Session M4C Medical Measurements & Instrumentation	Session M4D Tactile, Fluidic & Implantable Devices	Session M4E LF Resonant Systems & Sensors
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: F. Laermer, *Robert Bosch GmbH Stuttgart, GERMANY* T. Tsuchiya, *Kyoto University, JAPAN*	**Session Co-Chairs:** D. Arnold, *University of Florida, USA* P. Mitcheson, *Imperial College London, UK*	**Session Co-Chairs:** S. Konishi, *Ritsumeikan University, JAPAN* S. Tatic-Lucic, *Lehigh University, USA*	**Session Co-Chairs:** C. Livermore, *Northeastern University, USA* P. Woias, *University of Freiburg - IMTEK, GERMANY*	**Session Co-Chairs:** J. Hsieh, *Asia Pacific Microsystems, TAIWAN* M. Ziaei-Moayyed, *iSono Health, USA*
17:45 - 18:00				
M4A.008	**M4B.008**	**M4C.008**	**M4D.008**	**M4E.008**
ON-CHIP OVENIZATION OF ENCAPSULATED DISK RESONATOR GYROSCOPE (DRG) C.H. Ahn[1], V.A. Hong[1], W. Park[1], Y. Yang[1], Y. Chen[1], E.J. Ng[1], J. Huynh[1], A.D. Challoner[2], K.E. Goodson[1], and T.W. Kenny[1] [1]*Stanford University, USA and* [2]*Inertial Wave Inc., USA* .....39 This paper reports, for the first time, a single-chip ovenization of a fully-encapsulated MEMS gyroscope to improve the stability of the scale factor and bias. We use the frequency output of the gyroscope as a thermometer, and, in turn heat the device through an on-chip silicon heater defined in the encapsulation layer. During temperature-controlled operation, the scale factor is held constant and the bias remains less than 1°/s, even as external temperature changed from 0-80°C.	**DISPOSABLE HYDROGEN FUEL CELLS FOR POWERING NEXT-GENERATION LATERAL FLOW DEVICES** J.P. Esquivel[1,2], J.R. Buser[2], F.J. del Campo[1], S. Rojas[1], P. Yager[2], and N. Sabaté[1] [1]*Consejo Superior de Investigaciones Cientificas (CSIS), SPAIN and* [2]*University of Washington, USA* .....66 A paper-based hydrogen fuel cell with flowing electrolyte is presented. This concept brings together the high power density typically delivered by hydrogen PEM fuel cells with the convenience of portable and disposable paper-based power sources. The device has the potential to fulfill the power requirements of many portable diagnostic devices with a lower environmental impact than other power sources.	**FOUR-LEAF-CLOVER-SHAPED IMMUNE RESPONSE CHIP BY USING OPTOELECTRONIC TWEEZERS FORCE** L.-Y. Ke[1], Z.-K. Kuo[1,2], Y.-S. Chen[1], H.-H. Lo[1], H.-W. Tseng[2], and C.-H. Liu[1] [1]*National Tsing Hua University, TAIWAN and* [2]*Industrial Technology Research Institute (ITRI), TAIWAN* .....93 We study the immune system, the natural killer (NK) cell and target cell needs to contact for cell-cell interaction. Therefore, an optoelectronic tweezers (OET) complex optofluidic system and four-leaf-clover-shaped hydrogel microwells, multilayered platform was designed and fabricated to increase cell-cell interaction. A novel method was used to attract single immune cell into the dead zone by using OET.	**DETACHABLE ULTRASONIC ENABLED INSERTER FOR NEURAL PROBE INSERTION USING BIODISSOLVABLE POLYETHYLENE GLYCOL** P.-C. Chen and A. Lal *Cornell University, USA* .....125 We report a neural probe insertion method to reversibly bond neural probes to a silicon ultrasonic inserter horn to enable ultrasonic actuation during neural probe insertion. Neural probes can be attached using PEG polymer and debonded to the ultrasonic driver by aqueous dissolution. We demonstrate reduced force of insertion corresponding to ultrasonically microcutting of tissue. Reduced insertion forces can lead to less damage and reduced immune response for longer life neural interfaces.	**TEMPERATURE COMPENSATED FUSED SILICA RESONATORS USING EMBEDDED NICKEL-REFILLED TRENCHES** A. Peczalski and M. Rais-Zadeh *University of Michigan, USA* .....157 We report a novel fabrication process that utilizes nickel-refilled trenches to achieve passive temperature compensation in fused silica. Using these scheme, piezoelectrically actuated fused silica resonators are demonstrated with reduced temperature sensitivity and high quality factor. This method can be extended to actuate a compensated and a uncompensated mode of the same device. This is the first time that passive temperature compensation has been shown for fused silica resonators.

20:00 - 23:00 | **Dessert at the Anchorage Museum**

TUESDAY PROGRAM

Tuesday, June 23

07:30 - 08:00 | Continental Breakfast & Exhibit Inspection

Session T1A Mechanical Sensors	Session T1B Optical Systems	Session T1C MEMS Industry Group - Technology Transfer	Session T1D Electro Fluidics	Session T1E Optical Bio Sensing
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Ono, *Tohoku University, JAPAN* E. Wang , *Massachusetts Institute of Technology, USA*	**Session Co-Chairs:** X. Rottenberg, *Imec, Belgium* H. Toshiyoshi, *University of Tokyo, JAPAN*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** S. Choi, *State University of New York at Binghamton, USA* S. Prakash, *Ohio State University, USA*	**Session Co-Chairs:** K. Hishino, *University of Connecticut, USA* F.-G. Tseng, *National Tsing Hua University, TAIWAN*
08:00 - 08:15				
T1A.001	**T1B.001**	**T1C.001**	**T1D.001**	**T1E.001**
			INVITED SPEAKER	INVITED SPEAKER
POWER GENERATING TACTILE SENSOR ARRAY IN WOVEN FABRIC FORM Y. Ahn[1], S. Song[2], and K.-S. Yun[1] [1]*Sogang University, SOUTH KOREA and* [2]*Samsung Electronics Co., SOUTH KOREA* .....161 We propose and demonstrate a power-generating tactile sensor array designed for a self-powered sensor system. An energy harvester and a tactile sensor are integrated in a single device. The device consists of rows and columns of piezoelectric straps woven on a mesh structure of elastic hollow tubes. The results show that we can obtain electrical energy from stretching motion of the device and monitor the tactile input by measuring the capacitance value.	**FABRICATION AND CHARACTERIZATION OF ARRAY OF OPTICAL FIBERS INTEGRATED WITH CONCAVE LENS FOR SPATIAL FLUORESCENT OBSERVATION** H. Ohtake and S. Konishi *Ritsumeikan University, JAPAN* .....192 We report on fabrication and characterization of array of optical fibers integrated with concave lens for spatial fluorescent observation. Recent results will be presented on site.	**MIG INTRODUCTION** K. Lightman *MEMS Industry Group, USA* Ms. Lightman will give an overview of MEMS Industry Group (MIG). The presentation will also introduce the day's Conference track with regard to the MEMS and sensors industry and the challenges and opportunities therein. She will also highlight the day's agenda. NON IEEE Copyrighted Session	**HOW MICROTECHNOLOGIES ENABLE ORGANS-ON-A-CHIP** E. Verpoorte[1], P.E. Oomen[1], M.D. Skolimowski[1], P.P.M.F.A. Mulder[1], P.M. van Midwoud[1], V. Starokozhko[1], M.T. Merema[1], G. Molema[2], and G.M.M. Groothuis[1] [1]*University of Groningen, THE NETHERLANDS and* [2]*University Medical Center Groningen, THE NETHERLANDS* .....224 Engineering cellular microenvironments that more accurately reflect the *in vivo* situation is now recognized as being crucial for the improvement of the *in vitro* viability and *in vivo-like* function of cells or tissues. Microfluidic technologies have been increasingly applied since the late 1990's for this purpose, with a growing number of examples of perfused cell and tissue cultures in microfluidic chambers and channels. More recently, additional microfabricated features have been implemented in microfluidic structures to achieve 3-D cell culture systems which mimic not only *in vivo* fluid flows, but also the structure, transport, and mechanical properties of tissue in, for example, the lung or the intestine. The ultimate challenge becomes the combination of different organ functions into single, linked compartment devices – the body-on-the-chip.	**AXICONS ET AL. - HIGHLY ASPHERICAL ADAPTIVE OPTICAL ELEMENTS FOR THE LIFE SCIENCES** U. Wallrabe *University of Freiburg - IMTEK, GERMANY* .....251 Aspheric lenses or mirrors are used to correct abberations in all kinds of optical systems. In telescopes, for example, the correction needs to be dynamic, and hence a tunable asphericity and higher-order correction are mandatory, and are typically realized by an array of individually controllable mirror segments. The presentation will discuss several new concepts of tunable highly aspheric micro optical elements for various other purposes. It will focus on tunable micro axicons, but also present some free-form approaches, all of which are controlled by means of piezo electric actuators or by thermal expansion. The components are fabricated outside of the cleanroom using laser micro-structuring and polymer casting. Illuminated with ultra short laser pulses they produce variable Bessel or vortex beams which, in case of reflective elements, are almost dispersion free. Applications in life sciences range from the neuro-sciences to magnetic resonance imaging.

TUESDAY PROGRAM

Session T1A Mechanical Sensors	Session T1B Optical Systems	Session T1C MEMS Industry Group - Technology Transfer	Session T1D Electro Fluidics	Session T1E Optical Bio Sensing
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Ono, *Tohoku University, JAPAN* E. Wang , *Massachusetts Institute of Technology, USA*	**Session Co-Chairs:** X. Rottenberg, *Imec, Belgium* H. Toshiyoshi, *University of Tokyo, JAPAN*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** S. Choi, *State University of New York at Binghamton, USA* S. Prakash, *Ohio State University, USA*	**Session Co-Chairs:** K. Hishino, *University of Connecticut, USA* F.-G. Tseng, *National Tsing Hua University, TAIWAN*
08:15 - 08:30				
T1A.002	T1B.002			
FLEXIBLE, PRINTED TACTLE, FRICTION, AND TEMPERATURE SENSOR ARRAY FOR ARTIFICIAL SKIN S. Harada, K. Kanao, Y. Yamamoto, T. Arie, S. Akita, and K. Takei *Osaka Prefecture University, JAPAN* .....164 We develop printed, flexible multifunctional tactile, friction, and temperature sensors for the applications of an artificial electronic skin (e-skin). An e-skin reported previously does not have a capability to detect friction. It is important to allow us to imitate human functionalities and hold an object without dropping and breaking. This is due to difficulty of device fabrication on a flexible substrate. Here, we arrange the structure of device and fabricate using mainly printing technique.	**OPTICAL FIBER ATOMIC FORCE MICROSCOPE WITH PHOTONIC CRYSTAL FORCE SENSOR** A. Gellineau, Y.-P. Wong, A. Wang, M.J. Butte, and O. Solgaard *Stanford University, USA* .....196 We design, fabricate, and characterize a miniaturized atomic force microscope (AFM) directly integrated onto the facet of a standard single-mode optical fiber. The AFM utilizes a photonic-crystal Fabry-Perot force sensor to achieve high force sensitivity. We demonstrate that topography and tip-sample interaction force can be extracted from the optical-reflection signals. The compact and robust design opens new directions for AFM imaging in biology and other application areas.	MIG CONTINUED	INVITED CONTINUED	INVITED CONTINUED

TUESDAY PROGRAM

Session T1A
Mechanical Sensors

TIKAHTNU A

Session Co-Chairs:
T. Ono,
Tohoku University, JAPAN

E. Wang , *Massachusetts Institute of Technology, USA*

Session T1B
Optical Systems

TIKAHTNU B

Session Co-Chairs:
X. Rottenberg,
Imec, Belgium

H. Toshiyoshi,
University of Tokyo, JAPAN

Session T1C
MEMS Industry Group - Technology Transfer

TIKAHTNU CD

Session Chair:
K. Lightman,
MEMS Industry Group, USA

Session T1D
Electro Fluidics

TIKAHTNU EF

Session Co-Chairs:
S. Choi, *State University of New York at Binghamton, USA*

S. Prakash,
Ohio State University, USA

Session T1E
Optical Bio Sensing

TUBUGHNENQ

Session Co-Chairs:
K. Hishino,
University of Connecticut, USA

F.-G. Tseng, *National Tsing Hua University, TAIWAN*

08:30 - 08:45

T1A.003

BALLPOINT PEN LIKE PRESSURE SENSOR WITH LIQUID METAL ELECTRODES

T. Nakadegawa[1]
and N. Miki [1,2]
[1]*Keio University, JAPAN and* [2]*Japan Science and Technology Agency (JST), JAPAN*

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We develop a ballpoint pen-shaped pressure sensor, which can conduct continuous pressure measurement at different locations while a metal ball on the tip rotates. This device has 4 arranged electrodes to form 4 capacitors, surrounding the ball, which can detect the direction of the applied pressure. Note that a liquid metal is used to form the electrodes on the cylindrical sides. The device was fabricated, tested, and verified to be able to detect the pressure and its direction.

T1B.003

POWER EFFICIENT MICROHEATER FOR WAVELENGTH SELECTIVE INFRARED EMITTER AND CO_2 GAS SENSING

H. Ishihara[1], K. Masuno[1], M. Ishii[1], S. Kumagai[2], and M. Sasaki[2]
[1]*Yazaki Corporation, JAPAN and* [2]*Toyota Technical Institute, JAPAN*

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A new microheater for the wavelength selective infrared emitter is fabricated showing the enhanced emission peak due to the surface plasmon polariton. The thermal isolation is improved with 2um-thick Si membrane having 3.6 and 5.4mm outer diameter. The emission at the wavelength of the absorption band of CO2 gas is enhanced confirming the suitability for the gas sensing. Against input power, the intensity at the peak wavelength shows the steeper increase than the background intensity.

T1C.003

HOW TO SUCCESSFULLY TRANSFER MEMS PROTOTYPES FROM LAB TO FOUNDRY

A. Fitzgerald
AM Fitzgerald & Associates, USA

You've got your MEMS prototype working, your business strategy is coming together, and you're starting to think about manufacturing. Now what? In this talk, we will share best practices for choosing the right foundry partner, for preparing the technology for transfer, and for executing a successful transfer while maintaining good relations with your foundry. We'll also cover project planning considerations such as realistic timelines and budgets. We'll share our insights and the lessons we learned from transferring several of our MEMS prototypes to commercial foundries around the world.

T1D.003

AN ELECTROKINETIC DEVICE FOR SELECTIVE PRECONCENTRATION AND ONLINE COLLECTION BASED ON ION CONCENTRATION POLARIZATION

J. Choi[1], K. Huh[1], D.J. Moon[1], J.H. Chae[1], H.C. Kim[1], J.W. Hong[2], and S.J. Kim[1]
[1]*Seoul National University, SOUTH KOREA and* [2]*Hanyang University, SOUTH KOREA*

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This paper reports a device performing selective preconcentration and collection of charged molecules using ion concentration polarization (ICP) and the device, for the first time, allows subsequent processes of highly concentrated and separated molecules on-chip or off-chip in a single solution.

T1E.003

FLUORESCENCE SENSOR ARRAY FOR NON-CONTACT MEASUREMENT OF OXYGEN CONSUMPTION RATE OF SINGLE OOCYTE

H. Maruyama, K. Masanobu, and F. Arai
Nagoya University, JAPAN

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This paper reports non-contact measurement of oxygen consumption rate (OCR) of individual oocyte using fluorescence microsensor array. The sensor was patterned to stripe-shape in the microchannel made of polydimethylsiloxane (PDMS) to avoid the contact of the fluorescence material to oocyte. We kept the spherical diffusion of the target oocyte for calculating OCR using spherical diffusion theory by arranging the sensor stripe-shape. We demonstrated non-contact measurement of OCR of single oocyte

TUESDAY PROGRAM

Session T1A Mechanical Sensors	Session T1B Optical Systems	Session T1C MEMS Industry Group - Technology Transfer	Session T1D Electro Fluidics	Session T1E Optical Bio Sensing
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Ono, *Tohoku University, JAPAN* E. Wang , *Massachusetts Institute of Technology, USA*	**Session Co-Chairs:** X. Rottenberg, *Imec, Belgium* H. Toshiyoshi, *University of Tokyo, JAPAN*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** S. Choi, *State University of New York at Binghamton, USA* S. Prakash, *Ohio State University, USA*	**Session Co-Chairs:** K. Hishino, *University of Connecticut, USA* F.-G. Tseng, *National Tsing Hua University, TAIWAN*
08:45 - 09:00				
T1A.004	**T1B.004**		**T1D.004**	**T1E.004**
A HIGH-PERFORMANCE P-IN-G SENSOR WITH MULTIPLE-LEVEL 3D MICRO-STRUCTURE FABRICATED FROM ONE SIDE OF SINGLE WAFER J.C. Wang and X.X. Li *Chinese Academy of Sciences, CHINA* .....172 A single-wafer fabricated P-in-G composite-sensor for automobile TPMS application is firstly reported. Located inside the proof-mass of the accelerometer, the pressure sensor is freely suspended from the stress-free mass-end, thereby eliminating the influence of acceleration to the pressure sensor. This tested result is 36-fold better than that of the previous work. The IC-foundry compatible high-yield process has created a 6-level 3D micro-structure for the sensor.	**SMALL FOOTPRINT NANO-MECHANICAL PLASMONIC PHASE MODULATORS** V.A. Aksyuk[1], B.S. Dennis[1,2], M.I. Haftel[3], D.A. Czaplewski[4], D. Lopez[4], and G. Blumberg[2] [1]*National Institute of Standards and Technology (NIST), USA,* [2]*Rutgers, The State University of New Jersey, USA,* [3]*University of Colorado, Boulder, USA, and* [4]*Argonne National Laboratory, USA* .....204 We experimentally realize nano- mechanical plasmonic phase modulators based on strong dependence of the phase velocity of tightly confined metal-insulator-metal gap plasmons on a dynamically variable 200 nm gap. Low voltage electrostatic actuation results in phase modulation exceeding Pi radians with low excess optical loss in a 23 micrometer long device. The approach is extremely scalable and may allow 10x linear size reduction without loss of modulation range or increase in optical losses.	MIG CONTINUED	**FINGER-POWERED DROPLET ACTUATION BY ELECTROPHORETIC FORCE FOR PORTABLE MICROFLUIDICS** C. Peng and Y.S. Ju *University of California, Los Angeles, USA* .....232 We report finger-powered electrophoresis of droplets in digital microfluidics. An array of piezoelectric elements is connected in parallel to electrodes immersed in dielectric fluids. When deflected by human fingers, the elements charge and actuate droplets suspended between each electrode pair by electrophoretic force. Using this scheme, we demonstrated the transport and merging of water droplets and confirmed direct manipulation of body fluids such as human saliva sample using our device.	**INTEGRATED OPTOFLUIDIC DEVICE FOR THE MEASUREMENT OF THE ACTIVITY OF LYMPHOCYTES** R. Usuba[1], M. Yokokawa[1], A. Llobera[2], S. Murata[1], N. Ohkohchi[1], and H. Suzuki[1] [1]*University of Tsukuba, JAPAN and* [2]*Centre Nacional de Microelectronica, SPAIN* .....261 An optofluidic device developed for the measurement of the activity of lymphocytes is introduced. Optical components including lenses and mirrors were integrated for reproducible highly sensitive absorbance measurement. A microfluidic system with an air bypass structure was used to exchange solutions without introducing air into the measuring chamber and to merge two plugs of different solutions. Furthermore, we measured the activity of lymphocytes by ELISA using this device.

TUESDAY PROGRAM

Session T1A Mechanical Sensors	Session T1B Optical Systems	Session T1C MEMS Industry Group - Technology Transfer	Session T1D Electro Fluidics	Session T1E Optical Bio Sensing
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Ono, *Tohoku University, JAPAN* E. Wang , *Massachusetts Institute of Technology, USA*	**Session Co-Chairs:** X. Rottenberg, *Imec, Belgium* H. Toshiyoshi, *University of Tokyo, JAPAN*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** S. Choi, *State University of New York at Binghamton, USA* S. Prakash, *Ohio State University, USA*	**Session Co-Chairs:** K. Hishino, *University of Connecticut, USA* F.-G. Tseng, *National Tsing Hua University, TAIWAN*
09:00 - 09:15				
T1A.005	**T1B.005**	**T1C.005**	**T1D.005**	**T1E.005**
INDUCTIVE EDDY CURRENT SENSING AS A DISPLACEMENT SENSING MECHANISM FOR LARGE PISTON/ROTATION MICROMIRRORS V.F.G. Tseng and H. Xie *University of Florida, USA* .....176 This paper presents an inductive eddy current based position sensor that can monitor the piston position and tilt angle for large vertical displacement micromirrors (>100 microns). By sensing the coupling change or inductance change between two microfabricated coils due to mirror plate motion, the sensor can support both amplitude detection and frequency detection, allowing it to detect piston and tilt angle together. A displacement sensing range of 1 mm could be achieved with 70 nm resolution.	**A ROTATIONAL MEMS DIFFRACTION GRATING FOR REALIZATION OF MICRO-SIZED SPECTROSCOPE SYSTEM** Y. Yamamoto[1], R. Shinozaki[1], Y. Oka[1], I. Asahi[1,2], H. Ninomiya[2], H. Shimokawa[1], F. Oohira[1], and H. Takao[1] [1]*Kagawa University, JAPAN and* [2]*Shikoku Research Institute, JAPAN* .....208 In this paper, a novel rotational MEMS diffraction grating for realization of micro-sized spectroscope system with SiOB (Silicon Optical Bench) technology is newly developed, and its evaluation results are reported for the first time. A diffraction grating is mounted on the stage of an electrostatic rotational actuator. Driving the stage by ±3.5° at DC80V, wavelength of white light was successfully modulated in the range from 515nm to 763nm at an 11% diffraction efficiency.	**FROM LAB TO FAB – HOW CAD TOOLS CAN HELP THE TRANSITION** M.A. Maher *SoftMEMS, USA* Moving from a university prototype to a commercial MEMS fab is an important tech transfer challenge and can be one of the most critical steps in successful product development. This talk explores how CAD tools can ease this transition by providing an important medium for technical information exchange to help ensure successful transfer. It further describes how CAD tools can be used to perform important design checks and simulations, avoiding costly mistakes and helping to achieve targeted specifications at the commercial fab. Finally, it presents a case study of the use of CAD tools to ease the transfer from university prototype to product oriented commercial fab. **NON IEEE Copyrighted Session**	**REALIZATION OF 1 MILLION PIXEL CHARGE TRANSFER TYPE ION IMAGE SENSOR WITH 12 µM PIXEL PITCH** M. Futagawa[1], R. Otake[2], F. Dasai[2], M. Ishida[2,3], and K. Sawada[2] [1]*Shizuoka University, JAPAN,* [2]*Toyohashi University of Technology, JAPAN, and* [3]*Japan Science and Technology Agency (JST), JAPAN* .....236 An advanced charge transfer type hydrogen image sensor consisting of 1024 × 1024 pixels with 12.1 µm pixel pitch, which contains the most pixels to date and half pitch compared to previous works, was fabricated. The new pixel layout of common ID electrodes and partition scanning system were designed for high-density image element and preventing a readout lag time. To realize the high-density array sensor, observance of various movements of a cell can perform.	**FIBER-OPTIC LOCALIZED SURFACE PLASMON RESONANCE SENSOR COMBINED WITH MICRO FLUIDIC CHANNEL** J.S. Kim[1], S.K. Kang[1], S.M. Lee[2], H.Y. Lee[3], D.H. Jeong[3], J.H. Park[1], and S.K. Lee[1] [1]*Dankook University, SOUTH KOREA,* [2]*Kangwon National University, SOUTH KOREA, and* [3]*Seoul National University Bundang Hospital, SOUTH KOREA* .....265 This paper proposes Fiber Optic Localized Surface Plasmon Resonance (FO LSPR) sensor combined with micro fluidic channel, which enables the continuous supply of fluid for bio-reaction. The proposed method can prevent the degradation of the sensing characteristics due to the change of measurement condition. The feasibility of the FO LSPR sensor with micro fluidic channel is proved by computational fluid dynamics simulation(CFD). Also, the proposed method has been evidenced by measuring the output intensity of the FO LSPR sensor at various refractive index solutions.

TUESDAY PROGRAM

Session T1A Mechanical Sensors	Session T1B Optical Systems	Session T1C MEMS Industry Group - Technology Transfer	Session T1D Electro Fluidics	Session T1E Optical Bio Sensing
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Ono, *Tohoku University, JAPAN* E. Wang , *Massachusetts Institute of Technology, USA*	**Session Co-Chairs:** X. Rottenberg, *Imec, Belgium* H. Toshiyoshi, *University of Tokyo, JAPAN*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** S. Choi, *State University of New York at Binghamton, USA* S. Prakash, *Ohio State University, USA*	**Session Co-Chairs:** K. Hishino, *University of Connecticut, USA* F.-G. Tseng, *National Tsing Hua University, TAIWAN*
09:15 - 09:30				
T1A.006	**T1B.006**		**T1D.006**	**T1E.006**
III-V NITRIDE MICROCANTILEVER AS A DISPLACEMENT SENSOR A. Talukdar[1] and G. Koley[2] [1]*Univerity of South Carolina, USA and* [2]*Clemson University, USA* .....180 We demonstrate the development of III-V nitride microcantilever based Micro electro-mechanical System (MEMS) for the transduction of nanoscale displacements with an integrated electrical readout by means of a heterojunction field effect transistor (HFET) as a self sensing module. Design strategy, fabrication and characterizations of AlGaN/GaN HFET embedded GaN microcatilevers are discussed to showcase the sensing performances of this technology from DC to kHz range.	**A SILICON BASED FOURIER TRANSFORM SPECTROMETER BASE ON A OPEN-LOOP CONTROLLED ELECTROTHERMAL MEMS MIRROR** W. Wang[1,2], J. Chen[2], A.S. Zivkovic[1], C. Duan[1], and H. Xie[1] [1]*University of Florida, USA and* [2]*Shanghai Jiao Tong University, CHINA* .....212 This paper reports a compact Fourier transform spectrometer with a large-stroke electrothermal MEMS mirror and other optical components all integrated on a micro-machined silicon base. The overall size is reduced dramatically from the prior work and the linear scan range is extended by a factor of 2 with a new open-loop control method.	**MIG CONTINUED**	**NON-EQUILIBRIUM ELECTROKINETIC MICRO/NANO FLUIDIC MIXER WITH SPATIALLY CONTROLLED SELF-ASSEMBLED NANOPARTICLE NETWORKS** E. Choi, K. Kwon, S.J. Lee, D. Kim, and J. Park *Sogang University, SOUTH KOREA* .....240 This paper reports an active micromixer which utilizes vortex generation due to non-equilibrium electrokinetics near the geometrically controlled in situ self-assembled nanoparticles.	**OPTICALLY-INDUCED CELL FUSION ON MICROFLUIDIC CHIP UTILIZING LOCALLY ENHANCED ELECTRIC FIELD** P.F. Yang, C.H. Wang, and G.B. Lee *National Tsing Hua University, TAIWAN* .....269 We demonstrated a new approach called optically-induced cell fusion (OICF) which integrated cell pairing microstructures and optically-induced electrical system to achieve cell fusion with high yields and high efficiency.

TUESDAY PROGRAM

Session T1A
Mechanical Sensors

TIKAHTNU A

Session Co-Chairs:
T. Ono,
Tohoku University, JAPAN

E. Wang , *Massachusetts Institute of Technology, USA*

Session T1B
Optical Systems

TIKAHTNU B

Session Co-Chairs:
X. Rottenberg,
Imec, Belgium

H. Toshiyoshi,
University of Tokyo, JAPAN

Session T1C
MEMS Industry Group - Technology Transfer

TIKAHTNU CD

Session Chair:
K. Lightman,
MEMS Industry Group, USA

Session T1D
Electro Fluidics

TIKAHTNU EF

Session Co-Chairs:
S. Choi, *State University of New York at Binghamton, USA*

S. Prakash,
Ohio State University, USA

Session T1E
Optical Bio Sensing

TUBUGHNENQ

Session Co-Chairs:
K. Hishino,
University of Connecticut, USA

F.-G. Tseng, *National Tsing Hua University, TAIWAN*

09:30 - 09:45

T1A.007

DIRECT INTEGRATED STRAIN SENSORS FOR ROBUST TEMPERATURE BEHAVIOUR

S. Haas, M. Schramm, D. Reuter, K.-U. Loebel, J.-T. Horstmann, and T. Gessner
Technische Universität Chemnitz, GERMANY

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The detection of motion with an active electrical device like a transistor allows to shrink the transducer to few micrometers or even below. A promising method for that is using the piezoresistive effect in the transistor channel. In this paper the fundamental behavior of strain sensitive transistors has been investigated. For characterization pressure sensitive silicon membranes have been fabricated as strain inducing elements. Measurements show good sensitivity and robust temperature behavior.

T1B.007

MEMS ENDOMICROSCOPE FOR SIMULTANEOUS BRIGHT-FIELD MICROSCOPY AND OPTICAL COHERENCE TOMOGRAPHY

M. Blattmann[1], S. Kretschmer[1], S. Thiele[2], H. Zappe[1], A. Herkommer[2], and A. Seifert[1]
[1]*University of Freiburg, GERMANY and* [2]*University of Stuttgart, GERMANY*

.....216

To the best of our knowledge, we present the first silicon based endomicroscope for multi-modal imaging. Design, fabrication and characterization of a probe based on silicon bulk micromachining with cross-sectional dimensions of $2 \times 2.76mm^2$ is shown. For the first time, we demonstrate an endomicroscope that combines wide field and confocal imaging modalities in a single device by showing simultaneous bright field microscopy as well as optical coherence tomography (OCT). The probe achieves lateral resolutions of 6.2 µm and 17.4 µm with bright field microscopy and OCT, respectively.

T1C.007

TEACHING CUSTOMERS – THE LINK BETWEEN TECHNOLOGY AND PRODUCTS

J. Knutti
Acuity, USA

MEMS has been touted as an emerging technology for over 40 years. While tremendous deployment has been achieved, it has typically taken much longer than anticipated. False starts and missed expectations often occur between a great concept, initial prototype and the commercial adoption. A ubiquitous technology like MEMS must be adapted to a wide range of expectations and requirements in a variety of markets. There are tremendous opportunities for MEMS based autonomous devices that can be linked together. The key is insight and access to the specific constraints of each segment. History shows how to effectively use teaching customers to identify critical elements for commercial success, cut development time, and achieve faster adoption in diverse new markets using fewer resources.

T1D.007

HIGH EFFICIENT SYNTHESIS OF MANGANESE(II), COBALT(II) COMPLEXES CONTAINING LYSOZYME USING REACTION AREA SEPARATED MICRO FLUIDIC DEVICE

D. Tanaka[1], Y. Murakoshi[1], E. Tsuda[2], Y. Mitsumoto[2], D.H. Yoon[1], T. Sekiguchi[1], T. Akitsu[2], and S. Shoji[1]
[1]*Waseda University, JAPAN and* [2]*Tokyo University of Science, JAPAN*

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In this study, high yield synthesis of metal (Mn, Co) complex containing lysozyme using reaction area separated micro fluidic devices was realized. We investigate appling Mn, Co high efficient metal complex containing lysozyme new was successfully developed.

T1E.007

FIBERLESS MULTICOLOR OPTOELECTRODES USING INJECTION LASER DIODES AND GRADIENT INDEX LENS COUPLED OPTICAL WAVEGUIDES

K. Kampasi, J. Seymour, K. Na, K.D. Wise, and E. Yoon
University of Michigan, USA

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A monolithically integrated optoelectrode is presented that can deliver multicolor light output alternatively at a common waveguide port. This highly compact, efficient and fiberless device can provide unmatched spatial precision and scalability needed to enable independent activation and silencing of neural circuits, thus allowing neuroscientists to study brain activity. This approach also provides robust thermal packaging of laser diode chips and offers a low-noise system.

TUESDAY PROGRAM

Session T1A Mechanical Sensors	Session T1B Optical Systems	Session T1C MEMS Industry Group - Technology Transfer	Session T1D Electro Fluidics	Session T1E Optical Bio Sensing
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Session Co-Chairs: T. Ono, *Tohoku University, JAPAN* E. Wang , *Massachusetts Institute of Technology, USA*	**Session Co-Chairs:** X. Rottenberg, *Imec, Belgium* H. Toshiyoshi, *University of Tokyo, JAPAN*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** S. Choi, *State University of New York at Binghamton, USA* S. Prakash, *Ohio State University, USA*	**Session Co-Chairs:** K. Hishino, *University of Connecticut, USA* F.-G. Tseng, *National Tsing Hua University, TAIWAN*

09:45 - 10:00

T1A.008

MICROPILLAR TYPE THREE-AXIS FORCE SENSOR FOR MEASUREMENT OF CELLULAR FORCE

T. Omiya, T. Tsukagoshi, K. Hirayama, N. Thanh-Vinh, K. Noda, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN
.....188

We developed a three-axis force sensor that can measure cellular forces in real time with high sensitivity, which features a photoresist micropillar on a flexible cross-shaped piezoresistive silicon structure. The force resolution of a few nN was achieved by the structure which is composed of the micropillar and four silicon beams. We confirmed that our sensor can detect the forces caused by an osteosarcoma cell on the micropillar as it became detached from the surrounding walls.

T1B.008

FUNCTIONAL MOEMS PACKAGING WITH OPTICAL POSITION FEEDBACK

A. Tortschanoff, M. Baumgart, and M. Lenzhofer
Carinthian Tech Research, AG, AUSTRIA
.....220

This paper reports a novel integration concept for a package including optical position feedback and driver unit for MOEMS scanner mirrors. The optical feedback uses a quadrant diode with a central hole and a compact PCB-based module was realized, which combines all necessary electrical, optical and mechanical aspects using existingmanufacturing technologies. This module provides a functional MOEMS packaging, which can be realized within short time at a minimum cost.

MIG CONTINUED

T1D.008

CATION DEPENDENT TRANSPORT IN A FIELD EFFECT NANOFLUIDIC DEVICE

M. Fuest, C. Boone, A.T. Conlisk, and S. Prakash
Ohio State University, USA
.....247

We demonstrate preferential transport of monovalent cations with respect to divalent cations in a field effect nanofluidic switching device. Ion transport, quantified by the measured ionic current through 16 nm deep channels, is controlled using an embedded gate electrode. Based on valence, ion transport in a nanofluidic channel with the ability to switch 'off' net ionic current via an embedded gate electrode as a function of cation type is reported for the first time.

T1E.008

FLEXIBLE OPTRODE ARRAY: PARYLENE-FILM WAVEGUIDE ARRAYS WITH MICROELECTRODES FOR OPTOGENETICS

S. Yamagiwa, M. Ishida, and T. Kawano
Toyohashi University of Technology, JAPAN
.....277

We report flexible thin-film microelectrode/waveguide stacked 'optrode' arrays for optogenetics. We fabricated parylene-C(clad)/N(core)/C(clad) waveguides and confirmed the light propagation through the waveguides, while microelectrodes are integrated within the flexible parylene film for simultaneous optical stimulation and electrical recording of neurons. These results indicate that the proposed device can be used for numerous spherical bio-tissues, including brain and spinal cord.

10:00 - 10:45 Break & Exhibit Inspection

TUESDAY PROGRAM

Session T2A High Shock Environmental & Tactile Sensing	Session T2B Tunable & Switched RF/THz Systems	Session T2C MEMS Industry Group - Emerging MEMS/Sensors	Session T2D Physical Microfluidics I	Session T2E Cells & Tissues Analysis
TIKAHTNU A	**TIKAHTNU B**	**TIKAHTNU CD**	**TIKAHTNU EF**	**TUBUGHNENQ**
Session Co-Chairs: S.-S. Li, *National Tsing Hua University, TAIWAN* G. O'Brien, *Stanford University, USA*	**Session Co-Chairs:** F. Ayazi, *Georgia Institute of Technology, USA* M. Rais-Zadeh, *University of Michigan, USA*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** CJ Kim, *University of California, Los Angeles, USA* H. Kim, *University of Utah, USA*	**Session Co-Chairs:** D. DeVoe, *University of Maryland, USA* Z. Li, *Peking University, CHINA*

10:45 - 11:00

T2A.001

INVITED SPEAKER

CONCEPT TO COMMERCIALIZATION OF A MEMS-BASED BLAST DOSIMETRY SYSTEM

D.A. Borkholder
Rochester Institute of Technology, USA

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Traumatic brain injury (TBI) has emerged as the signature injury of modern war, impacting over 300,000 service members since 2000. While 82% of these injuries are classified mild, there is significant concern with the potential for long-lasting and neurodegenerative effects. Diagnosis of mild TBI is difficult, with symptoms that are wide-ranging, non-specific, and often delayed in onset. The Blast Gauge™ System was created to provide an objective measure of blast overpressure and acceleration exposure, providing triage data to assist in identifying soldiers at risk of TBI, and detailed waveforms to enable correlation of singular and repetitive exposure to acute and chronic injury. From concept to deployment in 11 months and company formation to first product shipment in 4 months, this MEMS-based soldier-borne blast dosimeter has rapidly provided a new capability to track exposure in training and operations for the US DoD, law enforcement, and international militaries. Widespread deployment of the technology has yielded new insight into previously unrecognized dangers of heavy weapons training and captured valuable information about IED exposures in theater.

T2B.001

AN ACTIVE METAMATERIALS ANTENNA CONTROLELD BY RF-MEMS SWITCHES

Y. Luo, Z.L. Han, K. Kikuta, T. Takahashi, A. Hirose, H. Fujita, and H. Toshiyoshi
University of Tokyo, JAPAN

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This paper proposes an active metamaterials-based CRLH (Composite Right Left Handed) antenna, in which RF-MEMS cantilevers are integrated as RF switches. By actuating the MEMS ON/OFF switches within each unit, the metamaterials properties are tuned and the spatial radiation patterns are correspondingly controlled from backward (around -30º) through broadside (0º) to forward (around +30º) in the fixed frequency band around 9 GHz.

T2C.001

OPTICAL IMAGE STABILIZATION APPLICATIONS

M. Judy
Analog Devices, USA

The ADXRS290 is a high performance pitch and roll (dual-axis in-plane) angular rate sensor (gyroscope) designed for use in stabilization applications. The ADXRS290 provides an output full-scale range of ±100°/s with a sensitivity of 200 LSB/°/s. Its resonating disk sensor structure enables angular rate measurement about the axes normal to the sides of the package around an in-plane axis. Angular rate data is formatted as 16-bit twos complement and is accessible through a SPI digital interface. The ADXRS290 exhibits a low noise floor of 0.004°/s/√Hz and features programmable high-pass and low-pass filters.

T2D.001

BACTERIA-BASED MICROROBOT FOR CHEMOTAXIS DELIVERY OF MICROCUBICS

K. Huh, D.R. Oh, H.J. Yoo, B.H. Song, D.I. Cho, J.M. Seo, and S.J. Kim
Seoul National University, SOUTH KOREA

.....327

We proposed a simple microfluidic device that enabled the anisotropic absorption of detoxified S. *typhimurium* bacteria to microcubics so that they can swim toward desirable direction by chemotaxis of the bacteria. The speed of the "bacteria-based microrobot" was ~5um/sec which is comparable to any previous demonstrations without sophisticated fabrication or toxic chemical treatments, leading to an effective drug delivery system.

T2E.001

OSMOTIC ERYTHROCYTE LYSIS FOR CHEMICAL- AND LABEL-FREE IMPEDANCE CYTOMETRY

T.E. Winkler, H. Ben-Yoav, D.L. Kelly, and R. Ghodssi
University of Maryland, USA

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We present the first implementation of osmotic erythrocyte (RBC) lysis for microfluidic leukocyte (WBC) impedance cytometry. The method relies on osmotic pressure differentials to rupture RBC membranes, and detection of WBCs based on changes in impedance. Specifically, we demonstrate an up to 1,200-fold decrease in noise from RBCs in WBC recordings. Our approach enables lab-on-a-chip (LOC)-based WBC counting on whole blood samples without traditionally required chemicals or labels.

TUESDAY PROGRAM

Session T2A High Shock Environmental & Tactile Sensing	Session T2B Tunable & Switched RF/THz Systems	Session T2C MEMS Industry Group - Emerging MEMS/Sensors	Session T2D Physical Microfluidics I	Session T2E Cells & Tissues Analysis
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: S.-S. Li, *National Tsing Hua University, TAIWAN* G. O'Brien, *Stanford University, USA*	**Session Co-Chairs:** F. Ayazi, *Georgia Institute of Technology, USA* M. Rais-Zadeh, *University of Michigan, USA*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** CJ Kim, *University of California, Los Angeles, USA* H. Kim, *University of Utah, USA*	**Session Co-Chairs:** D. DeVoe, *University of Maryland, USA* Z. Li, *Peking University, CHINA*
11:00 - 11:15				
	T2B.002		**T2D.002**	**T2E.002**
INVITED CONTINUED	**RF NANO SWITCH BASED ON SINGLE CRYSTALLINE GRAPHENE** P. Li[1,2] and T. Cui[2] [1]*Tsinghua University, CHINA and* [2]*University of Minnesota, USA* .....307 Radio frequency (RF) nano switches based on coplanar waveguide double-clamped single crystalline graphene (SCG) membrane is reported for the first time. Owing to the single crystalline nature, its life time is much longer than that of polycrystalline graphene (PCG) switches. It exhibits small pull-in voltage (~1 V) and superb signal isolation (~30 dB at 40 Ghz) which can be further improved by graphene's unique electric field effect.	MIG CONTINUED	**GRAPHENE - OXIDE ENABLED CENTRIFUGO-PNEUMATIC ROUTING OF FLOWS** J. Gaughran and J. Ducrée *Dublin City University, IRELAND* .....331 We develope a novel, centrifugo-pneumatic scheme for solvent-selective routing of organic and aqueous flows based on an integrated, Graphene Oxide (GO) membrane. We then implement a sequential, multi-reagent protocol geared towards automated solid-phase extraction of nucleic acids with a sequence of washing and elution steps with aqueous and organic liquids.	**MICRO ELECTRICAL IMPEDANCE SPECTROSCOPY (μEIS) WITH CELL TRAPS IN VARIOUS SIZE FOR DIFFERENTIATION BETWEEN NORMAL AND CANCEROUS HUMAN UROTHELIAL CELLS** Y. Park, H.W. Kim, J. Yun, G. Kang, S. Seo, C. Park, J. Yang, E. Chung, and J.-H. Lee *Gwangju Institute of Science and Technology (GIST), SOUTH KOREA* .....355 This paper reports a novel micro electrical impedance spectroscopy (μEIS) with cell traps, which can discriminate between normal and cancerous human urothelial cells.

TUESDAY PROGRAM

Session T2A
High Shock Environmental & Tactile Sensing

TIKAHTNU A

Session Co-Chairs:
S.-S. Li, *National Tsing Hua University, TAIWAN*

G. O'Brien, *Stanford University, USA*

11:15 - 11:30

T2A.003

SHOCK PROTECTION BASED ON CONFINED SELF-ADJUSTING CARBON NANOTUBE ARRAYS
J.-I. Lee, D.-S. Kwon, and J. Kim
Yonsei University, SOUTH KOREA
.....287

We demonstrate a novel shock protector based on confined self-adjusting carbon nanotube (CNT) arrays. The frictional contact between CNT arrays dissipates energy during impact and thus reduces the impact force applied on microstructures. The outstanding mechanical flexibility and resilience of CNTs make them suitable as a contact material that effectively absorbs energy through frictional contact preventing mechanical failure of microstructures.

Session T2B
Tunable & Switched RF/THz Systems

TIKAHTNU B

Session Co-Chairs:
F. Ayazi, *Georgia Institute of Technology, USA*

M. Rais-Zadeh, *University of Michigan, USA*

11:15 - 11:30

T2B.003

TUNABLE CAPACITORS AND MICROWAVE FILTERS BASED ON VANADIUM DIOXIDE METAL-INSULATOR TRANSITION
W.A. Vitale, M. Fernández-Bolaños, C.F. Moldovan, A. Paone, A. Schüler, and A.M. Ionescu
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND
.....311

We report the fabrication, modeling and characterization of novel microwave tunable capacitors based on the metal-insulator transition (MIT) of Vanadium Dioxide (VO2). We study the advantages of VO2-based capacitors on alternative technologies for RF reconfigurable electronics in terms of ease of integration, design and performance at high frequency. We show the potential of the proposed devices by fabricating a tunable bandstop filter (22.5-19.8 GHz) with insertion loss < 2 dB up to 40 GHz.

Session T2C
MEMS Industry Group - Emerging MEMS/Sensors

TIKAHTNU CD

Session Chair:
K. Lightman, *MEMS Industry Group, USA*

11:15 - 11:30

T2C.003

INTRODUCING NEW MATERIALS IN A FOUNDRY ENVIRONMENT
M. Rimskog
Silex Microsystems AB, USA

This talk will give an insight to how the different collaborative groups (consortiums) have been set up as well as present latest achievements regarding the advanced materials. As part of the presentation the following collaborations will be briefly introduced: PZT for RF MEMS actuator structures and IPDs within EPAMO ENIAC program. World leading results have already been achieved with regards to for example electrical breakdown levels as well as e31 and d31 values for the PZT films developed. The current status with regards to PZT capabilities will be presented including the future material focus. This presentation will also share measurement and analysis capabilities as well as other equipment deployed at Silex to offer a full manufacturing platform for PZT foundry services.

Session T2D
Physical Microfluidics I

TIKAHTNU EF

Session Co-Chairs:
CJ Kim, *University of California, Los Angeles, USA*

H. Kim, *University of Utah, USA*

11:15 - 11:30

T2D.003

CAPILLARY-DRIVEN AND VOLUME-METERED BLOOD PLASMA SEPARATION
G. Lenk, J. Hansson, W. van der Wijngaart, G. Stemme, and N. Roxhed
KTH Royal Institute of Technology, SWEDEN
.....335

We present the first capillary driven microfluidic device that separates a specific volume of plasma from a blood sample of unknown volume. The input to the system is a small amount of whole blood (30-60 µl) which results in a 4 µl isolated plasma sample, available for subsequent processing and/or analysis. This is highly relevant for billions of blood samples taken every year in laboratory analysis and drug development trials on both humans and animals requiring only a microsample of 50 µl.

Session T2E
Cells & Tissues Analysis

TUBUGHNENQ

Session Co-Chairs:
D. DeVoe, *University of Maryland, USA*

Z. Li, *Peking University, CHINA*

11:15 - 11:30

T2E.003

A MULTIFUNCTIONAL CELL-BASED IMPEDANCE BIOSENSOR SYSTEM FOR CARDIOVASCULAR DRUG AND MARINE TOXIN ANALYSIS
H. Li, Q. Zou, N. Hu, and P. Wang
Zhejiang University, CHINA
.....359

In this study, a multifunctional cell-based impedance biosensor system is established, using cell-based impedance biosensor (CIB) as the sensitive element. Cellular growth and beating experiments are carried out to verify the multifunction of the biosensor system. One typical marine diarrhetic toxin okadaic acid (OA) is used for cytotoxicity analysis and one heart-related compound verapamil is employed for cardiotoxicity analysis.

TUESDAY PROGRAM

Session T2A High Shock Environmental & Tactile Sensing	Session T2B Tunable & Switched RF/THz Systems	Session T2C MEMS Industry Group - Emerging MEMS/Sensors	Session T2D Physical Microfluidics I	Session T2E Cells & Tissues Analysis
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: S.-S. Li, *National Tsing Hua University, TAIWAN* G. O'Brien, *Stanford University, USA*	**Session Co-Chairs:** F. Ayazi, *Georgia Institute of Technology, USA* M. Rais-Zadeh, *University of Michigan, USA*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** CJ Kim, *University of California, Los Angeles, USA* H. Kim, *University of Utah, USA*	**Session Co-Chairs:** D. DeVoe, *University of Maryland, USA* Z. Li, *Peking University, CHINA*
11:30 - 11:45				
T2A.004	**T2B.004**	**T2C.004**	**T2D.004**	**T2E.004**
HIGH-G MEMS SHOCK THRESHOLD SENSOR INTEGRATED ON A COPPER FILLING THROUGH-GLASS-VIA (TGV) SUBSTRATE FOR SURFACE MOUNT APPLICATION Z. Yang, Y. Wang, H. Wang, Y. Wang, X. Dai, G. Ding, and X. Zhao *Shanghai Jiao Tong University, CHINA* .....291 We develop a through-glass-via (TGV) substrate with an integrated high-g MEMS threshold sensor on it, which will minimize the die size of whole sensor, avoid lead-wire bonding and facilitate the surface mount. Smaller volume could also improve the anti-shock capability of the sensor. TGV substrate is fabricated by composite-mask powder blasting and copper filling. Fabricated via holes are filled by PPR electroplating copper. Integrated sensor has a reliable switch-on signal under 1000g shock.	**A REAL-TIME TUNABLE TERAHERTZ METAMATERIAL BASED ON BROADSIDE-COUPLED SPLIT RING RESONATORS** X. Zhao[1], K. Fan[1], J. Zhang[1,2], G.R. Keiser[1], H.R. Seren[1], R.D. Averitt[2], and X. Zhang[1] [1]*Boston University, USA and* [2]*University of California, San Diego, USA* .....315 We report a dynamically tunable metamaterial based on the broadside-coupled split ring resonators (BC-SRRs). Compared to the state of art of the research on BC-SRRs, our metamaterial is the first device whose response can be tuned in a real-time fashion, thereby providing promising applications in the THz regime such as modulators, filters, and sensors.	**3D VERTICAL INTEGRATION OF MINIATURE MIRAU INTERFEROMETERS BY USING MULTI-WAFER BONDING TECHNOLOGY** M. Wiemer *Fraunhofer Institute for Electronic Nanosystems, GERMANY* This work presents multi-wafer bonding technology for a micromachined, vertically integrated array-type Mirau interferometer. The array-type Mirau interferomenter is a key-component of OCT (Optical Coherence Tomography) microsystem, which is suitable for medical imaging with high resolution. This paper focuses on vertical integration of multiple wafer stacks, where the bonding process fits the aforementioned requirements. By using multi-wafer bonding technology and flip chip PCB, 3D vertical integration of a Mirau interferometer along with electrical connections can be realized and further integrated with other components of the OCT system. **NON IEEE Copyrighted Session**	**A NOVEL LIQUID METAL-BASED INKJET NOZZLE FOR FLEXIBLE ELECTRONICS** G. Li, X. Wu, and D.W. Lee *Chonnam National University, SOUTH KOREA* .....339 In this paper, a novel liquid metal-based inkjet nozzle with coplanar microfluidic channels is firstly designed and fabricated to overcome the issues of clogging and liquid metal oxidation. The feasibility of the lquid metal pL-droplet (volume < 1pL) and metallic line (width < 10μm) formation on flexible substrates are demonstrated using proposed nozzle. It is believed that the liquid metal-based inkjet nozzle can provide a stronger vitality for advanced electronic applications in future.	**A MICROFLUIDIC LABCHIP FOR ANGIOGENESIS INHIBITOR STUDIES VIA MULTI-GRADIENTS OF CANCER AND FIBROBLAST STIMULI** C.-H. Chin[1], Y.-L. Chiu[1], K.-Y. Lee[2], and C.-H. Liu[1] [1]*National Tsing Hua University, TAIWAN and* [2]*Shuang Ho Hospital, TAIWAN* .....363 We develop a microfluidic device for angiogenesis inhibitor study by forming cancer-induced angiogenesis and fibroblast-induced angiogenesis simultaneously to mimic the in vivo environment. To form long-lasting concentration gradients on the chip, theory of hydraulic-electric analogy is applied for chip design and finite element software is used for verification.

TUESDAY PROGRAM

Session T2A High Shock Environmental & Tactile Sensing	Session T2B Tunable & Switched RF/THz Systems	Session T2C MEMS Industry Group - Emerging MEMS/Sensors	Session T2D Physical Microfluidics I	Session T2E Cells & Tissues Analysis
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: S.-S. Li, *National Tsing Hua University, TAIWAN* G. O'Brien, *Stanford University, USA*	**Session Co-Chairs:** F. Ayazi, *Georgia Institute of Technology, USA* M. Rais-Zadeh, *University of Michigan, USA*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** CJ Kim, *University of California, Los Angeles, USA* H. Kim, *University of Utah, USA*	**Session Co-Chairs:** D. DeVoe, *University of Maryland, USA* Z. Li, *Peking University, CHINA*
11:45 - 12:00				
T2A.005	**T2B.005**	**T2C.005**	**T2D.005**	**T2E.005**
CAPACITIVE SENSOR FUSION: CO-FABRICATED X/Y AND Z-AXIS ACCELEROMTERS, PRESSURE SENSOR, THERMOMETER V.A. Hong[1], J. Stehle[2], C.H. Ahn[1], D.B. Heinz[1], G. Yama[2], B. Kim[2], G.J. O'Brien[1], and T.W. Kenny[1] [1]*Stanford University, USA and* [2]*Robert Bosch RTC, USA* .....295 This paper presents a capacitive X/Y and Z-axis accelerometer, pressure sensor, and resonant thermometer, co-fabricated in a single die using an ultra-clean, high-temperature, wafer-scale, production-compatible encapsulation process. Sensitivities to environmental effects, such as temperature, are compensated to reveal a suite of on-chip high-performance sensors that is accurate over temperature.	**PERFORMANCE ENHANCEMENT OF BIMATERIAL CANTILEVER FOCAL PLANE ARRAY BY METAMATERIAL ABSORBER** W. Ma[1], Y. Wen[1], X. Yu[1], X. Liu[2], and Y. Zhao[2] [1]*Peking University, CHINA and* [2]*Institute of Beijing Technology, CHINA* .....319 We presents a bimaterial cantiliver based Focal Plane Array fabricated on a glass substrate by a polyimide (PI) sacrificial layer process, thus allowing a reverse readout configuration compared with preivious works. Metamaterial absorber (MMA) was conveniently integrated into the FPA pixels by introducing a periodic array of square resonators on top of the structrual layer. Performance improvement was verified through the comparative tests of the devices with and without MMA.	**OPTICAL MEMS FABRY-PEROT INTERFEROMETERS FOR MICROSPECTROMETER APPLICATIONS** A. Rissanen *VTT Technical Research Centre of Finland, FINLAND* VTT has developed microspectrometer technology based on optical MEMS Fabry-Perot interferometers (FPIs), which can be realized for various wavelengths within visible to NIR/IR and thermal IR. MEMS-based tunable optical filters enable miniaturization of spectrometers into small, mass producible sensors with potential for application in novel products based on identification of spectral fingerprints. This presentation is going to focus on our recent MEMS R&D efforts within near- and mid- infrared wavelength range, giving a detailed look into the MEMS fabrication, processing challenges and optical characterization results of the latest MEMS FPI chip prototypes. NIR- MIR wavelength region is of potential interest for various sensing application, for example fuel quality analysis, hydrocarbon sensing and OCT-based skin cancer detection; a final overview of optical instruments and demonstrators, including the latest mobile phone CO2 sensor is also given to illustrate the way in which optical MEMS and volume processing capability has potential for creating new product concepts. **NON IEEE Copyrighted Session**	**REDUCING INSTABILITY AND ENHANCING CRITICAL HEAT FLUX USING INTEGRATED MICROPILLARS IN TWO-PHASE MICROCHANNEL HEAT SINKS** Y. Zhu[1], D.S. Antao[1], D.W. Bian[1], T.J. Zhang[2], and E.N. Wang[1] [1]*Massachusetts Institute of Technology, USA and* [2]*Masdar Institute of Science and Technology, UAE* .....343 We present a novel two-phase microchannel heat sink design with integrated micropillars on the bottom heated surface to achieve significantly reduced flow boiling instability, enhanced heat transfer coefficient (40%) and critical heat flux (17%) compared to that without micropillars. This increase in performance is only possible via our design that decouples bubble nucleation and thin film evaporation.	**LOW-COST NANO-SPIKE BIO-IMPEDANCE SENSOR (NBIS) WITHOUT SURFACE FUNCTIONALIZATION FOR DETECTION AND PHENOTYPING OF CANCER CELLS** K. Riaz, C. Zhao, T.S. Lau, S.F. Leung, Z. Fan, and Y.-K. Lee *Hong Kong University of Science and Technology (HKUST), HONG KONG* .....367 We report a low-cost Nano-spike Bio-Impedance Sensor (nBIS) for detection and phenotyping of cancer/non-cancer cells (HeLa, MCF7 and HEK293). 3D self-aligned nano-spikes, fabricated by nanoimprint and electrochemical anodization, was used to measure electrical impedance of cancer cells without surface functionalization. The impedance spectra of cancer cells show significant differences in beta dispersion. From the modified Randle model, nano-spike electrodes can significantly reduce electrochemical and polarization problems at the electrode and liquid interface.

TUESDAY PROGRAM

Session T2A High Shock Environmental & Tactile Sensing	Session T2B Tunable & Switched RF/THz Systems	Session T2C MEMS Industry Group - Emerging MEMS/Sensors	Session T2D Physical Microfluidics I	Session T2E Cells & Tissues Analysis
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: S.-S. Li, *National Tsing Hua University, TAIWAN* G. O'Brien, *Stanford University, USA*	**Session Co-Chairs:** F. Ayazi, *Georgia Institute of Technology, USA* M. Rais-Zadeh, *University of Michigan, USA*	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** CJ Kim, *University of California, Los Angeles, USA* H. Kim, *University of Utah, USA*	**Session Co-Chairs:** D. DeVoe, *University of Maryland, USA* Z. Li, *Peking University, CHINA*

12:00 - 12:15

T2A.006

POROUS DIELECTRIC ELASTOMER BASED ULTRA-SENSITIVE CAPACITIVE PRESSURE SENSOR AND ITS APPLICATION TO WEARABLE SENSING DEVICE

D. Kwon, T.-I. Lee, M.S. Kim, S. Kim, T.-S. Kim, and I. Park
Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA

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We report a wearable and flexible capacitive pressure sensor based on porous dielectric elastomer with ultra-high sensitivity and stability. The capacitance response to a wide pressure range of 0~130kPa was investigated, which is generally considered as a human tactile pressure regime. As a real-life application, we demonstrate a bandage-type wearable pressure sensor for real-time monitoring of human wrist pulse.

T2B.006

HIGHLY RECONFIGURABLE ALUMINUM NITRIDE MEMS RESONATOR USING 12 MONOLITHICALLY INTEGRATED PHASE CHANGE MATERIAL SWITCHES

G. Hummel, Y. Hui, and M. Rinaldi
Northeastern University, USA

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We demonstrate a frequency reconfigurable and programmable Aluminum Nitride (AlN) piezoelectric MEMS resonator using phase change material (PCM) based switchable electrodes. For the first time, 12 miniaturized PCM switches are monolithically integrated with an AlN MEMS resonator and used to reconfigure the terminal connections of the individual metal fingers composing the device interdigital transducer.

MIG CONTINUED

T2D.006

A HIGH-EFFICIENCY OIL-TO-WATER MICRO-CHANNEL MIXER/EXTRACTOR BY SURFACE MODIFICATION WITH PATTERNED MULTIPLE SAMs FOR FLOW-GUIDE

C. Chen, P. Xu, and X. Li
Chinese Academy of Sciences, CHINA

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A top-down nanofabrication technology is developed to integrate three or more than three kinds of SAMs (self-assembled monolayers) into regioselective patterns. The SAMs are vapor-phase deposited before the channel is closed by a bonding process. By modifying a microchannel surface into an arrayed pattern of multi-SAM "two-tone" stripe array, 3D swirling flow is generated in a microfluidic channel that exhibits quick oil/water mixing and high-efficiency oil-to-water chemical extraction.

T2E.006

NEONATAL RAT VENTRICULAR MYOCYTES FORCE MAPPING USING DOUBLE-SIDED MICROPILLAR ARRAYS

F. Zhang[1], D.H. Ren[1], Z. You[1], S.W. Anderson[2], and X. Zhang[2]
[1]*Tsinghua Universiy, CHINA and* [2]*Boston University, USA*

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The measurement of cell forces is important for the investigation of cells behavior and mechanism to communicate with the environment. We report on a cell force sensor based on MEMS. A double-sided micropillar array was developed by poly (dimethylsiloxane), where one side is used to detect the deformation caused by cells forces, and the other side is designed as a reference for generating moiré patterns, allowing for the further integration to a miniature device.

12:15 - 13:30 | **Lunch on Own & Exhibit Inspection**

TUESDAY PROGRAM

Session T3A
Microphone & Flow Sensors

TIKAHTNU A

Session Co-Chairs:
T. Akin, *Middle East Technical University, TURKEY*

G. Krijnen, *University of Twente, THE NETHERLANDS*

Session T3B
Adaptive & Bioinspired Free-Space Optics

TIKAHTNU B

Session Co-Chairs:
K.-H. Jeong, *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA*

U. Wallrabe, University of Freiburg - IMTEK, GERMANY

Session T3C
MEMS Industry Group -Infrastructure/ Process Technology

TIKAHTNU CD

Session Chair:
K. Lightman, *MEMS Industry Group, USA*

Session T3D
Resonators for Chemical Sensors

TIKAHTNU EF

Session Co-Chairs:
X. Li, *Chinese Academy of Sciences, CHINA*

R. Lu, *SPAWAR Systems Center Pacific, USA*

Session T3E
BioMEMS

TUBUGHNENQ

Session Co-Chairs:
R. Ghodssi, *University of Maryland, USA*

A. Hierlemann, *ETH Zurich, SWITZERLAND*

13:30 - 13:45

T3A.001

INVITED SPEAKER

THE ERA OF SILICON MEMS MICROPHONE AND LOOK BEYOND

Z. Wang, Q. Zou, Q. Song, and J. Tao
GoerTek, CHINA
.....375

After had been long incubated originally for miniature hearing aid application, silicon condenser microphone found its adoption in mobile phone applications 10 years ago and has since then explosively grown to one of the most pursuit products in the MEMS industry. Development of silicon MEMS microphone looks simple but has many intrinsically hidden issues and challenges to overcome and solve. Lessons and experience from both failed and successful developments will be shared. Future outlook of its application roadmap will be envisioned. As being driven by fast paced mobile phones and smart devices, silicon MEMS microphone may soon encounter its technical boundary and restraints. Potential disruptive solutions for sustaining growth will be discussed in this talk.

T3B.001

MICROSCALE FRESNEL ZONE PLATE ARRAY ON FLEXIBLE SUBSTRATE

M.J. Moghimi, J. Fernandes, A. Kanhere, and H. Jiang
University of Wisconsin, Madison, USA
.....395

This paper describes microlens arrays implemented onto a flexible substrate. For the first time, we have demonstrated binary Fresnel zone plates fabricated from silicon nanowires embedded in a PDMS matrix. Moreover, lens arrays on flexible substrates can potentially increase the field of view, which is important for applications such as microscopy and surveillance. Lens arrays have wide applications in 3D displays, LCD projectors, optical switch and tunable lasers.

T3C.001

WAFER BONDING FOR MEMS - A BRIEF OVERVIEW OF AN ENABLING TECHNOLOGY

E. Pabo
EV Group, USA

Wafer bonding along with DRIE has enabled the amazing proliferation of MEMS devices over the last 20 years. The reasons for wafer bonding will be presented and then using the input, process, and output variables for wafer bonding as a framework, the tried and true bonding processes of anodic and glass frit will be discussed. Then metal bonding, direct bonding and polymer bonding will be reviewed. As time allows application examples will be given and the application of wafer bonding to back side illuminated (BSI) CMOS image sensors (CIS), and 3D integrated will be mentioned.

NON IEEE
Copyrighted Session

T3D.001

INVITED SPEAKER

DETECTION OF CANCER BIOMARKERS IN SERUM BY MERGING NANOMECHANICS AND OPTOPLASMONICS

P.M. Kosaka[1], V. Pini[1], J.J. Ruz[1], R.A. da Silva[1,2], M. Ujue-González[1], D. Ramos[1], M. Calleja[1], and J. Tamayo[1]
[1]*Instituto of Microelectronics, SPAIN and* [2]*Universidade de São Paulo, Brazil*
.....419

Blood contains a treasure trove of proteins biomarkers, most of them still to discover and that it will be crucial for early detection of cancer. A key point to achieve this goal is a technology capable of 'finding' ultralow concentrations of protein biomarkers secreted by the tumor to the blood stream in a 'haystack' of plasma proteins. Here we show an emergent technology that combines new physical phenomena at the frontier between nanoptics and nanomechanics for detecting low abundance protein-biomarkers. A detection limit of 1 x 10^{-16} g ml^{-1} in serum was achieved with prostate specific antigen (PSA), which is at least seven orders of magnitude lower than that achieved in routine clinical practice.

T3E.001

INVESTIGATION OF MOLECULAR CONDENSATION ON AIR-LIQUID INTERFACE FOR PROTEIN CRYSTALLIZATION

S. Takasawa[1], S. Hosoda[1], and Y. Yamanishi [1,2]
[1]*Shibaura Institute of Technology, JAPAN and* [2]*Japan Science and Technology Agency (JST), JAPAN*
.....440

We report the mechanism of the condensation of protein molecules on air-liquid interface of bubble. Electrically charged bubbles were confirmed to have clear advantage of producing protein crystal over general bubbles or conventional vapor diffusion method for the first time. The adsorption force between the protein molecular and air-liquid interface of bubble was successfully measured using force sensing optical tweezers. These findings contribute to the effective production of protein crystal.

TUESDAY PROGRAM

Session T3A Microphone & Flow Sensors	Session T3B Adaptive & Bioinspired Free-Space Optics	Session T3C MEMS Industry Group -Infrastructure/ Process Technology	Session T3D Resonators for Chemical Sensors	Session T3E BioMEMS
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Akin, *Middle East Technical University, TURKEY* G. Krijnen, *University of Twente, THE NETHERLANDS*	**Session Co-Chairs:** K.-H. Jeong, *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA* U. Wallrabe, University of Freiburg - IMTEK, GERMANY	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** X. Li, *Chinese Academy of Sciences, CHINA* R. Lu, *SPAWAR Systems Center Pacific, USA*	**Session Co-Chairs:** R. Ghodssi, *University of Maryland, USA* A. Hierlemann, *ETH Zurich, SWITZERLAND*
13:45 - 14:00				
	T3B.002			T3E.002
INVITED CONTINUED	**ULTRA-COMPACT, LARGE-APERTURE SOLID STATE ADAPTIVE LENS WITH ASPHERICAL CORRECTION** M.C. Wapler, C. Weirich, M. Stürmer, and U. Wallrabe *University of Freiburg - IMTEK, GERMANY* .....399 We report on a solid state adaptive lens based on an elastomer lens body and an active glass-piezo composite membrane. In contrast to existing lenses with integrated actuation, this allows for the control of the aspherical behavior and has a large aperture of 6.25mm at only 7.9mm outer diameter (9mm including packaging). The polymer instead of fluids as a refractive medium gives a good robustness and allows for a simple layout and fabrication.	MIG CONTINUED	INVITED CONTINUED	**A MICROFLUIDIC DEVICE OF BIODEGRADABLE POROUS SILICON NANOWIRES FOR SIZE BASED CAPTURING AND RELEASING VIRUSES** Y. Xia and S.-Y. Zheng *Pennsylvania State University, USA* .....444 A microfluidic device of porous silicon nanowire (PSNW) walls was fabricated to capture nanoparticles (NPs) based on their sizes. The space between PSNWs can be controlled to capture NPs with a specific size. For the first time, we demonstrated label-free virus capture with PSNW microfluidic device and later virus release due to PSNWs degradation.

TUESDAY PROGRAM

Session T3A Microphone & Flow Sensors	Session T3B Adaptive & Bioinspired Free-Space Optics	Session T3C MEMS Industry Group -Infrastructure/ Process Technology	Session T3D Resonators for Chemical Sensors	Session T3E BioMEMS
TIKAHTNU A	**TIKAHTNU B**	**TIKAHTNU CD**	**TIKAHTNU EF**	**TUBUGHNENQ**
Session Co-Chairs: T. Akin, *Middle East Technical University, TURKEY* G. Krijnen, *University of Twente, THE NETHERLANDS*	**Session Co-Chairs:** K.-H. Jeong, *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA* U. Wallrabe, University of Freiburg - IMTEK, GERMANY	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** X. Li, *Chinese Academy of Sciences, CHINA* R. Lu, *SPAWAR Systems Center Pacific, USA*	**Session Co-Chairs:** R. Ghodssi, *University of Maryland, USA* A. Hierlemann, *ETH Zurich, SWITZERLAND*
14:00 - 14:15				
T3A.003	**T3B.003**	**T3C.003**	**T3D.003**	**T3E.003**
A MICRO-MACHINED HYDROPHONE USING PIEZOELECTRICITY ON GATE OF A FIELD-EFFECT TRANSISTOR M. Sung, K. Shin, and W. Moon *Pohang University of Science and Technology (POSTECH), SOUTH KOREA* .....379 We report a miniaturized hydrophone using the electric field from a micro-sized piezoelectric body directly on a gate of a FET (Field-Effect Transistor), which allows overcoming the sensitivity limits of the micro-sized piezoelectric body for various underwater applications especially in low frequencies, as well as realizing the CMOS integrated underwater sensor system by using the CMOS compatible fabrication process designed in this work.	**ARTIFICIAL COMPOUND EYE INSPIRED BY IMAGING PRINCIPLE OF XENOS PECKII** D. Keum, D.S. Jeon, M.H. Kim, and K.H. Jeong *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA* .....403 This work reports an artificial compound eye inspired by the imaging principle of Xenos peckii, which is an endoparasite of paper wasps. The unique eye design of Xenos peckii exhibits higher spatial resolution and better sensitivity than conventional compound eyes. Each channel detects a different part of the whole scene, and the images are stitched in the following image processing step. The device can provide many opportunities for applications in medical, industrial and military fields.	**OPEN SOURCE SOFTWARE, ENABLING CUSTOMERS TO USE SENSOR PRODUCTS** A. Oliver *Freescale, USA* Software has become a big part of how people use embedded systems today. As such systems grow in complexity and flexibility, semiconductor companies now have to make a choice as to how to support their customer's efforts to program their devices. This topic aims to examine "going open source" as an option for customer software support, as compared to requiring the customer to write their code from scratch, or providing the software as additional enablement. By adopting an open source model, a company can build a community invested in their devices and get real time feedback on how well the software is working. Open source has its share of risks, but a well-maintained library of open source software can enable your customers to get to market faster, with cleaner results. **NON IEEE Copyrighted Session**	**GAS SENSING MATERIAL: SYNERGISTIC OPTIMIZATION AMONG SENSITIVITY, REPEATABILITY AND RESPONSE SPEED BY QUANTITATIVELY EXTRACTED KINETIC & THERMODYNAMIC MODEL PARAMETERS** P. Xu, S. Guo, H. Yu, and X. Li *Chinese Academy of Sciences, CHINA* .....424 Based on classical thermodynamic/kinetic theories like Langmuir model, a novel method is explored for comprehensive design/optimization of organophosphorus adsorbing/sensing nanomaterial, which is loaded on mass-type microcantilever sensor. Kinetic-thermodynamic model parameters are quantitatively extracted by experiment. Sensing-material performance is synergistically optimized by extracted parameters.	**KINESIN BEADS ASSAY IN MICRO CHANNELS TOWARD MOLECULAR MANIPULATION DIRECTLY DRIVEN BY MOTOR PROTEINS** K. Fujimoto, H. Shintaku, H. Kotera, and R. Yokokawa *Kyoto University, JAPAN* .....448 We propose a novel experimental setup toward molecular scale cargo transport directly driven by kinesin. In developed method, microtubules were immobilized in single micrometer scale channels and assayed fluoresecnt labeled kinesin in order to overcome the shortcomings of short run length of kinesin motility. The ratio between kinesin molecules moving on microtubule and diffusing was increased compared to conventional flowcell assay due to smaller volume where kinesin molecules can diffuse.

TUESDAY PROGRAM

Session T3A
Microphone & Flow Sensors

TIKAHTNU A

Session Co-Chairs:
T. Akin, *Middle East Technical University, TURKEY*

G. Krijnen, *University of Twente, THE NETHERLANDS*

Session T3B
Adaptive & Bioinspired Free-Space Optics

TIKAHTNU B

Session Co-Chairs:
K.-H. Jeong, *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA*

U. Wallrabe, University of Freiburg - IMTEK, GERMANY

Session T3C
MEMS Industry Group -Infrastructure/ Process Technology

TIKAHTNU CD

Session Chair:
K. Lightman, *MEMS Industry Group, USA*

Session T3D
Resonators for Chemical Sensors

TIKAHTNU EF

Session Co-Chairs:
X. Li, *Chinese Academy of Sciences, CHINA*

R. Lu, *SPAWAR Systems Center Pacific, USA*

Session T3E
BioMEMS

TUBUGHNENQ

Session Co-Chairs:
R. Ghodssi, *University of Maryland, USA*

A. Hierlemann, *ETH Zurich, SWITZERLAND*

14:15 - 14:30

T3A.004

MICRO ANEMOMETER BY A MEMS COMPATIBLE LAB-ON-A-TUBE TECHNOLOGY

Z. Yang[1], S. Liu[2], F. Xue[2], Y. Zhang[3], X. Zhao[1], J. Miao[1,2], and L.K. Norford[4]
[1]*Shanghai Jiao Tong University, CHINA,* [2]*Nanyang Technological University, SINGAPORE,* [3]*National Institute of Advanced Industrial Science and Technology (AIST), JAPAN, and* [4]*Massachusetts Institute of Technology, USA*
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This paper reports a novel micro airflow anemometer based on the hot-film sensing principle, i.e. gas cooling of electrically heated resistance. The sensor with three Ti/Pt hot-film components with width of 50μm and thickness of 130nm has been fabricated on a glass tube in a UV lithography system with multi-layer alignment by our developed MEMS compatible lab-on-a-tube technology. The micro anemometer has demonstrated high sensitivity, fast response ability to detect wind speed and direction.

T3B.004

MICROPATTERNING OF MULTIPLE PHOTONIC COLLOIDAL CRYSTALS IN SINGLE-LAYERED MICROCHANNELS FOR STRUCTURAL-COLOR OPTICAL FILTER

N. Suzuki[1], E. Iwase[2], and H. Onoe[1]
[1]*Keio University, JAPAN and* [2]*Waseda University, JAPAN*
.....407

We present a simple and rapid micro-patterning method of multiple types of photonic colloidal crystals (PCCs) on a single substrate for an optical color filter of a reflective display. We developed a "channel-cut method" to introduce multiple colloidal suspensions selectively and sequentially into a microchannel network. By combining this method with centrifugal crystallization, we succeeded in patterning of two different PCCs made of silica or polystyrene in a single-layered microchannel.

T3C.004

PANEL DISCUSSION INDUSTRY PERSPECTIVE ON MEMS AND SENSORS SUPPLY CHAIN - OPPORTUNITY AND CHALLENGES

Moderator:
R. O'Reilly, *Analog Devices, USA*

Panelists:
J. Knutti[1], M.A. Maher[2], A. Fitzgerald[3], and E. Pabo[4]
[1]*Acuity, USA,* [2]*SoftMEMS, USA,* [3]*AM Fitzgerald & Associates, USA, and* [4]*EV Group, USA*

There is still great-untapped opportunity for entrepreneurism and innovation in how MEMS and sensors can be brought from an idea to a commercial success. This panel, made up of industry veterans, will discuss the opportunities and challenges of navigating the MEMS and sensors supply chain. The panel will lend insight into how to navigate the partnerships and alliances required to ensure success. Researchers, entrepreneurs and seasoned engineers will benefit from the panelists advice on how to pick the right platform and partners for their applications. In MEMS and sensors, choosing the right path is vital to successful supply chain collaboration and achieving the best return on your investment. Come listen to this panel and get an inside perspective on the industry that you'll find nowhere else.

T3D.004

LOW-COST WEARABLE CANTILEVER-BASED NANOPARTICLE SENSOR MICROSYSTEM FOR PERSONAL HEALTH AND SAFETY MONITORING

H.S. Wasisto[1], W. Wu[1], S. Merzsch[1], E. Uhde[2], A. Waag[1], and E. Peiner[1]
[1]*Technische Universität Braunschweig, GERMANY and* [2]*Fraunhofer-WKI, GERMANY*
.....428

This paper describes a fully integrated low-cost wearable airborne nanoparticle (NP) detector based on silicon icroelectromechanical cantilever with an enhanced portability, functionality, electronics, time resolution, limit of detection (LOD), and calibration factor.

T3E.004

HIGH PERFORMANCE SIEVING OF BIOMOLECULES IN A CAPILLARY-WELL MOTIF

Z. Cao and L. Yobas
Hong Kong University of Science and Technology (HKUST), HONG KONG
.....452

We report a novel artificial sieving structure featuring a periodic array of nanometer-scale capillaries interleaved with deep wells by using standard microfabrication techniques. This capillary-well motif can maintain Ogston and entropic sieving mechanisms at higher fields ($\lesssim$1000 V/cm) than conventional artificial gel structures by adopting vastly steep entropic barriers; consequently, the resolution is greatly enhanced and the run time is concomitantly cut down by an order of magnitude.

TUESDAY PROGRAM

Session T3A Microphone & Flow Sensors	Session T3B Adaptive & Bioinspired Free-Space Optics	Session T3C MEMS Industry Group -Infrastructure/ Process Technology	Session T3D Resonators for Chemical Sensors	Session T3E BioMEMS
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: T. Akin, *Middle East Technical University, TURKEY* G. Krijnen, *University of Twente, THE NETHERLANDS*	**Session Co-Chairs:** K.-H. Jeong, *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA* U. Wallrabe, University of Freiburg - IMTEK, GERMANY	**Session Chair:** K. Lightman, *MEMS Industry Group, USA*	**Session Co-Chairs:** X. Li, *Chinese Academy of Sciences, CHINA* R. Lu, *SPAWAR Systems Center Pacific, USA*	**Session Co-Chairs:** R. Ghodssi, *University of Maryland, USA* A. Hierlemann, *ETH Zurich, SWITZERLAND*
14:30 - 14:45				
T3A.005	**T3B.005**		**T3D.005**	**T3E.005**
SMART SKIN OF SELF-POWERED HAIR CELL FLOW SENSORS FOR SENSING HYDRODYNAMIC FLOW PHENOMENA A.G.P. Kottapalli[1], M. Asadnia[1], E. Kanhere[2], M.S. Triantafyllou[3], and J.M. Miao[2] [1]*Singapore-MIT Alliance for Research and Technology (SMART), SINGAPORE,* [2]*Nanyang Technological University, SINGAPORE, and* [3]*Massachusetts Institute of Technology, USA* .....387 This work presents a flexible biomimetic smart skin of self-powered piezoelectric hair cell flow sensors capable of sensing various underwater flow phenomena. We developed 2D array of 20 MEMS flow sensors arranged in a 4×5 pattern spanning a foot-print of 30mm×40mm. The size of an individual sensor is 1.2mm×1.2mm. This paper presents the design, fabrication and complete underwater characterization of the PZT sensors.	**BIOINSPIRED BROAD-SPECTRUM MICRO-PHOTOCOLLECTORS IMPROVE SENSITIVITY OF IMAGE SENSORS IN LOW-LIGHT ENVIRONMENT** H. Liu, Y. Huang, and H. Jiang *University of Wisconsin, Madison, USA* .....411 This paper reports an imaging system inspired from the eyes of elephantnose fish for the detection of objects in low-light environment. Our bioinspired approach realizes broad-spectrum micro-photocollectors onto image sensors to increase their overall sensitivity, significantly improving the imaging performance in the dark. The novel fabrication process that creates the micro-photocollectors on curved surfaces can be applied to fabricate other 3D microstructures.	MIG CONTINUED	**TOWARDS REAL-TIME METHANE (CH_4) CAPTURE AND DETECTION BY NANOPARTICLE-ENHANCED SILICON CARBIDE TRAMPOLINE OSCILLATORS** Z. Wang, P. Wang, J. Lee, C.-C. Liu, and P.X.-L. Feng *Case Western Reserve University, USA* .....432 We report real-time methane detection using silicon carbide (SiC) resonant MEMS coated with SnO_2 nanoparticles (NPs). The coating greatly boosts the active adsorption area, toward enhancing the capture. SiC tethered square trampoline devices coated with ultrathin SnO_2 layers exhibit robust resonances in both vacuum and air, featuring large capturing area. Closed-loop oscillators with embedded SiC resonators enable fast, real-time readout of device responses upon exposure to CH_4.	**USING GELATIN METHACRYLATE COVERING AND DIELECTROPHORESIS FORCE MANIPULATING FOR LOBULE-MIMICKING CULTURE CHIP IN VITRO** Y.-S. Chen[1], C.-K. Tung[1], L.-Y. Ke[1], S.-K. Fan[2], X. Wang[3], and C.-H. Liu[1] [1]*National Tsing Hua University, TAIWAN,* [2]*National Taiwan University, TAIWAN, and* [3]*Tsinghua University, CHINA* .....456 In the paper, we demonstrate lobule-mimicking culture chip by using gelatin methacrylate (GelMA) covering and dielectro-phoresis (DEP) force manipulating. GelMA is a biocompatible and photocrosslinkable material and a kind of the hydrogel. The hydrogel material was used in chip for three purposes: precluding the damage between cells or tissue, providing a biological scaffold to keep cell growth, and supplying the nutrient to cells in diffusible situation.

TUESDAY PROGRAM

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14:45 - 15:00				
T3A.006 **MICRO ROTARY-LINEAR ACTUATOR ASSITED BY FERROFLUID LEVITATION FOR 3-DIMENSIONAL ENDOSCOPIC IMAGING** B. Assadsangabi and K. Takahata *University of British Columbia, CANADA* .....391 This paper reports the first microactuator that can selectively and simultaneously control rotary and linear motions of the rotor/slider developed forminimally invasive diagnostic and therapeuticcatheter applications. The rotor/slider is levitated by ferrofluid to achieve frictionless actuation of a prism mirror inside a cylindrical tube, enabling 360 continuous rotation while moving in the axial direction for full 3D scanning of an energy beam.	**T3B.006** **BIOINSPIRED HIERARCHICAL STRUCTURES OF FIREFLY LIGHT ORGAN** J.J. Kim, S.P. Yang, and K.H. Jeong *Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA* .....415 This work presents an engineering inspiration of hierarchical structures inspired from cuticular photonic structures of firefly light organ. The hierarchical structures which have asymmetric microstructures and longitudinal nanostructures were successfully mimicked by using geometry-guided resist reflow, replica molding, and PDMS oxidation. The measurement results show that the hierarchical structures improve light extraction and change light distribution.	**MIG CONTINUED**	**T3D.006** **PIEZOELECTRIC MEMS RESONATORS FOR DENSITY AND VISCOSITY SENSING IN ENGINE OIL WITH DIESEL FUEL** J. Toledo[1], T. Manzaneque[1], V. Ruiz-Díez[1], M. Kucera[2], G. Pfusterschimied[2], E. Wistrela[2], W. Steindl[2], U. Schmid[2], and J.L. Sánchez-Rojas[1] [1]*Universidad de Castilla-La Mancha, SPAIN,* [2]*Vienna University of Technology, AUSTRIA, and* [3]*AC2T research GmbH, AUSTRIA* .....436 We demonstrate the reliability of AlN-based resonators for the achievement of low-cost, miniaturized, on-line sensors for the monitoring of lubricant oil dilution with diesel. One of the resonators is actuated in the first extensional in-plane mode, in the MHz range. The second device is based on an out-of-plane mode, working at 340 kHz. Both devices are designed to feature high quality factor and low motional resistance in liquid, and allow to discriminate variations in density or viscosity.	**T3E.006** **DIGITAL DROPLET ELOHA FOR NUCLEIC ACID MOLECULE COUNTING AND ANALYSIS** W. Guan[1,2], L. Chen[2], T. Rane[2], A. Kaushik[2], and T.-H. Wang[2] [1]*Pennsylvania State University, USA and* [2]*Johns Hopkins University, USA* .....460 We present a new technology and method (Droplet Digital ELOHA: Enzyme-Linked Oligonucleotide Hybridization Assay) for digital quantification of nucleic acids, which enables extremely sensitive and specific quantification of nucleic acid molecules. Droplet digital ELOHA allows for absolute quantification without reliance on reference standards. Due to its hybridization nature, droplet digital ELOHA is particularly suitable for RNA quantification due to its single stranded nature and no reverse transcription is required. We demonstrate the absolute quantification ability of droplet digital ELOHA with clinical Neisseria Gonorrhoeae 16S rRNA to show its potential diagnostic values.

15:00 - 15:30	**Break & Exhibit Inspection**
15:30 - 17:30	**Poster/Oral Session T4P** Poster/Oral presentations are listed by topic category with their assigned number starting on page 64.
17:00 - 18:00	**Social Hour in Exhibit Hall**
20:00 - 24:00	**Tuesday Night at Chilkoot Charlie's (optional - over 21)**

WEDNESDAY PROGRAM

Wednesday, June 24

08:00 - 08:30 Continental Breakfast & Exhibit Inspection

Session W1A Packaging	Session W1B Batteries & Supercapacitors	Session W1C Microfluidic Tools	Session W1D Electro Kinetics	Session W1E Relays (LF Switches)
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Session Co-Chairs: J. Miao, *Nanyang Technological University, SINGAPORE* C. Spangler, *Aspen Microsystems, USA*	**Session Co-Chairs:** R. Candler, *University of California, Los Angeles, USA* J.B. Kim, *Yonsei University, SOUTH KOREA*	**Session Co-Chairs:** C. Buie, *Massachusetts Institute of Technology, USA* J. Ducree, *Dublin City University, IRELAND*	**Session Co-Chairs:** S. Pennathur, *University of California, Santa Barbara, USA* Y. Suzuki, *University of Tokyo, JAPAN*	**Session Co-Chairs:** R. Baskaran, *Intel Corp, USA* A. Lal, *Cornell University, USA*

08:30 - 08:45

W1A.001

FABRICATION OF THROUGH-SILICON-VIA (TSV) BY COPPER ELECTROPLATED IN AN ELECTROLYTE MIXED WITH SUPERCRITICAL CARBON DIOXIDE

H.C. Chuang[1], J. Sanchez[1], A.H. Liao[2], C.C. Shen[2], and C.C. Huang[3]
[1]*National Taipei University of Technology, TAIWAN,* [2]*National Taiwan University of Science and Technology, TAIWAN, and* [3]*National Cheng Kung University, TAIWAN*

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We have implemented a supercritical electroplating method for the filling of Through Silicon Vias (TSV). In this work, different supercritical-CO2 electroplating parameters, such as the supercritical pressure, the electroplating current density's effect on the TSV Cu pillar filling time, I-V Curve, electrical resistance and the hermeticity were discussed.

W1B.001

INVITED SPEAKER

MICRO SUPERCAPACITORS FOR ENERGY STORAGE, ON-CHIP DEVICES BASED ON PROTOTYPING OF PATTERNED NANOPOROUS CARBON

X. Wang[1] and S. Li[2]
[1]*Tsinghua University, CHINA and* [2]*Chinese Academy of Science, CHINA*

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Today's rapid growth of portable electronic equipment, wireless sensor networks and other micro systems is driving an increasing demand for better power supply and energy storage under various conditions. With the advantages of high charge/discharge rate, long cycle life and high energy efficiency, supercapacitors can bridge the gap between traditional capacitors and batteries, and are of the same importance as rechargeable batteries to energy storage systems. In order to develop an effective and direct way for batch fabrication of micro energy storage devices at wafer level, we demonstrate an idea of incorporating nano templating method into photolithography technology. Based on this prototyping of patterned nanoporous carbon electrode, we achieved 3D micro supercapacitors, silicon-based anode Li-ion batteries, as well as asymmetric supercapacitor-batteries.

W1C.001

FABRICATION AND BIOCHEMICAL SENSING APPLICATIONS OF CONTROLLABLE GERMANIUM NANOWIRES ARRAY

Q. Cai, L. Ye, B.J. Xu, Z.F. Di, Q.H. Jin, and J.L. Zhao
Chinese Academy of Sciences, CHINA

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In this work, we presented a new method to fabricate high-quality, controllable germanium nanowires (GeNW) array by combining the electron beam lithography (EBL) and Ge-condensation technology. Through this method, well-ordered, SiO2 coated GeNW array was obtained, and the preliminary biochemical sensing applications including pH and DNA sensors were realized.

W1D.001

SENSING AT THE NANOPARTICLE TRAPPED TIP OF FUNNEL NANOCHANNEL

J. Huang[1], S.W. Li[1], R. Zhang[1], and W. Wang[1,2,3]
[1]*Peking University, CHINA,* [2]*National Key Laboratory of Science and Technology on Micro/Nano Fabrication, CHINA, and* [3]*Innovation Center for Micro-Nano-Electronics and Integrated System, CHINA*

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We report ion transportation in the nanoparticles trapped tip of funnel nanochannel and its applicability in nucleic acid detection. Simulation showed H^+ distribution in funnel nanochannel was sensitive to surface charge density of the trapped nanoparticle, which resulted in the reported high sensitivity. 1fM biotin was detected in 100μM KCl solution and sensing of 22mer ssDNA and 22bp dsDNA was also achieved, which provided a potential application in ultra-sensitive microRNA detection on chip.

W1E.001

BATTERYLESS CONTINOUS ENVIRONMENT SENSING USING MEMS-CMOS NON VOLATILE MEMORY AND CHARGE STORAGE

W. Zhu, C.S. Wallace, Y. Zhang, and N. Yazdi
Evigia Systems Inc., USA

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This paper reports an Always “ON” wireless sensor that continuously tracks the environment and stores sense data on-chip without a battery. The sensor is enabled by ultra energy-efficient single transistor MEMS-CMOS non-volatile memory (NVM) and sensor switch arrays that extract energy for switching directly from their sense parameter. The overall energy requirements for sensing and digital data storage are lowered by 100-1000x enabling operation using on-chip MEMS-switch isolated stored charge.

WEDNESDAY PROGRAM

Session W1A Packaging	Session W1B Batteries & Supercapacitors	Session W1C Microfluidic Tools	Session W1D Electro Kinetics	Session W1E Relays (LF Switches)
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08:45 - 09:00				
W1A.002 **COMPREHENSIVE STUDY ON WAFER-LEVEL VACUUM PACKAGING USING ANODICALLY-BONDABLE LTCC WAFER AND THIN FILM GETTER** S. Tanaka and H. Fukushi *Tohoku University, JAPAN* .....468 An anodically-bondable LTCC wafer is a new wafer-level MEMS packaging material. In this study, the sealing pressure was investigated systematically under various anodic bonding conditions with and without a thin film getter. The vacuum sealing pressure was a few kPa or even higher, and more importantly, often different for each sample without the getter. However, samples with the getter always exhibited good vacuum level. Various standard process conditions for borosilicate glass worked well.	**INVITED CONTINUED**	**W1C.002** **SINGLE-STEP MANUFACTURING OF FEMTOLITER MICROWELL ARRAYS IN A NOVEL SURFACE ENERGY MIMICKING POLYMER** D.S. Decrop[1], G. Pardon[2], T. Kokalj[1], R. Puers[1], T. Haraldsson[2], J. Lammertyn[1], and W. van der Wijngaart[2] [1]*KU Leuven, BELGIUM and* [2]*KTH Royal Institute of Technology, SWEDEN* .....514 We developed a novel rapid and high-yield stamp-molding method for single-step manufacturing of hydrophilic-in-hydrophobic microwell arrays, allowing the self-assembly of 62'000 isolated femtoliter-droplets for digital ELISA application. We developed a novel thiol-ene-epoxy polymer, mOSTE+, which mimics the surface energy of its mold during polymerization, enabling simultaneous microstructuring and surface energy modification by mimicking during a single molding step.	**W1D.002** **ULTRA-THIN, EVAPORATION-RESISTENT PDMS-DEVICES FOR ABSOLUTE QUANTIFICATION OF DNA USING DIGITAL PCR** H.C. Zec, C. O'Keefe, P. Ma, and T.-H. Wang *Johns Hopkins University, USA* .....536 We present an array-based nanoliter digital PCR (dPCR) platform. The ultra-thin microfluidic device can accommodate high temperatures for extended periods. We believe this simple and cost-effective device will encourage wider adoption of dPCR. Furthermore, we demonstrate proof-of-concept digital PCR on the device.	**W1E.002** **LOW-VOLTAGE ELECTROSTATICALLY DRIVEN NANOELECTRO-MECHANICAL-SWITCHES** H. Iizuka and T. Ono *Tohoku University, JAPAN* .....560 The nanoelectromechanical (NEM) switches are designed and fabricated using nanofabrication technologies, and their switching properties are evaluated. The NEM-switches consist of three isolated electrodes. A low switching voltages of 0.8 V is achieved for Si based switch because of the flexible mechanical structure and the narrow electrode gaps of electrostatic actuators. The W based NEM-switches are also developed by an optimized deep-RIE method of W.

WEDNESDAY PROGRAM

Session W1A Packaging	Session W1B Batteries & Supercapacitors	Session W1C Microfluidic Tools	Session W1D Electro Kinetics	Session W1E Relays (LF Switches)
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09:00 - 09:15				
W1A.003	**W1B.003**	**W1C.003**	**W1D.003**	**W1E.003**
THE ADVANCED MEMS *(aMEMS)* PROCESS FOR FABRICATING WAFER LEVEL VACUUM PACKAGED SOI-MEMS DEVICES WITH EMBEDDED VERTICAL FEEDTHROUGHS M.M. Torunbalci, S.E. Alper, and T. Akin *Middle East Technical University (METU), TURKEY* .....472 This work presents novel and low-cost wafer level hermetic packaging method for SOI-MEMS devices, where an SOI wafer is used for the fabrication of MEMS structures as well as vertical feedthroughs, while a glass cap wafer is used for hermetic encapsulation and routing metallization. Glass-Si anodically bonded seals yield a very stable cavity pressure of 150mTorr after 15 days. The shear strength of the chips is above 7MPa. Reliability tests show no degradation in the hermeticity of the chips.	**IMMOBILIZED ELECTROLYTE BIODEGRADABLE BATTERIES FOR IMPLANTABLE MEMS** D. She[1], M. Tsang[2], J.K. Kim[1], and M.G. Allen[1] [1]*University of Pennsylvania, USA and* [2]*Georgia Institute of Technology, USA* .....494 We report a biodegradable battery featuring a solid electrolyte of sodium chloride (NaCl) and polycaprolactone (PCL). This approach harnesses in-diffusing bodily fluid as an element of the electrolyte; however, the large excess of ionic material suspended in the PCL acts to hold intracell conditions constant. A constant discharge profile can then be achieved even in the presence of varying external aqueous conditions, enabling ultracompact, stably-performing cells.	**INKJET PRINTING OF FUNCTIONALIZED SILK PROTEINS FOR ENHANCED STABILITY AND COLORIMETRIC BACTERIAL SENSING APPLICATIONS** H. Tao[1], B. Marelli[2], M. Yang[2], B. An[2], D.L. Kaplan[2], and F.G. Omenetto[2] [1]*Chinese Academy of Sciences, CHINA and* [2]*Tufts University, USA* .....518 We demonstrate a set of functionalized silk proteins by doping with biochemically active agents for enhanced stability and colorimetric bacterial sensing applications.	**3D SILICON ELECTRODES WITH BUILT-IN GLASS CAPILLARIES FOR DIELECTROPHORETIC SINGLE-CELL POSITIONING AND ANAYLISIS** Y. Luo[1,2] and L. Yobas[1] [1]*California Institute of Technology, USA and* [2]*Hong Kong University of Science and Technology, HONG KONG* .....540 A microfluidic platform featuring 3D silicon electrodes with built-in glass capillaries has been demonstrated for dielectrophoretic positioning and subsequent analysis of single cells	**NOVEL PIEZOELECTRIC OHMIC SWITCHES FEATURING FAST SWITCHING AND HIGH CONTACT FORCES** F. Stoppel, T. Lisec, and B. Wagner *Fraunhofer Institute for Silicon Technology (ISIT), GERMANY* .....564 In this paper fabrication and first measurement results of ohmic switches combining piezoelectric and electrostatic actuation are presented. The switches are based on novel design concepts offering very high contact forces at small device size of less than 0.05 mm^2. First fabricated MEMS switches enable ultra-fast on- and off-switching speed of less than 850 ns and 450 ns, respectively. Beyond that the switches feature very low contact resistances of less than 300 mΩ during on-state.

WEDNESDAY PROGRAM

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09:15 - 09:30				
W1A.004	**W1B.004**	**W1C.004**	**W1D.004**	**W1E.004**
A GENERIC PACKAGING TECHNIQUE USING FLUIDIC ISOLATION FOR LOW-DRIFT IMPLANTABLE PRESSURE SENSORS A. Kim[1], C.R. Powell[2], and B. Ziaie[1] [1]*Purdue University, USA and* [2]*Indiana University, USA* 476	**ALD TITANIUM NITRIDE COATED CARBON NANOTUBE ELECTRODES FOR ELECTROCHEMICAL SUPERCAPACITORS** E. Kao, C. Yang, R. Warren, A. Kozinda, and L. Lin *University of California, Berkeley, USA* 498	**PLASMA-CAVITATION PENCIL CUTTER FOR POWERFUL MICRO-PROCESSING** Y. Arakawa[1], M. Ohmura[1], D. Tsujimoto[1], and Y. Yamanishi[1,2] [1]*Shibaura Institute of Technology, JAPAN and* [2]*Japan Science and Technology Agency (JST), JAPAN* 521	**AN ELECTROKINETIC MICRODEVICE FOR ISOLATION AND QUANTIFICATION OF CIRCULATING CELL-FREE DNA FROM PHYSIOLOGICAL SAMPLES** A. Lamanda, Y. Lu, N.K. Gill, and P.K. Wong *University of Arizona, USA* 544	**STRESS-TOLERANT FULLY INKJET-PRINTED REED RELAYS** M. Ahosan Ul Karim, S. Chung, E. Alon, and V. Subramanian *University of California, Berkeley, USA* 568
We develop a generic packaging method for reducing drift in implantable pressure sensors. The described technique uses fluidic isolation by encasing the pressure sensor in a liquid-filled medical-grade polyurethane balloon; thus, isolating it from surrounding aqueous environment which is the major source of baseline drift. In-Vitro results showed 0.66 mmHg/month while non-packaged showed 20.3 mmHg/month. To our knowledge, this is the lowest reported drift for an implantable pressure sensor	We present titanium nitride coated carbon nanotube (CNT) forest electrodes by means of atomic layer deposition to store charge in the form of electrochemical supercapacitors. The specific achievements as compared with the state-of-art supercapacitor electrodes include: (1) conformal and uniform coating of TiN; and (2) greater than 500% enhancement of electrochemical capacitance at 81mF/cm2 over CNT electrodes without TiN due to increased oxygen vacancies on the TiN surfaces.	We have successfully developed novel processing device based on the combination mechanisms of cavitation and plasma irradiation. This technique uses the strong points of the powerful ablation of cavitation as well as plasma irradiation. The novelty of the technique enable to process not only conductive material but also non-conductive material such as polymer, CFRP and silicon, which is unlike conventional wire electric discharge machine.	This study reports a hybrid electrokinetic microdevice for rapid concentration and detection of circulating cell-free (cf)DNA.	A fully printed micro-electro-mechanical (MEM) Reed Relay is demonstrated to provide zero off-state leakage (I_{OFF}), low on-state resistance (R_{ON}) (~15 Ω), and moderate switching delay (~30 µs), while offering excellent immunity to mechanical stress variations in the printed cantilevers. Leveraging the stress gradient in sintered metal nanoparticles films and using a novel device architecture, this device is promising for large area electronics.

WEDNESDAY PROGRAM

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09:30 - 09:45				
W1A.005	**W1B.005**	**W1C.005**	**W1D.005**	**W1E.005**
A MICRO LASER DOPPLER VELOCIMETER DESIGNED FOR A WAFER-LEVEL PACKAGING PROCESS N. Morita[1], T. Akiyama[1], H. Nogami[1], Y. Hayashida[2], E. Higurashi[2], T. Ito[3], and R. Sawada[1] [1]*Kyushu University, JAPAN,* [2]*University of Tokyo, JAPAN, and* [3]*Kyushu Institute of Technology, JAPAN* .....480 We develop a micro laser Doppler velocimeter (μ-LDV), designed for a wafer-level packaging process for small size and mass productivity. This sensor is only 1/10,000th the volume of commercial LDVs. It can measure the velocity of solid objects such as aluminum and cardboard, and fluids such as water, oil, and air, using irradiated laser beam scattering by constituent particles, bubbles, cells, emulsion, etc.	**A 3D ALL-SOLID-STATE MICROSUPERCAPACITOR WITH ELECTRODES CONSISTING OF ACTIVATED CARBON/POLYMER ELECTROLYTE COMPOSITE** J. Pu[1,2], X. Wang[1], J. Liu[3], S. Li[1], and K. Komvopoulos[2] [1]*Tsinghua University, CHINA,* [2]*University of California, Berkeley, USA, and* [3]*Nankai University, CHINA* .....502 We demonstrates an all-solid-state microsupercapacitor (MSC) with thick electrodes consisting of activated carbon (AC)/polymer electrolyte (PE, PVA-H3PO4) composite. A novel electrode material with PE integrated with AC that has been adpoted to overcome the difficulty of PE penetrating the conventional porous electrodes and allow the use of thick electrodes for high capacitance and high energy density.	**FACILE INTEGRATION OF FREE-STANDING NANOFIBER MEMBRANE WITH MICROFLUIDIC DEVICE VIA ELECTROLYTE-ASSISTED ELECTROSPINNING** S.M. Park, W. Kim, H. Hong, and D.S. Kim *Pohang University of Science and Technology (POSTECH), SOUTH KOREA* .....525 This paper reports facile integration of a free-standing nanofiber membrane in a microfluidic device by electrolyte-assisted electrospinning, called ELES. We introduced an electrolyte solution as a collector for nanofibers, which enables flexible shaping of the collector from a two-dimensional to three-dimensional geometry. Furthermore, the electrolyte solution, filled in a microchannel of a microfluidic device, allows the nanofiber membrane to be spontaneously integrated with the device.	**AUTONOMOUS CAPILLARY MICROFLUIDICS FOR RAPID NANORECEPTOR ASSEMBLY AND BIOSENSING** F. Zang, K. Gerasopoulos, K. McKinzie, J.N. Culver, and R. Ghodssi *University of Maryland, USA* .....548 We report an autonomous integrated microsystem comprising capillary microfluidics and impedimetric sensors for rapid nanosensing probe assembly and antibody detection. The integrated system autonomously delivers Tobacco mosaic virus-like particles on the impedance sensor using open-channel microfluidics to form a dense functional sensing layer due to enhanced surface evaporation-assisted assembly within 6 minutes, detect the presence of the target antibody in 10 minutes after functionalization.	**A NORMALLY CLOSED MEMS MICRO REED SWITCH WITH FILL IN LIQUID METAL MICRO HINGE STRUCTURE** W.-C. Lai[1], C. Hong[2], W.-C. Lai[3], C.-H. Chang[3], C.-P. Chang[3], C.-H. Chen[3], and W. Fang[1] [1]*National Tsing Hua University, TAIWAN,* [2]*National Synchrotron Radiation Research Center (NSRRC), TAIWAN, and* [3]*WinMEMS Technologies, TAIWAN* .....572 This study has designed and implemented the first normally-closed (NC) micro reed-switch. The NC-type reed-switch is realized after special assembly of three separate metal structures (hinge, movable pad/spring, and fixed-pad). Merits of this NC reed-switch: (1) filed liquid-metal to ensure electrical connection at hinge, (2) UV-gel fixed hinge structure, and (3) magnetized repulsive actuating mechanism. The contact resistance is between 0.2-5Ω with 13% variation under a 20G excitation.

WEDNESDAY PROGRAM

Session W1A Packaging	Session W1B Batteries & Supercapacitors	Session W1C Microfluidic Tools	Session W1D Electro Kinetics	Session W1E Relays (LF Switches)
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: J. Miao, *Nanyang Technological University, SINGAPORE* C. Spangler, *Aspen Microsystems, USA*	**Session Co-Chairs:** R. Candler, *University of California, Los Angeles, USA* J.B. Kim, *Yonsei University, SOUTH KOREA*	**Session Co-Chairs:** C. Buie, *Massachusetts Institute of Technology, USA* J. Ducree, *Dublin City University, IRELAND*	**Session Co-Chairs:** S. Pennathur, *University of California, Santa Barbara, USA* Y. Suzuki, *University of Tokyo, JAPAN*	**Session Co-Chairs:** R. Baskaran, *Intel Corp, USA* A. Lal, *Cornell University, USA*
09:45 - 10:00				
W1A.006 **LONG-TERM EVALUATION OF A NON-HERMETIC MICROPACKAGE TECHNOLOGY FOR MEMS-BASED, IMPLANTABLE PRESSURE SENSORS** P. Wang[1], S.J.A. Majerus[1], R. Karam[1], B. Hanzlicek[2], D.L. Lin[2], H. Zhu[2], J.M. Anderson[1], M.S. Damaser[2], C.A. Zorman[1], and W.H. Ko[1] [1]*Case Western Reserve University, USA and* [2]*Louis Stokes Cleveland VA Medical Center, USA* .....484 We report the long-term evaluation of an all-polymer micropackage technology for an implantable MEMS pressure sensor. The micropackaged devices (N=2) show sensitivity and nonlinearity deviations of less than 5% and 0.3%, respectively after 160-day accelerated lifetime test in 85Celsius saline solution. A 6-month implant evaluation (N=16) further demonstrated good biocompatibility. To the best of our knowledge, these results establish new implant lifetime record for all-polymer micropackaging.	**W1B.006** **A SURFACE-MOUNT FLEXIBLE MICRO-SUPERCAPACITOR ON ULTRA THIN PARYLENE-C SUBSTRATE** S. Chen[1], X. Wang[1,2], J. Pu[1,3], and S. Li[1] [1]*Tsinghua University, CHINA,* [2]*Chinese Academy of Sciences, CHINA, and* [3]*University of California, Berkeley, USA* .....506 We report a surface-mount flexible micro-supercapacitor employing a thin parylene-C membrane (10 μm) as the substrate and activated carbon (AC) as the electrodes. A thin parylene-C layer was deposited on a Si wafer by chemical vapor deposition (CVD) without silanization and then peeled off mechanically with the fabricated interdigital electrodes on it. Our method and design offer an opportunity to apply energy storage devices for wearable electronics.	**W1C.006** **MULTILEVEL (3D) LAB ON CHIP FOR IMPLEMENTING RECONFIGURABLE MAGNETOPHORETIC FUNCTIONNALITIES** M. Fouet[1,2], S. Cargou[1,2], R. Courson[1,2], X. Bouquet[1,2], L. Salvagnac[1,2], and A.M. Gué[1,2] [1]*LAAS-CNRS, FRANCE and* [2]*Université de Tolouse, FRANCE* .....529 We demonstrate the integration of a multilevel magnetophoretic lab on chip: combining 3D fluid engineering and localized magnetic actuation enables the full integration of a cell tagging and magnetic separation device. The lab on chip was manufactured using a powerful and low cost dry film lamination technique enabling microcoils integration. A system performing magnetic handling of beads at cell resolution was devised and we proved that cell arrays can be organized dynamically and reversibly.	**W1D.006** **A HYDROGEL-BASED MEMS DIELECTRIC AFFINITY GLUCOSE SENSOR** J. Shang[1], Z. Zhang[1], J. Yan[2], Q. Wang[2], and Q. Lin[1] [1]*Columbia University, USA and* [2]*University of South Carolina, USA* .....552 We demonstrate a MEMS affinity glucose sensor that for the first time measures glucose concentrations through glucose-induced changes in the dielectric properties of a surface-immobilized functional hydrogel. This hydrogel-based approach simplifies the device structure, involves no mechanical moving parts and eliminates the use of semi-permeable membranes found in existing devices. Our experimental data demonstrates that this sensor can be potentially used for continuous glucose monitoring.	**W1E.006** **CONTACT RELIABILITY IMPROVEMENT OF A POLY-SIGE BASED NANO-RELAY WITH TITANIUM NITRIDE CONTACT** M. Ramezani[1,2], S. Severi[1], A. Moussa[1], H. Osman[1], H.A.C. Tilmans[1], and K. De Meyer[1,2] [1]*imec, BELGIUM and* [2]*KU Leuven, BELGIUM* .....576 We fabricate and characterize a vertical SiGe-based NEM relay with TiN contact compatible with CMOS post processing for monolithic integration. This NEM relay provides an optimal combination of small motional volume and long mechanical lifetime. With a total contact area of 0.01um^2, among the smallest reported so far, a low ON-resistance of around 1Mohm is achieved.

10:00 - 10:30	**Break & Exhibit Inspection**
10:30 - 12:30	**Poster/Oral Session W2P** Poster/Oral presentations are listed by topic category with their assigned number starting on page 64.
12:30 - 14:00	**Lunch on Own & Exhibit Inspection**

WEDNESDAY PROGRAM

Session W3A
Fabrication

TIKAHTNU A

Session Co-Chairs:
C.-W. Baek, *Chung-Ang University, SOUTH KOREA*

X. Wang, *Tsinghua University, CHINA*

Session W3B
Electromagnetic Power Generation & Management

TIKAHTNU B

Session Co-Chairs:
L. Fréchette, *Université de Sherbrooke, CANADA*

E. Halvorson, *Buskerud and Vestfold University College, NORWAY*

Session W3C
Chemical Sensors I

TIKAHTNU CD

Session Co-Chairs:
K. Sawada, *Toyohashi University of Technology, JAPAN*

T. Sikanen, *University of Helsinki, FINLAND*

Session W3D
Cellular Networks & Mechanics

TIKAHTNU EF

Session Co-Chairs:
W. Wu, *Peking University, CHINA*

X. Zhang, *Boston University, USA*

Session W3E
Ultrasound - Acoustic Sensors

TUBUGHNENQ

Session Co-Chairs:
B. Jakoby, *Johannes Kepler University Linz, Austria*

C. Lee, *National University of Singapore, SINGAPORE*

14:00 - 14:15

W3A.001

INVITED SPEAKER

SMART (SHRINK MANUFACTURING ADVANCED RESEARCH TOOLS)

S. Lin, E. Lee, J. Pegan, H. Sharma, and M. Khine
University of California, Irvine, USA

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The challenge of micro- and nano-fabrication lies in the difficulties and costs associated with patterning at such high resolution. To make such promising technology - which could enable pervasive health monitoring and disease detection/surveillance - more accessible and pervasive, there is a critical need to develop a manufacturing approach such that prototypes as well as complete manufactured devices cost only pennies. To accomplish this, instead of relying on traditional fabrication techniques largely inherited from the semiconductor industry, we have pioneered a radically different approach. Leveraging the inherent heat-induced relaxation of pre-stressed thermoplastic sheets - commodity shrink-wrap film - we pattern in a variety of ways at the large scale and achieve our desired structures by controlled shrinking down to 5% of the original, patterned sizes.

W3B.001

INVITED SPEAKER

EFFECT OF CURRENT DENSITY ON ELECTROPLATED CoPt THICK FILMS

O.D. Oniku, B. Qi, and D.P. Arnold
University of Florida, USA

.....596

In this talk, I will summarize advancements in electroplated Co-Pt alloys as candidate permanent magnetic materials for wafer-level integration and realization of magnetic microsystems, such as sensors, actuators, powerMEMS, and bioMEMS. As a fabrication technology, electrodeposition offers advantages of speed, cost, and process integrability. Compared to other magnetic materials, Co-Pt alloys offer good energy density, high Curie temperature, and high corrosion-resistance. Specific attention is focused on the Co-rich composition (Co80Pt20) as well as the equiatomic composition (Co50Pt50) in the ordered L10 phase. This talk will expound on the electrodeposition of these two alloys, the resultant magnetic properties, and their usage in example microsystem applications.

W3C.001

FLEXIBLE AND TRANSPARENT BENZENE SENSOR USING FUNCTIONALIZED FEW-LAYER MoS_2

D.-H. Baek, K. Lee, S. Pyo, J. Choi, and J. Kim
Yonsei University, SOUTH KOREA

.....618

We demonstrated a flexible and transparent benzene sensor using cobalt-metalloporphyrin (Co-MPP)-functionalized few-layer MoS_2 as sensing material for the first time. The sensor detected benzene down to 3 ppm at room temperature. The functionalization with Co-MPP catalysts enhanced sensitivity over 200% compared to the pristine MoS_2. The fabricated sensor showed good mechanical flexibility and optical transparency, which is advantageous for a wide variety of applications.

W3D.001

EMBRYO LAB CHIP TAKING ADVANTAGE OF MICROFLUIDICS AND CELL CO-CULTURING

C.-H. Liu[1], K.-W. Chang[1], P.-Y. Chang[1], Y.-J. Sung[1], H.-Y. Huang[2], D.-J. Yao[1], S.-K. Fan[3], W. Hsu[4], and C.-J. Li[2]
[1]*National Tsing Hua University, TAIWAN,* [2]*Chang Gung Memorial Hospital, TAIWAN,* [3]*National Taiwan University, TAIWAN, and* [4]*National Chiao Tung University, TAIWAN*

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The three-dimensional biomimetic microsystem described in this research integrates various functions of the fallopian tube to serve as an in vitro platform for fertilization and embryonic development. This device mimics the in vivo embryo-epithelial cell monolayer coculture to enhance the group culture of embryos. We demonstrated such an embryo Labchip taking advantage of microfluidics, cell co-culturing and dynamical culture environment toenhance the embryo development.

W3E.001

CAPACITIVE MICROMACHINED ULTRASONIC TRANSDUCERS FOR ACOUSTIC MANIPULATION

S.P. Mao[1,2], K. Zhong[2], V. Rochus[1], S. Severi[1], B. Nauwelaers[2], H.A.C. Tilmans[1], and X. Rottenberg[1]
[1]*imec, BELGIUM and* [2]*KU Leuven, BELGIUM*

.....662

We present a novel acoustic tweezer using capacitive micromachined ultrasonic transducers (cMUTs), which allows a stable trapping of PDMS micro-particles in water. To demonstrate this idea, a cMUT hexagonal annular array is assembled and characterized. PDMS micro-particles are successfully trapped to the maximum pressure position, which matches the numerical simulation well. To our best knowledge, it is the first time to realize a single acoustic beam trapping of micro-particles by cMUTs.

WEDNESDAY PROGRAM

Session W3A Fabrication	Session W3B Electromagnetic Power Generation & Management	Session W3C Chemical Sensors I	Session W3D Cellular Networks & Mechanics	Session W3E Ultrasound - Acoustic Sensors
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: C.-W. Baek, *Chung-Ang University, SOUTH KOREA* X. Wang, *Tsinghua University, CHINA*	**Session Co-Chairs:** L. Fréchette, *Université de Sherbrooke, CANADA* E. Halvorson, *Buskerud and Vestfold University College, NORWAY*	**Session Co-Chairs:** K. Sawada, *Toyohashi University of Technology, JAPAN* T. Sikanen, *University of Helsinki, FINLAND*	**Session Co-Chairs:** W. Wu, *Peking University, CHINA* X. Zhang, *Boston University, USA*	**Session Co-Chairs:** B. Jakoby, *Johannes Kepler University Linz, Austria* C. Lee, *National University of Singapore, SINGAPORE*
14:15 - 14:30				
		W3C.002	**W3D.002**	**W3E.002**
INVITED CONTINUED	INVITED CONTINUED	**AN INTEGRATED CARBON DIOXIDE SENSOR BASED ON RATIOMETRIC THERMAL-CONDUCTIVITY MEASUREMENT** Z. Cai[1], R.H.M. van Veldhoven[2], A. Falepin[3], H. Suy[2], E. Sterckx[3], K.A.A. Makinwa[1], and M.A.P. Pertijs[1] [1]*Delft University of Technology, THE NETHERLANDS,* [2]*NXP Semiconductors, THE NETHERLANDS, and* [3]*NXP Semiconductors, BELGIUM* .....622 We present an integrated CO_2 sensor for indoor air-quality sensing. The thermal-conductivity-based transducer and its readout circuit have been realized in 0.16µm CMOS technology. The $\Delta\Sigma$ readout employs ratiometric measurements to circumvent a stable power reference. The sensor achieves the highest resolution among thermal conductivity CO_2 sensors. It facilitates full integration of CO_2 sensors for air-quality sensing and reduces cost and volume significantly compared to NDIR sensors.	**STACKABLE OCTAHEDRON-BASED PHOTORESIST SCAFFOLD BY DIRECT LASER WRITING FOR CONTROLLED THREE-DIMENSIONAL CELL NETWORKS** F. Larramendy[1], S. Yoshida[2], Z. Fekete[1], D. Serien[2], S. Takeuchi[2], and O. Paul[1] [1]*University of Freiburg - IMTEK, GERMANY and* [2]*University of Tokyo, JAPAN* .....642 This paper reports a new technique for creating controlled, three-dimensional (3D) cellular networks. The method is based on stackable photoresist structural layers realized by direct laser writing. Cells can be positioned and cultured on the layers, which are then stacked, forming 30-µm-wide cages containing the cultured cells. Cells are able to communicate from cage to cage through openings, e.g., by developing neurites in networks of neuron-like cell.	**PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCER OF FLAT MEMBRANE WITH BOOSTED TRANSMITTING PERFORMANCE** T. Wang and C. Lee *National University of Singapore, SINGAPORE* .....666 We report a new piezoelectric micromachined ultrasonic transducer (pMUT) with a flat membrane, i.e. zero-bending membrane, in this paper. Leveraging on the pressure difference between atmosphere and vacuum, the initial deflection of membrane is significantly suppressed to 0.005% only for pMUT integrated with vacuum cavity. Transmitting sensitivity of the zero-bending pMUT is boosted to 450% of the reference pMUT with slightly non-zero initial deflection.

WEDNESDAY PROGRAM

Session W3A
Fabrication

TIKAHTNU A

Session Co-Chairs:
C.-W. Baek, *Chung-Ang University, SOUTH KOREA*

X. Wang, *Tsinghua University, CHINA*

Session W3B
Electromagnetic Power Generation & Management

TIKAHTNU B

Session Co-Chairs:
L. Fréchette, *Université de Sherbrooke, CANADA*

E. Halvorson, *Buskerud and Vestfold University College, NORWAY*

Session W3C
Chemical Sensors I

TIKAHTNU CD

Session Co-Chairs:
K. Sawada, *Toyohashi University of Technology, JAPAN*

T. Sikanen, *University of Helsinki, FINLAND*

Session W3D
Cellular Networks & Mechanics

TIKAHTNU EF

Session Co-Chairs:
W. Wu, *Peking University, CHINA*

X. Zhang, *Boston University, USA*

Session W3E
Ultrasound - Acoustic Sensors

TUBUGHNENQ

Session Co-Chairs:
B. Jakoby, *Johannes Kepler University Linz, Austria*

C. Lee, *National University of Singapore, SINGAPORE*

14:30 - 14:45

W3A.003

MINIATURE ORIGAMI-LIKE FOLDED MEMS TIMU
A. Efimovskaya, D. Senkal, and A.M. Shkel
University of California, Irvine, USA
.....584

We report implementation of the miniature Timing and Inertial Measurement Unit, utilizing a Folded MEMS approach. The Folded TIMU technique is based on wafer-level fabrication of single-axis sensors, interconnected by flexible polyimide hinges, and then folded, like a silicon origami, into a 3D configuration. We demonstrate for the first time operational TIMU prototypes <50 mm3 volume with near tactical grade performance.

W3B.003

MICROTRANSFORMERS ON 3D CLOSED-LOOP CORES MADE OF AMORPHOUS MAGNETIC ALLOYS
A. Moazenzadeh, F. Suárez Sandoval, N. Spengler, and U. Wallrabe
University of Freiburg - IMTEK, GERMANY
.....602

We present a novel approach for 3D microstructuring of amorphous soft magnetic alloys. Our unique process is MEMS-compatible and leaves the magnetic properties of the alloys intact. The applicability of the process has been demonstrated in fabrication of closed-loop core microtransformers. The microtransformers show higher performance in terms of inductance-density, coupling-factor, and power efficiency compared to conventional planar inductors or other published 3D microtransformers.

W3C.003

AN ALL ELECTRONIC, FULLY MICROFABRICATED MICRO GAS CHROMATOGRAPH
Y. Qin and Y.B. Gianchandani
University of Michigan, USA
.....626

We report a full micro gas chromatograph (μGC) in which all the components are electronic. All components, including a Knudsen pump, a preconcentrator, separation columns, and capacitive gas detectors, form a complete μGC system, which has no moving parts, uses room air as carrier gas, and can be co-fabricated by a common low-cost process. The extended abstract describes sampling, separation, and detection of 12 chemicals with 1-10 ppm concentrations.

W3D.003

LUNG CANCER MODEL ON CHIP FOR DRUG TESTING
K.-W. Chang[1], T.H. Punde[1], G.P. Pendharkar[1], P.-C. Shih[1], Y.-F. Chan[2], K.-Y. Lee[2], M.-Y. Chen[1], and C.-H. Liu[1]
[1]*National Tsing Hua University, TAIWAN and* [2]*Shuang Ho Hospital, TAIWAN*
.....646

In this research, we have mimicked the lung cancer microenvironment on chip which integrates a microfluidic gradient generator and electrode pattern. Six different concentrations of the anticancer drug of the Iressa were generated to treat the in vitro lung cancer (A549) and fibroblast cells (3T3) pattern which imitates the in vivo situation. The goal of this research was to investigate the effective minimum drug concentration for treating lung cancer cells.

W3E.003

PIEZOELECTRIC MICROMACHINED ULTRASONIC TRANSDUCER WITH INCREASED OUTPUT PRESSURE VIA CONCENTRIC VENTING RINGS
O. Rozen[1], S.T. Block[1], S.E. Shelton[2], and D.A. Horsley[1]
[1]*University of California, Davis, USA and* [2]*Chirp Microsystems, Inc., USA*
.....670

In a conventional piezoelectric micromachined ultrasonic transducer (PMUT), only half the acoustic output is used, because pressure emerging from the back of the PMUT is wasted. Here, we demonstrate a novel method to recycle the back-side acoustic pressure by redirecting it to the front-side through concentric venting rings. The ring diameter determines the phase-shift between the sound emerging from the front-side port and the ring, and can be adjusted to either amplify the far-field sound pressure level (SPL) or change the directivity of the output beam. Here, we demonstrate an 8 dB increase in the output SPL.

WEDNESDAY PROGRAM

Session W3A
Fabrication

TIKAHTNU A

Session Co-Chairs:
C.-W. Baek, *Chung-Ang University, SOUTH KOREA*

X. Wang, *Tsinghua University, CHINA*

Session W3B
Electromagnetic Power Generation & Management

TIKAHTNU B

Session Co-Chairs:
L. Fréchette, *Université de Sherbrooke, CANADA*

E. Halvorson, *Buskerud and Vestfold University College, NORWAY*

Session W3C
Chemical Sensors I

TIKAHTNU CD

Session Co-Chairs:
K. Sawada, *Toyohashi University of Technology, JAPAN*

T. Sikanen, *University of Helsinki, FINLAND*

Session W3D
Cellular Networks & Mechanics

TIKAHTNU EF

Session Co-Chairs:
W. Wu, *Peking University, CHINA*

X. Zhang, *Boston University, USA*

Session W3E
Ultrasound - Acoustic Sensors

TUBUGHNENQ

Session Co-Chairs:
B. Jakoby, *Johannes Kepler University Linz, Austria*

C. Lee, *National University of Singapore, SINGAPORE*

14:45 - 15:00

W3A.004

PREDICTION OF NEW ETCH FRONTS IN BLACK SILICON FORMATION AT CRYOGENIC TEMPERATURES

D. Abi Saab[1], P. Basset[1], M.J. Pierotti[2], M.L. Trawick[2], and D.E. Angelescu[1]
[1]*Université Paris-Est, FRANCE and* [2]*University of Richmond, USA*

.....588

This paper presents an explanation of the dynamic formation of black silicon (BSi) during cryogenic reactive ion etching (RIE) processes. It has been confirmed by both experimental data and computational modeling. The model correctly describes characteristics, such as the dependence of aspect ratio on process time, and the prediction of new etching fronts appearing at topographical saddle points during the incipient stages of BSi development.

W3B.004

MICROFABRICATED THOUSAND-TURN COILS FOR mW POWER GENERATION FROM SUB-mm VIBRATIONS

Q. Zhang, Y.F. Wang, L.R. Zhao, and E.S. Kim
University of Southern California, USA

.....606

This paper presents two microfabrication approaches for 3D multiple-layer coils for vibration-energy havesters. One type of coils is made out of 300μm thick copper that is electroplated with Si mold, while the other is built on 25μm thick copper electroplated with photoresist mold. The latter approach is used to obtain 1,080-turn coil for microfabricated electromagnetic energy harvester with magnet array and plastic spring.

W3C.004

QUANTITATIVELY EXTRACTED Gibbs FREE-ENERGY (ΔG) AS CRITERION TO DETERMINE WORKING TEMPERATURE RANGE OF GAS SENSING-MATERIAL

P. Xu, H. Yu, and X. Li
Chinese Academy of Sciences, CHINA

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For the first time, micro-gravimetric resonant micro-cantilever is used as a tool to determine the working temperature-range of molecule-adsorbing type sensing-material. According to the criterion of ΔG(T) above 0, the maximum working-temperature (T_{max}) for molecule-adsorbing function of the material can be obtained. This method is successfully used to determine the Tmax for two organophosphorus sensitive materials of mesoporous-silica and nano-spheric Stöber silica.

W3D.004

A FLOW-THROUGH ELECTROPORATION DEVICE UTILIZING DEAN VORTEX TO ENHANCE CELL VIABILITY

D. Huang, D. Zhao, M. Wu, Z. Liang, and Z. Li
Peking University, CHINA

.....650

This paper reports a flow electroporation device, in which the Dean vortex is employed to separate the cells from toxic by-product near the electrode during electroporation. This technique dramatically increases the cell viability, without decreasing the transfection rate. Furthermore, the simple structure of the proposed device eases the operation and allows high throughput.

W3E.004

PULSE-ECHO ULTRASONIC FINGERPRINT SENSOR ON A CHIP

H. Tang[1], Y. Lu[2], S. Fung[2], J.M. Tsai[3], M. Daneman[3], D.A. Horsley[2], and B.E. Boser[1]
[1]*University of California, Berkeley, USA,* [2]*University of California, Davis, USA, and* [3]*Invensense, USA*

.....674

A fully-integrated ultrasonic fingerprint sensor based on pulse-echo imaging is presented. The device consists of a 24x8 Piezoelectric Micromachined Ultrasonic Transducer (PMUT) array bonded at the wafer level to custom readout electronics fabricated in a 180-nm CMOS process. Monolithic integration is key to reducing interconnect parasitics and consequent signal degradation as well as scaling up to larger arrays.

WEDNESDAY PROGRAM

Session W3A
Fabrication

TIKAHTNU A

Session Co-Chairs:
C.-W. Baek, *Chung-Ang University, SOUTH KOREA*

X. Wang, *Tsinghua University, CHINA*

15:00 - 15:15

W3A.005

A MODIFIED INDUCTIVELY COUPLED PLASMA FOR HIGH-SPEED, ULTRA-SMOOTH REACTIVE PHASE ETCHING OF SILICA GLASS

C. Zhang, G. Hatipoglu, and S. Tadigadapa
Pennsylvania State University, USA

.....592

We report on the etching of various glass composition substrates in a modified inductively coupled plasma – reactive ion etch tool using SF6 as plasma source gas and NF3 and H2O gases introduced downstream near the surface of the wafer. Etch rates as high as 1.06 µm/min, 1.04 µm/min, and 0.45 µm/min with surface smoothness of ~2 Å, ~67 Å, ~4 Å for fused silica, borosilicate glass, and aluminosilicate glass respectively after 5 minutes etch.

Session W3B
Electromagnetic Power Generation & Management

TIKAHTNU B

Session Co-Chairs:
L. Fréchette, *Université de Sherbrooke, CANADA*

E. Halvorson, *Buskerud and Vestfold University College, NORWAY*

W3B.005

FABRICATION OF MULTI-LAYER WINDINGS IN SILICON-EMBEDDED TOROIDAL INDUCTORS

X. Yu[1] and M.G. Allen[2]
[1]*Georgia Institute of Technology, USA and*
[2]*University of Pennsylvania, USA*

.....610

We report a fabrication method for silicon-embedded toroidal inductors with multi-layer windings, based on 3D shadow mask technology. Such multilayer devices boost inductance density within a limited footprint, which is vital for realization of integrated high-power high-frequency power converters. Fabrication of the embedded toroidal inductors with double-layer windings is illustrated; characterization shows a 4x inductance increase compared to an embedded inductor with single-layer windings.

Session W3C
Chemical Sensors I

TIKAHTNU CD

Session Co-Chairs:
K. Sawada, *Toyohashi University of Technology, JAPAN*

T. Sikanen, *University of Helsinki, FINLAND*

W3C.005

MOLECULARLY IMPRINTED ORGANIC TRANSISTOR-BASED SENSOR FOR SELECTIVE TRACE CHEMICAL VAPOR DETECTION

H. Zheng and S. Gangopadhyay
University of Missouri, USA

.....634

We report a vapor phase MIP technique suitable for an organic semiconducting layer in an organic field-effect transistors (OFET)-based sensor. Pentacene MIP OFET-based sensor showed enhanced selectivity to dinitrotoluene (DNT) vapor against various interfering analytes. This method can be extended to improve the selectivity of most OFET- and chem-resistor-based sensors without adversely affecting device electronic properties.

Session W3D
Cellular Networks & Mechanics

TIKAHTNU EF

Session Co-Chairs:
W. Wu, *Peking University, CHINA*

X. Zhang, *Boston University, USA*

W3D.005

SINGLE CELL MANIPULATION IN CELL CULTURE MEDIA WITH SELF-LOCKING OPTOELECTRONIC TWEEZERS ACROSS A LARGE AREA

Y.J. Yang, Y.F. Mao, X.F. Zhu, K.S. Shin, C.O. Chui, and P.Y. Chiou
University of California, Los Angeles, USA

.....654

We report a novel Self-Locking Optoelectronic Tweezers (SLOT) for single cell manipulation in cell culture media across a large area. SLOT overcomes two major technical barriers of conventional optoelectronic tweezers (OET) toward high throughput single cell manipulation. Its unique lateral, ring-shaped phototransistor design enables manipulation in high conductivity media (1 S/m) and overcomes a fundamental blurry optical pattern issue for single cell manipulation in large area (> 1 cm^2).

Session W3E
Ultrasound - Acoustic Sensors

TUBUGHNENQ

Session Co-Chairs:
B. Jakoby, *Johannes Kepler University Linz, Austria*

C. Lee, *National University of Singapore, SINGAPORE*

W3E.005

FLEXIBLE ACOUSTIC EMISSION SENSOR ARRAY WITH THERMORESPONSIVE ACTUATOR ENHANCING SENSITIVITY FOR MONITORING OSTEOARTHRITIS

G.-H. Feng and W.-M. Chen
National Chung Cheng University, TAIWAN

.....678

We develop a novel flexible piezoelectric film acoustic emission sensor array with thermoresponsive polymer actuators enhancing its sensitivity. A PZT film is grown on a micromachined titanium beam array as an acoustic sensing material. Thermoresponsive polymer actuators fabricated with Poly(N-isopropylacrylamide) are constructed onto the beam array. The thermoresponsive actuators achieve excellent force contact with the target so as to increase detection sensitivity.

WEDNESDAY PROGRAM

Session W3A Fabrication	Session W3B Electromagnetic Power Generation & Management	Session W3C Chemical Sensors I	Session W3D Cellular Networks & Mechanics	Session W3E Ultrasound - Acoustic Sensors
TIKAHTNU A	**TIKAHTNU B**	**TIKAHTNU CD**	**TIKAHTNU EF**	**TUBUGHNENQ**
Session Co-Chairs: C.-W. Baek, *Chung-Ang University, SOUTH KOREA* X. Wang, *Tsinghua University, CHINA*	**Session Co-Chairs:** L. Fréchette, *Université de Sherbrooke, CANADA* E. Halvorson, *Buskerud and Vestfold University College, NORWAY*	**Session Co-Chairs:** K. Sawada, *Toyohashi University of Technology, JAPAN* T. Sikanen, *University of Helsinki, FINLAND*	**Session Co-Chairs:** W. Wu, *Peking University, CHINA* X. Zhang, *Boston University, USA*	**Session Co-Chairs:** B. Jakoby, *Johannes Kepler University Linz, Austria* C. Lee, *National University of Singapore, SINGAPORE*
15:15 - 15:30				
	W3B.006 **NON-RESONANT, BROAD-BAND VIBRATION-ENERGY HARVESTER BASED ON SELF-ASSEMBLED LIQUID BEARING** Y. Wang, Q. Zhang, L. Zhao, and E.S. Kim *University of Southern California, USA* .....614 This paper reports a non-resonant, broad-band electromagnetic energy harvester based on self-assembled liquid bearing made of ferrofluid. Hydrophobic surface is adopted to reduce the friction. Microfabricated multi-layer coil plate is employed to increase electromotive force (EMF). The liquid bearing has produced μW level of power from 1 g acceleration with a non-resonant structure ($20.7 \times 12 \times 4.5$ mm^3) even at 2 – 4 Hz, a frequency range that would be too low for a resonant energy harvester.		**W3D.006** **A MICROFLUIDIC DEVICE FOR AUTOMATED, HIGH-SPEED MICROINJECTION OF CAENORHABDITIS ELEGANS** P.F. Song, X.K. Dong, and X.Y. Liu *McGill University, CANADA* .....658 This paper reports a novel microfluidic worm trapping device that enables, for the first time, fully-automated, high-speed microinjection of the nematode worm C. elegans. The microfluidic device, integrated with a robotic system, is capable of sequentially loading, immobilizing, injecting, and sorting C. elegans without human intervention. We demonstrate an injection speed of 5.0 worm/min and a pre-sorting success rate of 77.5%, both much higher than the performance of manual operation.	**W3E.006** **EFFECT OF FLUID LOSSES AND ACOUSTIC RESONANCES IN CMUTS WITH VENTED CAVITIES** N. Apte[1], K.K. Park[2], A. Nikoozadeh[1], and B.T. Khuri-Yakub[1] [1]*Stanford University, USA and* [2]*Hanyang University, SOUTH KOREA* .....682 We report on capacitive micromachined ultrasonic transducers with vented cavities for varying their bandwidth and sensitivity in airborne applications. The devices are simulated using a finite element model which incorporates viscous and thermal fluid losses in the squeeze film and the vent holes, as well as acoustic radiation and acoustic resonance in the backing. Our model accurately predicts the behavior of such CMUTs. The model is also validated with measurements at elevated pressure.
16:30 - 24:30	**Transducers Prince William Sound Dinner Cruise (optional)**			

THURSDAY PROGRAM

Thursday, June 25

08:30 - 09:30 | Continental Breakfast

Session Th1A
Physical Microfluidics II

TIKAHTNU A

Session Co-Chairs:
Y.-K. Lee, Hong Kong University of Science and Technology, HONG KONG

W. Li, *Michigan State University, USA*

Session Th1B
Piezoelectric & SMA Energy Conversion Devices

TIKAHTNU B

Session Co-Chairs:
D. Horsley, *University of California, Davis, USA*

M. Rinaldi, *Northeastern University , USA*

Session Th1C
Integrated, Portable Bio Devices

TIKAHTNU CD

Session Co-Chairs:
K. Bohringer, *University of Washington, USA*

Y.-C. Lin, *National Cheng Kung University, TAIWAN*

Session Th1D
Microfabrication & Materials

TIKAHTNU EF

Session Co-Chairs:
S. Franssila, *Aalto University, FINLAND*

N. Miki, *Keio University, JAPAN*

Session Th1E
Micro/Nano Scale Physics Characterization

TUBUGHNENQ

Session Co-Chairs:
Q.-A. Huang, *Southeast University, CHINA*

O. Paul, *University of Freiburg - IMTEK, GERMANY*

09:00 - 09:15

Th1A.001

INVITED SPEAKER

PHYSICAL SENSORS FOR FLUIDS

B. Jakoby
University of Linz, AUSTRIA
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Modern process control and condition monitoring applications frequently require information on the state or composition of (process) fluids. Often such sensors are chemical sensors achieving the required specificity by means of chemical reactions taking place in a chemical interface which is placed on a physical sensor. Here, chemical reactions with substances in the fluid change some physical property of the interface (e.g., density or conductivity), which is the final parameter being sensed. However, chemical interfaces often do not conform to the requirements in terms of robustness, e.g., in industrial applications. As an alternative, physical parameters of the fluid can be sensed such that no chemical interface is required. This approach works particularly well, if the monitored process is well understood and thus the physical parameters are clearly correlated to the chemical information that is actually required. The quality of this relation can often be further improved by utilizing physical sensor arrays yielding additional correlations. Examples for physical parameters are thermal and electrical conductivity, permittivity, viscosity, speed of sound, and density. In this contribution these concepts are reviewed with a particular focus on mechanical fluid properties. We discuss issues arising with complex fluids, suitable sensor designs in different technologies, and illustrate these aspects by means of examples.

Th1B.001

SCALABLE TEXTILE ENERGY HARVESTER IN WOVEN PIEZOELECTRIC STRUCTURES

S. Song[1], Y. Ahn[2], and K.S. Yun[2]
[1]*Samsung Electronics Co., SOUTH KOREA and* [2]*Sogang University, SOUTH KOREA*
.....708

This paper reports a piezoelectric energy harvester with a fabric textile structure for wearable applications. We present theoretical analysis and experimental demonstration of proposed device using multi-thread structures with various thread dimensions. The results show that a large-area device for wearable application can be easily obtained using the proposed structure and we can increase the output power density using highly dense textiles with fine threads.

Th1C.001

INVITED SPEAKER

SINGLE-CELL MORPHOLOGICAL ANALYSIS FOR RAPID ANTIMICROBIAL SUSCEPTIBILITY TEST

J. Choi[1], J. Yoo[2], M. Lee[2], E.-G. Kim[2], J.S. Lee[3], S. Lee[4], S. Joo[5], S.H. Song[5], E.-C. Kim[5], J.C. Lee[1], H.C. Kim[1], Y.-G. Jung[2], and S. Kwon[1,2]
[1]*Seoul National University, SOUTH KOREA,* [2]*Quanta Matrix Inc., SOUTH KOREA,* [3]*Seoul National University Graduate, SOUTH KOREA,* [4]*Incheon St. Mary's Hospital, The Catholic University School of Medicine, SOUTH KOREA, and* [5]*Seoul National University Hospital, SOUTH KOREA*
.....730

I will present recent examples in my lab that successfully made translation from lab invention to hospital usage. A rapid antibiotic susceptibility test (RAST) is desperately needed in clinical settings for fast and appropriate antibiotic administration. Traditional ASTs are not suitable for urgent cases of bacterial infection and antibiotic resistance due to their relatively long test time. I will present a fast AST method named single-cell morphological analysis (SCMA) that can determine antimicrobial susceptibility by analyzing and categorizing morphological changes in single bacterial cells under various antimicrobial conditions. With SCMA, AST is finished only in 3 hours satisfying FDA guidelines. I will discuss application of SCMA to fast diagnostics of multi-drug resistant tuberculosis.

Th1D.001

INVITED SPEAKER

SURFACE DESIGN FOR HIGH-SENSITIVITY MICRO-BIOSENSOR

M. Takai
University of Tokyo, JAPAN
.....751

To obtain high-sensitivity on biosensor for instance immunoassay, the amount of immobilized antibody should be increased and the orientation of immobilized antibody should be controlled. Moreover the decrease of non-specific protein adsorption also is requested to decrease the noise. Two typed bio-conjugated interfaces to be achieved highly sensitive immunoassay were developed by integrating a phospholipid polymer, which is cell-membrane mimetic material. In this paper, overview of surface design for high-sensitivity micro-biosensor is presented.

Th1E.001

ATOMIC SCALE ADHESION PHENOMENA IN A TWO MILLION CYCLE SIDEWALL CONTACT EXPERIMENT

J. Kokorian[1], U. Staufer[1], and W.M. van Spengen[1,2]
[1]*Delft University of Technology, THE NETHERLANDS and* [2]*Falco Systems B.V., THE NETHERLANDS*
.....772

We present a measurement that shows the adhesion development of two contacting poly-silicon sidewalls as a function of the number of contact cycles, with single nanonewton resolution. We identify four distinct stages of adhesion behavior. The adhesion curves of each of the stages reveal nanometer sized features that suggest the gradual formation of a soft substance with a long relaxation time.

THURSDAY PROGRAM

Session Th1A Physical Microfluidics II	Session Th1B Piezoelectric & SMA Energy Conversion Devices	Session Th1C Integrated, Portable Bio Devices	Session Th1D Microfabrication & Materials	Session Th1E Micro/Nano Scale Physics Characterization
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: Y.-K. Lee, Hong Kong University of Science and Technology, HONG KONG W. Li, *Michigan State University, USA*	**Session Co-Chairs:** D. Horsley, *University of California, Davis, USA* M. Rinaldi, *Northeastern University , USA*	**Session Co-Chairs:** K. Bohringer, *University of Washington, USA* Y.-C. Lin, *National Cheng Kung University, TAIWAN*	**Session Co-Chairs:** S. Franssila, *Aalto University, FINLAND* N. Miki, *Keio University, JAPAN*	**Session Co-Chairs:** Q.-A. Huang, *Southeast University, CHINA* O. Paul, *University of Freiburg - IMTEK, GERMANY*
09:15 - 09:30				
	Th1B.002			**Th1E.002**
INVITED CONTINUED	**A NON-HARMONIC MOTION-POWERED PIEZOELECTRIC FM WIRELESS SENSING SYSTEM** H. Jiang, M.E. Kiziroglou, D.C. Yates, and E.M. Yeatman *Imperial College London, UK* .....710 We present a piezoelectric wireless sensing device which is completely powered by inertial motions. Self-synchronous switching is applied to the device using switching diodes and reed switches, which allows the system to function in response to its moving proof mass. By combining piezoelectric energy harvesting and radio frequency (RF) transmission, a fully functional piezoelectric system is built, for the first time, allowing instantaneous wireless monitoring of signals from a passive sensor using frequency modulation (FM).	INVITED CONTINUED	INVITED CONTINUED	**A COMPARISON BETWEEN EXPERIMENTS AND FEM PREDICTIONS FOR BLOWTORCH REFLOW OF FUSED SILICA MICRO-SHELL RESONATORS** B. Shiari, A. Darvishian, T. Nagourney, J. Cho, and K. Najafi *University of Michigan, USA* .....776 We report a non-isothermal model and FEM results for prediction of geometries of fused silica (FS) micro-shell resonators, which are fabricated by blowtorch molding process. The model is successfully applied to investigate the production details of 3-D hemi-ellipsoidal shells of revolutions with eccentricity such as Bird-Bath (BB) shell resonators. The simulation results display in form contours associated with different blow-torching process parameters at each time step.

THURSDAY PROGRAM

Session Th1A Physical Microfluidics II	Session Th1B Piezoelectric & SMA Energy Conversion Devices	Session Th1C Integrated, Portable Bio Devices	Session Th1D Microfabrication & Materials	Session Th1E Micro/Nano Scale Physics Characterization
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: Y.-K. Lee, Hong Kong University of Science and Technology, HONG KONG W. Li, *Michigan State University, USA*	**Session Co-Chairs:** D. Horsley, *University of California, Davis, USA* M. Rinaldi, *Northeastern University , USA*	**Session Co-Chairs:** K. Bohringer, *University of Washington, USA* Y.-C. Lin, *National Cheng Kung University, TAIWAN*	**Session Co-Chairs:** S. Franssila, *Aalto University, FINLAND* N. Miki, *Keio University, JAPAN*	**Session Co-Chairs:** Q.-A. Huang, *Southeast University, CHINA* O. Paul, *University of Freiburg - IMTEK, GERMANY*
09:30 - 09:45				
Th1A.003	**Th1B.003**	**Th1C.003**	**Th1D.003**	**Th1E.003**
ACOUSTICALLY DRIVEN MICROFLUIDIC DEVICES BASED ON HEXAGONAL PHONONIC CRYSTAL STRUCTURES D. Feng, D.H. Xu, B. Xiong, and Y.L. Wang *Chinese Academy of Sciences, CHINA* .....692 This paper demonstrates the novel use of hexagonal phononic crystal structure based microchip, which is actuated by surface acoustic waves (SAW), to concentrate polystyrene particles in microliter droplet. The phononic structure interacts with the acoustic field, providing reflectivity, scattering or diffraction to the acoustic waves. Thus, efficiently manipulation of the droplet could be achieved.	**THIN-FILM PIEZOELECTRIC TRANSFORMERS OPERATING IN HARMONICS OF OUT-OF-PLANE FLEXURE MODES** S.S. Bedair, J.S. Pulskamp, R.G. Polcawich, R.Q. Rudy, and J.M. Puder *US Army Research Laboratory, USA* .....714 We present disc-shaped flexure-mode piezoelectric transformers constructed with 0.5 µm lead-zirconate-titanate (PZT) on 4 µm silicon resonators. The transformers are electrode shaped to excite out-of-plane flexure harmonic modes at ~12, ~34, and ~63 MHz. Expected efficiencies >50% with ~5X open-circuit voltage gains are shown. Transformer figures of merit equivalent to previously-reported extensional modes are demonstrated with 3X-13X size reductions.	**COCKTAIL DRUG DELIVERY CHIP FOR CANCER DRUG SCREENING** Y.-T. Chen[1], R.-G. Wu[1], C.-S. Yang[2], and F.-G. Tseng[3] [1]*National Tsing Hua University, TAIWAN,* [2]*National Health Research Institutes, TAIWAN, and* [3]*Academia Sinica, TAIWAN* .....735 This study introduces a combinatory assay platform that allows high-throughput but low-drug-dosage screening of five anti-cancer drugs as a cocktail for personalized cancer treatment. Photo sensitive PEGDA hydrogel was employed for drug dosage definition through drop array formation and selective UV crosslinking process. The finally defined cocktail drugs in hydrogel will be directly released in parallel when combined with cell chips. This device is able to combine 5 drugs with 1000 folds dynamic range in 30 second with low drug consumption for in-parallel cocktail screening process.	**MICROCAPSULE ARRAY FABRICATED BY ICE-PRINTING TECHNOLOGY FOR ON-SITE BIOCHEMICAL DETECTION** H.Z. Zhang, F.T. Zhang, D. Huang, Y.L. Zhou, X.X. Zhang, and Z.H. Li *Peking University, CHINA* .....757 In this paper, we proposed a portable, easy-to-operate, low cost and anti-fouling microcapsule array aiming for multitarget biochemical assay. This novel microcapsule array is achieved by ice printing and photopolymerization sealing. Only tiny amount of sample (2µL) is needed to fulfill the assay. Nitrite was chosen as a model target as a proof of concept. An instant qualitative detection by naked eyes was achieved without the need of any external sophisticated instruments.	**VIBRATIONS REJECTION IN GYROSCOPES BASED ON PIEZORESISTIVE NANOGAUGES** F. Giacci, S. Dellea, A.F. Longoni, and G. Langfelder *Politecnico di Milano, ITALY* .....780 The work discusses effects of vibrations on rate gyroscopes performance in terms of Allan variance, and presents the results of vibrations rejection on a z-axis gyroscope based on piezoresistive NEMS readout. In a comparative analysis with a consumer off-the-shelf gyroscope, the proposed device shows 10-fold better angle random walk (ARW) under no vibrations, and at least 100-fold better Allan variance when acquired under vibration amplitude of ±6 g (gravity units), at frequencies up to 10 kHz.

THURSDAY PROGRAM

Session Th1A
Physical Microfluidics II

TIKAHTNU A

Session Co-Chairs:
Y.-K. Lee, Hong Kong University of Science and Technology, HONG KONG

W. Li, *Michigan State University, USA*

09:45 - 10:00

Th1A.004

PARTICLE SEPARATION UNDER THE CO-ACTION OF BROWNIAN MOTION AND OPTICAL FORCE IN NEAR-FIELD SPECKLE PATTERNS

H.T. Zhao[1], G. Zhang[1], L.K. Chin[1], H. Cai[2], J.F. Song[2], Z.C. Yang[3], E.P.H. Yap[1], W. Ser[1], D.L. Kwong[2], and A.Q. Liu[1]
[1]*Nanyang Technological University, SINGAPORE,* [2]*Institute of Microelectronics, SINGAPORE, and* [3]*Peking University, CHINA*

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We investigate the particle's statistical motion under the co-action of Brownian motion and optical force in near-field speckle patterns. This method avoids the stringent optical systems and broadens the perspectives of optical manipulation for real-life applications.

Session Th1B
Piezoelectric & SMA Energy Conversion Devices

TIKAHTNU B

Session Co-Chairs:
D. Horsley, *University of California, Davis, USA*

M. Rinaldi, *Northeastern University , USA*

09:45 - 10:00

Th1B.004

THERMAL ENERGY HARVESTING BY HIGH FREQUENCY ACTUATION OF MAGNETIC SHAPE MEMORY ALLOY FILMS

M. Gueltig[1], M. Ohtsuka[2], H. Miki[2], T. Takagi[2], and M. Kohl[1]
[1]*Karlsruhe Institute of Technology (KIT), GERMANY and* [2]*Tohoku University, JAPAN*

.....718

A novel energy harvesting device using magnetic shape memory alloy film actuation is presented showing a power density of up to 3 mW/cm^3 that exceeds the power output of previous MSMA harvesting devices by three orders of magnitude and challenges state-of-the-art thermoelectrics. This is accomplished by using a tailored Ni-Co-Mn-Ga film with a high change of magnetization at the Curie temperature and a new cantilever design, with low thermal mass for rapid heat transfer in the order of 10 ms.

Session Th1C
Integrated, Portable Bio Devices

TIKAHTNU CD

Session Co-Chairs:
K. Bohringer, *University of Washington, USA*

Y.-C. Lin, *National Cheng Kung University, TAIWAN*

09:45 - 10:00

Th1C.004

CONNECTABLE DNA-LOGIC OPERATION USING DROPLETS AND RUPTURE/REFORMATION OF BILAYER LIPID MEMBRANES

K. Inoue[1,2], R. Kawano[3], H. Yasuga[1], M. Takinoue[4], T. Osaki[2,5], K. Kamiya[2], N. Miki[1,2], and S. Takeuchi[2,5]
[1]*Keio University, JAPAN,* [2]*Kanagawa Academy of Science and Technology, JAPAN,* [3]*Tokyo University of Agriculture and Technology, JAPAN,* [4]*Tokyo Institute of Technology, JAPAN, and* [5]*University of Tokyo, JAPAN*

.....739

This paper demonstrated connection of logic gates using DNA and membrane protein's channel reconstituted into bilayer lipid membrane (BLM). In this gate, droplets are used to convey DNA to next stage and BLM's rupture accelerates the DNA transfer between droplets. Moreover, DNA is detected based on the electrical and physical characters of DNA translocation via the channel. In this work, we successfully demonstrated NOR gate. This system is readily applicable to develop high sensitive biosensor.

Session Th1D
Microfabrication & Materials

TIKAHTNU EF

Session Co-Chairs:
S. Franssila, *Aalto University, FINLAND*

N. Miki, *Keio University, JAPAN*

09:45 - 10:00

Th1D.004

BIOLOGICAL INSPIRED SUPERHYDROPHOBIC AND SELF-CLEANING FLEXIBLE SILICONE RUBBER

S. Harada, T. Arie, S. Akita, and K. Takei
Osaka Prefecture University, JAPAN

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We develop a flexible and stretchable superhydrophobic surface on a silicone rubber by one-step laser treatment. Previously, there are some studies about the fabrication of superhydrophobic surface on silicone rubber. However, the superhydrophobicity and self-cleaning under bending/stretching and time reliability have yet to be demonstrated. Here, we conduct a systematic study of superhydrophobic and self-cleaning surface under applying a tensile stress and its application of microfluidic valve.

Session Th1E
Micro/Nano Scale Physics Characterization

TUBUGHNENQ

Session Co-Chairs:
Q.-A. Huang, *Southeast University, CHINA*

O. Paul, *University of Freiburg - IMTEK, GERMANY*

09:45 - 10:00

Th1E.004

DYNAMIC TRAPPING EXPERIMENT IN AN ELCTROSTATICLLY ACTUATED INITIALLY CURVED BEAM

L.M. Medina[1], R.G. Gilat[2], B.I. Ilic[3], and S.K. Krylov[1]
[1]*Tel-Aviv University, ISRAEL,* [2]*Ariel University, ISRAEL, and* [3]*Cornell University, USA*

.....784

We report on a first experimental demonstration of dynamic trapping of electrostatically actuated double clamped curved micro beam. The beam is configured in an isolated singular post-buckled configuration, showing enhanced gap usage which cannot be reached by either static or by a suddenly applied single step load. The trapping is achieved using a dynamic snap-through induced by a tailored two step time dependent electrostatic loading.

THURSDAY PROGRAM

Session Th1A
Physical Microfluidics II

TIKAHTNU A

Session Co-Chairs:
Y.-K. Lee, Hong Kong University of Science and Technology, HONG KONG

W. Li, *Michigan State University, USA*

10:00 - 10:15

Th1A.005

RADICAL INDUCED PROTEIN CRYSTALLIZATION BY RADICAL AMPLIFICATION MICROFLUIDIC CHIP

T. Kobayashi[1]
and Y. Yamanishi[1,2]
[1]*Shibaura Institute of Technology, JAPAN and* [2]*Japan Science and Technology Agency (JST), JAPAN*

.....700

We report plasma induced radical concentration microfluidic chip and radical induced protein crystallization. Formation of bubbles accelerates the production of radical species at air-liquid interface and these bubbles are concentrated by the circulating flow in a chip. It was also confirmed that the radical-induced protein crystal are produced with increasing of the circulation time. This microfluidic chip contributes to the protein crystal production and bio-medical applications.

Session Th1B
Piezoelectric & SMA Energy Conversion Devices

TIKAHTNU B

Session Co-Chairs:
D. Horsley, *University of California, Davis, USA*

M. Rinaldi, *Northeastern University , USA*

Th1B.005

FLEXIBLE COMPOSITE THERMAL ENERGY HARVESTER USING PIEZOELECTRIC PVDF POLYMER AND SHAPE MEMORY ALLOY

B. Gusarov[1,2], L. Gimeno[1,2], E. Gusarova[3], B. Viala[3], S. Boisseau[3], and O. Cugat[1,2]
[1]*University Grenoble Alpes, FRANCE,* [2]*CNRS, FRANCE and* [3]*CEA, LETI, FRANCE*

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A novel flexible composite thermal energy harvester is presented, which couples pyroelectric and piezoelectric effects of PVDF with shape memory effect of TiNiCu alloy. The harvester combines superior flexibility of PVDF with large temperature-induced strain of the shape memory alloy to harvest small and quasi-static temperature variations: 0.38 mJ/cm^3 energy was harvested from 20 CΔT. The use of PVDF quadruples the energy output, compared to previously reported PZT-based composite.

Session Th1C
Integrated, Portable Bio Devices

TIKAHTNU CD

Session Co-Chairs:
K. Bohringer, *University of Washington, USA*

Y.-C. Lin, *National Cheng Kung University, TAIWAN*

Th1C.005

AUTOMATED SAMPLE-TO-ANSWER NUCLEIC ACID TESTING WITH FREQUENCY CONTROLLED REAGENT RELEASE FROM CARTRIDGE INTEGRATED STICKPACKS

F. Stumpf[1], F. Schwemmer[2], T. Hutzenlaub[1], D. Baumann[1], O. Strohmeier[1], F. von Stetten[1], R. Zengerle[1,2], and D. Mark[1]
[1]*Institute for Micromachining and Information Technology (HSG-IMIT), GERMANY and* [2]*University of Freiburg - IMTEK, GERMANY*

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We demonstrate an automated centrifugal LabDisk system for sample-to-answer point-of-care testing of multiple nucleic acid targets that features pre-storage of all required liquid reagents for nucleic acid extraction as well as primer and probes and magnetic beads. Liquid buffers were pre-stored in stickpacks with frequency controlled reagent release. The LabDisk system automates all assay steps for PCR-based pathogen detection: RNA extraction, aliquoting and geometrically multiplexed RT-PCR.

Session Th1D
Microfabrication & Materials

TIKAHTNU EF

Session Co-Chairs:
S. Franssila, *Aalto University, FINLAND*

N. Miki, *Keio University, JAPAN*

Th1D.005

SUPERPARAMAGNETIC HYDROGELS FOR TWO-PHOTON POLYMERIZATION AND THEIR APPLICATION FOR THE FABRICATION OF SWIMMING MICROROBOTS

C. Peters, V. Costanza, S. Pané, B.J. Nelson, and C. Hierold
ETH Zürich, SWITZERLAND

.....764

We report on superparamagnetic hydrogel composites for Two Photon Polymerization and their application for the fabrication of helical swimming micro robots, also known as Artificial Bacterial Flagella (ABFs). Suitable hydrogel compositions consisting of multifunctional monomers were identified based on a newly derived percolation model. ABFs 25 µm in length and 3 µm in diameter were fabricated. Locomotion based on the well-known cork-screw propulsion was demonstrated.

Session Th1E
Micro/Nano Scale Physics Characterization

TUBUGHNENQ

Session Co-Chairs:
Q.-A. Huang, *Southeast University, CHINA*

O. Paul, *University of Freiburg - IMTEK, GERMANY*

Th1E.005

IMPROVEMENT OF THIN FILM TENSILE TESTING TECHNOLOGY USING PROCESS INTEGRATED SPECIMEN AND CONSIDERING ITS OUT-OF-PLANE DEFORMATION

Y.C. Lin, C.L. Cheng, and W. Fang
National Tsing Hua University, TAIWAN

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This study has demonstrated a novel micro testing device to easily fabricate/integrate the thin-film specimen, and further improve the measurements of thin-film tensile-test by considering the out-of-plane deformation. Due to boundary condition from microfabrication, additional bending moment is introduced during tensile-test and cause the specimen an out-of-plane deformation. This study exploits such characteristic to determine thin-film elastic modulus and modify the measured fracture strain.

THURSDAY PROGRAM

Session Th1A Physical Microfluidics II	Session Th1B Piezoelectric & SMA Energy Conversion Devices	Session Th1C Integrated, Portable Bio Devices	Session Th1D Microfabrication & Materials	Session Th1E Micro/Nano Scale Physics Characterization
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: Y.-K. Lee, Hong Kong University of Science and Technology, HONG KONG W. Li, *Michigan State University, USA*	**Session Co-Chairs:** D. Horsley, *University of California, Davis, USA* M. Rinaldi, *Northeastern University , USA*	**Session Co-Chairs:** K. Bohringer, *University of Washington, USA* Y.-C. Lin, *National Cheng Kung University, TAIWAN*	**Session Co-Chairs:** S. Franssila, *Aalto University, FINLAND* N. Miki, *Keio University, JAPAN*	**Session Co-Chairs:** Q.-A. Huang, *Southeast University, CHINA* O. Paul, *University of Freiburg - IMTEK, GERMANY*
10:15 - 10:30				
Th1A.006 **MODULAR STACKED VARIABLE-COMPRESSION RATIO MULTI-STAGE GAS MICROPUMP** A. Sandoughsaz, A. Besharatian, L.P. Bernal, and K. Najafi *University of Michigan, USA* .....704 We report the design, fabrication and testing of a new "stacked" multi-stage electrostatic micropump. The new design presents a novel method to adjust the volume ratio of a given stage to achieve a uniform pressure increase across individual micropump stages. A pressure difference of 1.1 kPa and air flow rate of 85 µL/min is obtained by a 3-stage stacked micropump. An individual micropump stage is $5.5 \times 4 \times 0.5$ mm^3 and each pumping/microvalve membrane is 2×2 mm^2.	**Th1B.006** **ELASTOCALORIC HEAT PUMPING USING A SHAPE MEMORY ALLOY FOIL DEVICE** H. Ossmer[1], S. Miyazaki[2], and M. Kohl[1] [1]*Karlsruhe Institute of Technology (KIT), GERMANY and* [2]*University of Tsukuba, JAPAN* .....726 This paper explores, develops and demonstrates a miniature heat pump based on the elastocaloric effect in shape memory alloys (SMAs). The active material is a Ti50.5Ni49.1Fe0.4 foil of 30 µm thickness showing a maximum temperature change during pseudoelastic loading/unloading up to +20/-16 K. First-of-its-kind heat pump demonstrators reveal a temperature difference of about 7 K between heat sink and source after 100 s for a ratio of heat capacities of SMA bridge and heat source of 1:60.	**Th1C.006** **A VACNT INTEGRATED HANDHELD DEVICE FOR LABEL-FREE VIRUS CAPTURE, DETECTION AND ENRICHMENT FOR GENOMIC ANALYSIS** Y.T. Yeh, Y. Tang, H. Lu, M. Terrones, and S.Y. Zheng *Pennsylvania State University, USA* .....747 We present a portable carbon nanotube (CNT) integrated microfluidic device to capture virus by a nanoscale filtration. The device contains porous array made of CNT with a tunable gap size on a fused silica substrate. We isolated avian influenza virus (AIV) H5N8 subtype from chicken swab samples, detected it by on-chip immunofluorescence staining and successfully propagated the isolated H5N8 ex vivo inside chicken eggs.	**Th1D.006** **WRINKLED MICROPARTICLES FOR UNCLONABLE MICROTAGGANTS** H.J. Bae[1], S. Bae[1], C. Park[2], S. Han[1], J. Kim[1], L.N. Kim[1], K. Kim[2], S.-H. Song[2], W. Park[2], and S. Kwon[1] [1]*Seoul National University, SOUTH KOREA and* [2]*Kyung Hee University, SOUTH KOREA* .....768 We present wrinkled microparticles as unreplicable, unique, yet configurable microtaggants for anti-counterfeiting purposes. We mimicked the shape of the human fingerprint on a microscopic level using three-dimensional microstructures. We utilized irreproducible distributions of ridges on wrinkled microparticles as a unique code, similar to a human fingerprint, for identification. This wrinkled microparticles provide reliable authentication and exhibit high individuality.	**Th1E.006** **CHARACTERIZATION OF ELECTROTHERMAL ACTUATION WITH NANOMETER AND MICRORADIAN PRECISION** C.R. Copeland[1,2], C.D. McGray[1], J. Geist[1], V.A. Aksyuk[1], and S.M. Stavis[1] [1]*National Institute of Standards and Technology (NIST), USA and* [2]*University of Maryland, USA* .....792 We track fluorescent nanoparticles as optical indicators of micromechanical motion, and report the first measurements with nanometer and microradian precision of the single motion cycles of an electrothermal actuator with a mechanical linkage. Our measurements reveal the sensitivity of device translation and rotation to millivolt fluctuations in driving voltage, which we use to characterize the mechanical linkage as it couples and decouples in deterministic or stochastic modes.
10:30 - 11:00	**Break**			

THURSDAY PROGRAM

Session Th2A
Magnetic Sensors

TIKAHTNU A

Session Co-Chairs:
W. Fang, *National Tsing Hua University, TAIWAN*

A. Ionescu, *EPF Lausanne, SWITZERLAND*

Session Th2B
Micromanipulation & Tactile Systems

TIKAHTNU B

Session Co-Chairs:
S. Bedair, *US Army Research Laboratory, USA*

Y.-T. Cheng, *National Chiao Tung University, TAIWAN*

Session Th2C
Micromirrors & Scanning Systems

TIKAHTNU CD

Session Co-Chairs:
S. Bhave, *Analog Devices Inc., USA*

D. Elata, *Technion - Israel Institute of Technology, ISRAEL*

Session Th2D
Medical Devices

TIKAHTNU EF

Session Co-Chairs:
S. Kwon, *Seoul National University, SOUTH KOREA*

L. Nicu, *CNRS, FRANCE*

Session Th2E
Materials & Characterization

TUBUGHNENQ

Session Co-Chairs:
J. Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND*

P. Feng, *Case Western Reserve University, USA*

11:00 - 11:15

Th2A.001

INVITED SPEAKER

VOLTAGE CONTROL OF SINGLE MAGNETIC DOMAIN NANOSCALE MULTIFERROIC HETEROSTRUCTURE

S.M. Keller, C.-Y. Liang, A. Sepulveda, and G.P. Carman
University of California, Los Angeles, USA
.....796

Micromagnetic simulations of magneto elastic nanostructures traditionally rely on either the Stoner-Wohlfarth model or the Landau-Lifshitz-Gilbert LLG model assuming uniform strain (and/or assuming uniform magnetization). While the uniform strain assumption is reasonable when modeling magnetoelastic thin films, this constant strain approach becomes increasingly inaccurate for smaller in-plane nanoscale structures. This paper presents analytical work verified with experimental data to significantly improve simulation of finite structures by fully coupling LLG with elastodynamics, i.e. the partial differential equations are intrinsically coupled. Analytical predictions for reorienting a single domain element is also described.

Th2B.001

FLUID-FILLED MICRO SUCTION-CONTROLLER ARRAY FOR HANDLING OBJECTS

S. Nishita and H. Onoe
Keio University, JAPAN
.....815

We present fluid-filled flexible micro suction-controller array (MISCA) that can hold diverse shape of objects. MISCA is made of PDMS and each suction unit works independently. Key technical issue was gas permeability of PDMS, which decreases the suction pressure. We confirmed that MISCA filled with ethylene glycol as working fluid had the highest suction pressure, and successfully demonstrated that MISCA can hold a 75g object, or a grooved object held by partial contact of the suction array.

Th2C.001

ELECTROMAGNETICALLY ACTUATED 2-AXIS SCANNING MICROMIRROR WITH LARGE APERTURE AND TILTING ANGLE FOR LIDAR APPLICATIONS

J.H. Kim[1], S.W. Lee[1], H.S. Jeong[1], S.K. Lee[1], C.H. Ji[2], and J.H. Park[1]
[1]*Dankook University, SOUTH KOREA and* [2]*Ewha Womans University, SOUTH KOREA*
.....839

This paper presents electromagnetically actuated 2-axis scanning micromirror with large aperture and tilting angle for laser pointing applications such as LIDAR systems. The 2-axis micromirror with the plate size of 3 mm in diameter was fabricated using gimbaled single crystal silicon with a coil and assembled with permanent magnet forming radial magnetic field. The micromirror was realized on SiOG wafer using 4 photolithography masks and the magnet assembly was optimized to maximize the torque.

Th2D.001

INVITED SPEAKER

SMALL, SOFT AND SAFE MICRO-MACHINES FOR BIOMEDICAL APPLICATIONS

S. Konishi
Ritsumeikan University, JAPAN
.....863

The talk introduces small, soft, and safe (S3) micro-machines for various biomedical applications. We have developed a polymer-based pneumatic balloon actuator (PBA) as S3 actuator. Polymers such as PDMS and polyimide allow soft and flexible structure for PBA. Pneumatic driving principle provides safe operation. Various biomedical applications of PBA including a retractor for endoscopic surgery, a transplantation tool for eye surgery, and cellular aggregates manipulation for tissue engineering will be presented.

Th2E.001

INVITED SPEAKER

HOW MATERIALS INNOVATIONS WILL LEAD TO DEVICE REVOLUTION?

E. Fortunato and R. Martins
Universidade Nova de Lisboa, PORTUGAL
.....884

Transparent electronics has arrived and is contributing for generating a free real state electronics that is able to add new electronic functionalities onto surfaces, which currently are not used in this manner and where silicon cannot contribute. The already high performance developed n- and p-type TFTs have been processed by physical vapour deposition (PVD) techniques like rf magnetron sputtering at room temperature which is already compatible with the use of low cost and flexible substrates (polymers, cellulose paper, among others). Besides that a tremendous development is coming through solution-based technologies very exciting for ink-jet printing, where the theoretical limitations are becoming practical evidences. In this presentation we will review some of the most promising new technologies for n- and p-type thin film transistors based on oxide semiconductors and its currently and future applications.

THURSDAY PROGRAM

Session Th2A Magnetic Sensors	Session Th2B Micromanipulation & Tactile Systems	Session Th2C Micromirrors & Scanning Systems	Session Th2D Medical Devices	Session Th2E Materials & Characterization
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: W. Fang, *National Tsing Hua University, TAIWAN* A. Ionescu, *EPF Lausanne, SWITZERLAND*	**Session Co-Chairs:** S. Bedair, *US Army Research Laboratory, USA* Y.-T. Cheng, *National Chiao Tung University, TAIWAN*	**Session Co-Chairs:** S. Bhave, *Analog Devices Inc., USA* D. Elata, *Technion - Israel Institute of Technology, ISRAEL*	**Session Co-Chairs:** S. Kwon, *Seoul National University, SOUTH KOREA* L. Nicu, *CNRS, FRANCE*	**Session Co-Chairs:** J. Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND* P. Feng, *Case Western Reserve University, USA*
		11:15 - 11:30		
	Th2B.002	Th2C.002		
INVITED CONTINUED	**PIEZOELECTRIC ACTUATOR ARRAY FOR MOTION-ENABLED RECONFIGURABLE RF CIRCUITS** M.C. Tellers[1,2], J.S. Pulskamp[1], S.S. Bedair[1], R.Q. Rudy[1], I.M. Kierzewski[1], R.G. Polcawich[1], and S.E. Bergbreiter[2] [1]*Army Research Laboratory, USA and* [2]*University of Maryland, College Park, USA* .....819 To create motion-enabled reconfigurable RF circuits, we design and test piezoelectric cantilever arrays for electronic component conveyance. The array is driven with different waveforms, voltages, and frequencies to characterize the velocity, rotational speed, and off-axis translational deviation of a silicon chip placed on the array. The effort identifies significant operational and design variables using the first dynamic contact model developed for micromanipulation surfaces.	**BIAXIAL VECTOR-GRAPHIC SCANNING MICROMIRROR USING RADIAL MAGNETIC FIELD** A. Han[1], A.R. Cho[1], S. Ju[1], B. Yoon[2], S. Lee[2], T. Kim[2], J.-U. Bu[2], and C.-H. Ji[1] [1]*Ewha Womans University, SOUTH KOREA and* [2]*SenPlus Inc., SOUTH KOREA* .....843 This paper presents the design, fabrication, and measurement results of an electromagnetic biaxial vector-graphic scanning micromirror. Instead of utilizing locally distributed magnetic fields from multiple magnets, radial magnetic field from concentric magnet assembly and unique coil geometry have been used to realize independent scan along two perpendicular axes irrespective of operation frequency.	INVITED CONTINUED	INVITED CONTINUED

THURSDAY PROGRAM

Session Th2A
Magnetic Sensors

TIKAHTNU A

Session Co-Chairs:
W. Fang, *National Tsing Hua University, TAIWAN*

A. Ionescu, *EPF Lausanne, SWITZERLAND*

Session Th2B
Micromanipulation & Tactile Systems

TIKAHTNU B

Session Co-Chairs:
S. Bedair, *US Army Research Laboratory, USA*

Y.-T. Cheng, *National Chiao Tung University, TAIWAN*

Session Th2C
Micromirrors & Scanning Systems

TIKAHTNU CD

Session Co-Chairs:
S. Bhave, *Analog Devices Inc., USA*

D. Elata, *Technion - Israel Institute of Technology, ISRAEL*

Session Th2D
Medical Devices

TIKAHTNU EF

Session Co-Chairs:
S. Kwon, *Seoul National University, SOUTH KOREA*

L. Nicu, *CNRS, FRANCE*

Session Th2E
Materials & Characterization

TUBUGHNENQ

Session Co-Chairs:
J. Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND*

P. Feng, *Case Western Reserve University, USA*

11:30 - 11:45

Th2A.003

A COMBINED HALL AND STRESS SENSOR FOR HIGHLY ACCURATE MAGNETIC FIELD SENSING FREE FROM THE PIEZO-HALL EFFECT

S. Huber[1], J. Raman[2], A. van der Wiel[1], C. Schott[1], P. Rombouts[2], and O. Paul[3]
[1]*Melexis Technologies SA, SWITZERLAND,* [2]*Ghent University, BELGIUM, and* [3]*University of Freiburg - IMTEK, GERMANY*

.....799

This paper reports the use of a plate-like four-contact device for the simultaneous measurement of the magnetic field via the Hall effect and mechanical stress via the piezoresistance effect within the same device. The mechanical stress measurement is used to compensate for the piezo-Hall effect, i.e., the undesired cross-sensitivity of the magnetic sensitivity to mechanical stress. Thereby the drift of the magnetic sensitivity was reduced by a factor of 20 to 0.15% for stresses up to 75 MPa.

Th2B.003

DEVELOPMENT OF A MEMS-BASED ELECTRO-RHEOLOGICAL MICROFINGER SYSTEM WITH AN ALTERNATING PRESSURE SOURCE

T. Miyoshi, K. Yoshida, J.-W. Kim, S.I. Eom, and S. Yokota
Tokyo Institute of Technology, JAPAN

.....823

This paper presents a novel MEMS-based hydraulic microfinger system using an alternating pressure source and electro-rheological (ER) fluid for multiple actuator systems. The ER microfinger is realized by newly developed PDMS micromolding and silicon micromachining processes, and only required one pipe for supply and return having small diameter. This is the first time demonstration of bi-directional, large-displacement and high-speed bending motion of the fabricated 1.6 mm long ER microfinger.

Th2C.003

MEMS MIRRORS SUBMERGED IN LIQUID FOR WIDE-ANGLE SCANNING

X. Zhang[1], R. Zhang[1], S. Koppal[1], L. Butler[1], X. Cheng[2], and H. Xie[1]
[1]*University of Florida, USA and* [2]*Xiamen University, CHINA*

.....847

This paper reports an MEMS scanning mirror that works in liquid. By submerging an electrothermal bimorph MEMS mirror into mineral oil whose refraction index is greater than the air's, a wide-angle optical scan (>120°) is achieved at small driving voltage (<10V), and the MEMS mirror works up to 30 Hz. The wide angle is due to the large tilt angle (35°) of the MEMS mirror as well as the angular increase of the ''Snell Window'' effect.

Th2D.003

SU-8 C-MEMS AS CANDIDATE FOR LONG-TERM IMPLANTABLE PACEMAKER MICRO ELECTRODES

J. Grossenbacher[1], M.R. Gullo[1], S. Lecaudé[2], H. Tevaearai Stahel[3], and J. Brugger[1]
[1]*École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND and* [2]*University Hospital Bern, SWITZERLAND*

.....867

We present for the first time the successful implantation of electrically conductive SU-8 C-MEMS electrodes able to pace muscle tissue in an animal model. The electrochemical characterizations of the ceramic electrodes show comparable values to standard Pt metal electrodes. The micron scale pacemaker electrodes were successfully tested in vitro (cardiomyocyte), in vivo (rat peripheral muscle) and ex vivo (ex-planted rat heart) pacing experiments.

Th2E.003

CREEP-RESISTANT NANOCRYSTALLINE GOLD-VANADIUM ALLOYED MICROCORRUGATED DIAPHRAGMS (MCDS)

J. Li[1], Z. Yang[2], D. Psychogiou[2], M.D. Sinanis[2], and D. Peroulis[2]
[1]*University of Electronic Science and Technology of China, CHINA and* [2]*Purdue University, USA*

.....888

We develop new Au-V microcorrugated diaphragms (MCDs) capable of achieving large displacements with the lowest reported stress relaxation today. Au-V co-sputtering and isothermal annealing are first introduced to the fabrication of the MCDs. Compared to conventional Au-sputtered films, the Au-V MCDs show a significantly lower stress relaxation rate, much smaller grain size, and excellent process compatibility. They are very promising in widely-tunable high-reliability RF MEMS devices.

THURSDAY PROGRAM

Session Th2A
Magnetic Sensors

TIKAHTNU A

Session Co-Chairs:
W. Fang, *National Tsing Hua University, TAIWAN*

A. Ionescu, *EPF Lausanne, SWITZERLAND*

Session Th2B
Micromanipulation & Tactile Systems

TIKAHTNU B

Session Co-Chairs:
S. Bedair, *US Army Research Laboratory, USA*

Y.-T. Cheng, *National Chiao Tung University, TAIWAN*

Session Th2C
Micromirrors & Scanning Systems

TIKAHTNU CD

Session Co-Chairs:
S. Bhave, *Analog Devices Inc., USA*

D. Elata, *Technion - Israel Institute of Technology, ISRAEL*

Session Th2D
Medical Devices

TIKAHTNU EF

Session Co-Chairs:
S. Kwon, *Seoul National University, SOUTH KOREA*

L. Nicu, *CNRS, FRANCE*

Session Th2E
Materials & Characterization

TUBUGHNENQ

Session Co-Chairs:
J. Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND*

P. Feng, *Case Western Reserve University, USA*

11:45 - 12:00

Th2A.004

100 µA, 320 nT/√HZ, 3-AXIS LORENTZ FORCE MEMS MAGNETOMETER

G. Laghi[1], A.F. Longoni[1], P. Minotti[1], and A. Tocchio[2], and G. Langfelder[1]
[1]*Politecnico di Milano, ITALY and* [2]*ST Microelectronics, ITALY*

.....803

The work presents a module for earth magnetic field detection based on four MEMS: one out-of-plane and two in-plane Lorentz-force magnetometers, and a Tang resonator. The latter provides the reference frequency in off-resonance mode, a way that enables the magnetometers to share the same current, giving an intrinsic 3-fold consumption decrease. At the same time, a 5-fold larger sensitivity and a 4-fold better resolution are obtained using multiple loops. The bandwidth is selectable up to 50 Hz.

Th2B.004

LIVING PERISTALTIC MICRO CONVEYOR TUBE OF OPTOGENETICALLY CONTROLLABLE BIOACTUATOR

E. Yamatsuta, S.P. Beh, and K. Morishima
Osaka University, JAPAN

.....827

We develop and optimize a muscle-powered miniaturized cylindrical conveyor which has peristaltic movement and bending motion. By observing muscle contraction wave on living Drosophila melanogaster (DM, fruit fly) larvae, we specify the optimum wave condition. Speed and width of the peristaltic waves on DM larvae is controlled with blue light using optogenetics and micro beads are transported arbitrarily by combining a variety of local stimulations.

Th2C.004

DESIGN, FABRICATION AND CHARACTERIZATION OF PIEZOELECTRICALLY ACTUATED GIMBAL-MOUNTED 2D MICROMIRRORS

S. Gu-Stoppel, H.J. Quenzer, and W. Benecke
Fraunhofer Institute for Silicon Technology, GERMANY

.....851

This paper reports design, fabrication and characterization of piezoelectric gimbal-mounted 2D micromirrors. The two axes of this integrated micromirror are resonantly actuated rotating about two perpendicular axes. It achieves the total optical scan angles of 20° and 16° at 23. kHz and 1.5 kHz, respectively. The primary novelty of this device is the integrated technology solution to realize a micromirror allowing 2D scanning with a large enough frequency difference to decouple the two motions.

Th2D.004

PIEZOELECTRIC TACTILE SENSOR FOR SUBMUCOSAL TUMOR HARDNESS DETECTION IN ENDOSCOPY

C.H. Chuang[1], T.H. Li[1], I.C. Chou[2], and Y.J. Teng[2]
[1]*Southern Taiwan University of Science and Technology, TAIWAN and* [2]*Kuang Tai Metal Industrial Co., Ltd., TAIWAN*

.....871

We developed a miniaturized tactile sensor, which is compatible to mount on the endoscopy accessory for the hardness detection of submucosal tumors. We embedded different elastomers in a pic stomach for simulating the condition of submucosal tumors in stomach. The experimental results show the tactile sensor is capable to differentiate the different artificial tumors between normal tissues in pig stomach.

Th2E.004

FABRICATION OF POLYCRYSTALLINE DIAMOND ON A FLEXIBLE PARYLENE SUBSTRATE

B. Fan[1], R. Rechenberg[2], M.F. Becker[2], and W. Li[1]
[1]*Michigan State University, USA and* [2]*Fraunhofer USA-CCL, USA*

.....892

This paper presents a unique transferring method for making polycrystalline diamond (PCD) structures on flexible polymer substrates, which is scalable, cost-effective, and compatible with conventional microfabrication techniques. As a proof-of-concept, we transferred boron-doped PCD (BDD) onto a wafer-scale Parylene-C thin film and characterized the properties of the transferred BDD patterns.

THURSDAY PROGRAM

Session Th2A Magnetic Sensors	Session Th2B Micromanipulation & Tactile Systems	Session Th2C Micromirrors & Scanning Systems	Session Th2D Medical Devices	Session Th2E Materials & Characterization
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF	TUBUGHNENQ
Session Co-Chairs: W. Fang, *National Tsing Hua University, TAIWAN* A. Ionescu, *EPF Lausanne, SWITZERLAND*	**Session Co-Chairs:** S. Bedair, *US Army Research Laboratory, USA* Y.-T. Cheng, *National Chiao Tung University, TAIWAN*	**Session Co-Chairs:** S. Bhave, *Analog Devices Inc., USA* D. Elata, *Technion - Israel Institute of Technology, ISRAEL*	**Session Co-Chairs:** S. Kwon, *Seoul National University, SOUTH KOREA* L. Nicu, *CNRS, FRANCE*	**Session Co-Chairs:** J. Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND* P. Feng, *Case Western Reserve University, USA*
12:00 - 12:15				
Th2A.005	**Th2B.005**	**Th2C.005**	**Th2D.005**	**Th2E.005**
MAGNETOSTRICTIVELY INDUCED FLEXURE IN A MICROMACHINED PLATE RESONATOR FOR MAGNETIC FIELD SENSING APPLICATIONS G. Hatipoglu and S. Tadigadapa *Pennsylvania State University, USA* .....807 We demonstrate a micromachinedmagneto-electric (ME) resonator based magnetometercapable of sensing nanoTesla magnetic fields.The device consists of ~7.5 µm thick (223 MHz)AT-cut Quartz bulk acoustic wave, plate-resonatoron which a 500 nm thick magnetostrictive Metglas®film is deposited. Application of magnetic fieldsinduces flexural bending in the plate-resonatorunimorph structure which results in a shift of theresonance frequency. The MDF is measured as ~80 nT.	**BIOMIMETIC LOCOMOTION FOR A ROBOTIC STINGRAY USING MEMS SENSORS** M. Asadnia[1,2], A.G.P. Kottapalli[2], A. Cloitre[3], R. Haghighi[1], M. Triantafyllou[3], and J. Miao[1] [1]*Nanyang Technological University, SINGAPORE,* [2]*Singapore-MIT Alliance for Research and Technology, SINGAPORE, and* [3]*Massachusetts Institute of Technology, USA* .....831 In this paper, we present design, fabrication and experimental results of two types of MEMS sensors for maneuvering and control of a robotic stingray. The first sensor is a piezoresistive liquid crystal polymer hair cell flow sensor which is employed to determine the velocity of propagation of the stingray. The second sensor is a piezoelectric micro-diaphragm pressure sensor which measures various flapping profiles of the stingray's fins which help to control the robot locomotion.	**A LARGE ANGLE, LOW VOLTAGE, SMALL FOOTPRINT MICROMIRROR FOR EYE TRACKING AND NEAR-EYE DISPLAY APPLICATIONS** N. Sarkar[1,2], D. Strathearn[1,2], G. Lee[1,2], M. Olfat[1], A. Rohani[1], and R.R. Mansour[1,2] [1]*University of Waterloo, CANADA and* [2]*ICSPI Corp., CANADA* .....855 This paper introduces a micromirror device to enable a compact, low power eye-tracking system that may be integrated within eyeglasses or heads-up-displays. The device operates at CMOS-compatible voltages (<5V) and currents (<10mA), and employs isothermal scanning to suppress thermal excursions from electrothermal actuation. The footprint of the device is 40x smaller than commercially available devices at a mere 750µm × 750µm. Scan angles of 90x30 degrees (optical) are achieved.	**AN ULTRASONICALLY POWERED IMPLANTABLE MICRO-LIGHT SOURCE FOR LOCALIZED PHOTODY-NAMIC THERAPY** J. Zhou, A. Kim, S.H. Song, and B. Ziaie *Purdue University, USA* .....876 We have developed an ultrasonically powered light source which is small enough that can be easily implanted inside solid tumors using a biopsy needle. In-vitro light intensity measurements indicate that the implant light sources can provide sufficient optical power for localized photodynamic therapy.	**SHEAR STRESS WITH HYDROGEN, NOT OXYGEN, MATTERS TO THE FATIGUE LIFETIME OF SILICON** S. Kamiya, A. Udhayakumar, H. Izumi, and K. Koiwa *Nagoya Institute of Technology, JAPAN* .....896 This paper presents a new finding over fatigue mechanism in silicon. Fatigue degradation eventually takes place due to defect accumulation in crystal, with the aid of not only humidity but also hydrogen as well and shear stress. Silicon would behave in a more metallic manner than was believed before even at room temperature, leading to fatigue fracture.

THURSDAY PROGRAM

Session Th2A Magnetic Sensors	Session Th2B Micromanipulation & Tactile Systems	Session Th2C Micromirrors & Scanning Systems	Session Th2D Medical Devices	Session Th2E Materials & Characterization
TIKAHTNU A	**TIKAHTNU B**	**TIKAHTNU CD**	**TIKAHTNU EF**	**TUBUGHNENQ**
Session Co-Chairs: W. Fang, *National Tsing Hua University, TAIWAN* A. Ionescu, *EPF Lausanne, SWITZERLAND*	**Session Co-Chairs:** S. Bedair, *US Army Research Laboratory, USA* Y.-T. Cheng, *National Chiao Tung University, TAIWAN*	**Session Co-Chairs:** S. Bhave, *Analog Devices Inc., USA* D. Elata, *Technion - Israel Institute of Technology, ISRAEL*	**Session Co-Chairs:** S. Kwon, *Seoul National University, SOUTH KOREA* L. Nicu, *CNRS, FRANCE*	**Session Co-Chairs:** J. Brugger, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND* P. Feng, *Case Western Reserve University, USA*
12:15 - 12:30				
Th2A.006	**Th2B.006**	**Th2C.006**	**Th2D.006**	**Th2E.006**
MULTILAYER FERROMAGNETIC COMPOSITES ENABLING ON-CHIP MAGNETIC-CORE INDUCTORS BEYOND 1 GHZ J. Liljeholm[1], T. Ebefors[1], H. Rohrmann[2], U. Shah[3], and J. Oberhammer[3] [1]*Silex Microsystems, SWEDEN, and* [2]*Evatec Advanced Technologies AG, LIECHTENStein, and* [3]*KTH Royal Institute of Technology, SWEDEN* .....**811** We have manufactured ferromagnetic NiFe/AlN multilayer composites as magnetic core materials for on-chip inductors. The proposed composite structure reduces RF induced currents and thus pushes the permeability cut-off beyond 1 GHz, significantly higher than for homogeneous NiFe layers. We have achieved ferromagnetic resonance frequency of 3.7 GHz and an inductance enhancement of 4 at 1 GHz, verified by test inductors using the new laminated NiFe magnetic layers.	**A DIGITAL TACTILE ACTUATOR ARRAY WITH NORMAL AND SHEAR CONTACT FORCE CONTROLLABILITY FOR REFRESHABLE BRAILLE DISPLAY APPLICATION** G.H. Feng and S.Y. Hou *National Chung Cheng University, TAIWAN* .....**835** We develop a novel digital controlled tactile actuator array driven with ionic polymer metal composite actuators. A PDMS bump array can be controlled individually to touch human sensory receptors (e.g. on the fingertips) with different force levels. The contact between the fingertip and the bump on the actuator can be manipulated in normal and shear modes. The fast response of bump array makes the actuator array very suitable for refreshable Braille display application.	**A MEMS-BASED INTERACTIVE LASER SCANNING DISPLAY WITH A BUILT-IN LASER RANGE FINDER** S. Jeon, H. Fujita, and H. Toshiyoshi *University of Tokyo, JAPAN* .....**859** We present a viewer-interactive laser scanning display (LSD) that could control the projected images by optically detecting an object in the projected ray. A piezoelectric PZT scanner is used as a spatial modulator to construct the full-color VGA-class LSD optics and also to develop the triangulation laser range finder that is sensitive in a 20 to 60 cm distance. Distance to screen was successfully measured to give feedback to the projected image. We also demonstrate page-turning using gesture.	**SHAPE ANISOTROPIC MAGNETIC PARTICLES FOR HIGH THROUGHPUT AND HIGH EFFICIECY INTRACELLUAR DELIVERY OF FUNCTIONAL MACROMOLECULES** M.Y. Lin[1], Y.C. Wu[2], J.A. Lee[2], J. Zhou[2], M.A. Teitell[2], and P.Y. Chiou[2] [1]*National Applied Research Laboratories, TAIWAN and* [2]*University of California, Los Angeles, USA* .....**880** We report a novel intracellular delivery system based on aligning shape-anisotropic magnetic particles (SAMP) to deliver functional molecules with high efficiency and high viability. We have achieved more than 100-fold improvement of enzyme delivery efficiency in primary human dermal fibroblast, and high delivery efficiency of large molecules (dextran 40K) into mouse cortical neurons.	**EFFECT OF CRYSTALLINITY-DAMAGE RECOVERY ON MECHANICAL PROPERTIES OF GA-IMPLANTED SUB-100NM SI NANOWIRES** T. Fujii[1,2], T. Kozeki[1], S. Inoue[1], and T. Namazu[1] [1]*University of Hyogo, JAPAN and* [2]*Japan Society for the Promotion of Science, JAPAN* .....**900** We report the effect of crystallinity-damage recovery by high-vacuum annealing on mechanical characteristics of Ga-implanted Si nanowires (NWs) fabricated by FIB. "Beetle-like" tensile test device is specially developed to directly tension Si NWs with high precision, and "cassette-type" sample-preparation technique of Si NWs is contrived for annealing at 700degC in high-vacuum.

12:30 - 14:00 | **Lunch on Own**

THURSDAY PROGRAM

Session Th3A
Thermal Actuators & Absorbers

TIKAHTNU A

Session Co-Chairs:
M. Maher,
SoftMEMS LLC, USA

S. Tanaka,
Tohoku University, JAPAN

14:00 - 14:15

Th3A.001

REVERSING THE ACTION OF THERMOELASTIC BIMORPHS USING SELECTIVE DIRECTIONAL STIFFENERS
I.H. Grinberg,
S. Shmulevich, and D. Elata
Technion - Israel Institute of Technology, ISRAEL
.....904

We present for the first time ever, a method for reversing the response of thermoelastic bimorph actuators without changing the order of their layers. A central flat stage is suspended on three spiral thermoelastic bimorph arms. We demonstrate that the thermoelastic response of the spiral bimorphs can be controlled by using directional stiffeners, which are angled relative to the spiral tangent.

Session Th3B
Alternative Power Sensors: Wireless & BioChem

TIKAHTNU B

Session Co-Chairs:
A. Duwel,
Draper Laboratory, USA

E. Yeatman,
Imperial College London, UK

14:00 - 14:15

Th3B.001

INVITED SPEAKER

ALTERNATIVE POWER SOURCES FOR MINIATURE AND MICRO DEVICES
P.D. Mitcheson
Imperial College, UK
.....928

Energy harvesting, which in the modern literature can be traced back to the late 90s, has been thought of as a ground breaking substitute for exhaustible energy sources for powering miniature devices. However, there are still very few areas in which harvesters, at either the MEMS or macro-scale, have made significant impact. In comparison, a different technological solution to the same problem, that of wireless power delivery, either as near or far field electromagnetic transfer, is already gaining traction in several areas from charging electric vehicles to powering wireless sensors. In this talk I will review the state of the art in each of these areas, discuss current innovations and discuss and compare the potential for future development of these two alternatives to batteries.

Session Th3C
Chemical Sensors II

TIKAHTNU CD

Session Co-Chairs:
M. Fleischer,
Siemens AG

S. Tadigadapa, *Pennsylvania State University, USA*

14:00 - 14:15

Th3C.001

μGC × μGC MICROSYSTEM WITH RESISTIVE AND OPTICAL DETECTION
W.R. Collin, K. Scholten,
D. Paul, K.W. Kurabayashi,
X. Fan, and E.T. Zellers
University of Michigan, USA
.....949

Progress toward an all-MEMS μGC × μGC is described. Integration of Si 1D and 2D μcolumns with a μthermal modulator yielded excellent separations with commercial coatings and FID detection. Use of an ionic-liquid stationary phase in the 2D μcolumns enhanced resolution. A Au-NP coated chemiresistor and a PDMS-coated μoptofluidic ring resonator sensor as detectors yielded mixed results for the former and excellent results for the latter.

Session Th3D
Piezoelectric Actuators & RF Resonators

TIKAHTNU EF

Session Co-Chairs:
C.-Y. Kwok, *University of New South Wales, AUSTRALIA*

G. Piazza, *Carnegie Mellon University, USA*

14:00 - 14:15

Th3D.001

UV-LIGHT DRIVEN PIEZOELECTRIC THIN-FILM ACTUATORS
F. Kurokawa, Y. Ohchi,
A. Sadanda, Y. Tsujiura,
H. Hida, and I. Kanno
Kobe University, JAPAN
.....973

We fabricated UV-light driven micro-actuators utilizing epitaxial piezoelectric thin films. We deposited 3 μm-thick $Pb(Zr,Ti)O_3$ (PZT) epitaxial thin films on cantilever-shaped MgO single crystals. When the UV-LED light was irradiated to PZT thin film, the cantilever deflected due to the coupling of photovoltaic and piezoelectric effects of the PZT thin films. The deflection of the cantilever was proportionally increased with increasing the UV light intensity. These results indicate that UV-light driven piezoelectric thin-film actuators will open a new avenue for remote controlled micro-actuators.

THURSDAY PROGRAM

Session Th3A Thermal Actuators & Absorbers	Session Th3B Alternative Power Sensors: Wireless & BioChem	Session Th3C Chemical Sensors II	Session Th3D Piezoelectric Actuators & RF Resonators
TIKAHTNU A	**TIKAHTNU B**	**TIKAHTNU CD**	**TIKAHTNU EF**
Session Co-Chairs: M. Maher, *SoftMEMS LLC, USA* S. Tanaka, *Tohoku University, JAPAN*	**Session Co-Chairs:** A. Duwel, *Draper Laboratory, USA* E. Yeatman, *Imperial College London, UK*	**Session Co-Chairs:** M. Fleischer, *Siemens AG* S. Tadigadapa, *Pennsylvania State University, USA*	**Session Co-Chairs:** C.-Y. Kwok, *University of New South Wales, AUSTRALIA* G. Piazza, *Carnegie Mellon University, USA*
14:15 - 14:30			
Th3A.002 **FAST PULSED HEATING AND IMPACT COOLING OF THERMAL MICROACTUATORS** S.S. Pandey, A. Banerjee, N. Hasan, N. Banerjee, and C.H. Mastrangelo *University of Utah, USA* .....908 This paper reports techniques to rapidly heat and cool thermal actuators in ~10 µs. The rapid temperature cycling produces high-speed motion and theroretically realize a 100-fold improvement in load power delivery compared to conventional thermal microactuator devices. Rapid heating is achieved by sudden discharge of a capacitor across the heated element. Rapid cooling is achieved by impacting a thin cold plunger that quickly extracts heat from the hot actuator beams by ultrafast diffusion.	**INVITED CONTINUED**	**Th3C.002** **RESONANT-CANTILEVER AS MICRO-INSTRUMENT TO EXTRACT ACTIVATION-ENERGY (Ea) OF MOLECULE ADSORPTION FOR KINETICS MODELING OF GAS SENSING MATERIALS** P. Xu, X. Li, and H. Yu *Chinese Academy of Sciences, CHINA* .....953 For the first time, micro-gravimetric resonant-cantilever sensor is used for real-time record of gas uptake on sensing material to extract the key kinetic parameter of activation-energy (Ea), which characterizes molecule adsorbing rate. With the extracted model-parameter of Ea, the important gas sensing performance of response speed can be quantitatively evaluated with theory of molecule sorption kinetics and optimally designed based on modeling guidance.	**Th3D.002** **SUB-MILLIWATT INTEGRATED OVEN FOR TEMPERATURE STABLE LATERALLY VIBRATING PIEZOELECTRIC MEMS RESONATORS** C. Xu, J. Segovia-Fernandez, and G. Piazza *Carnegie Mellon University, USA* .....977 We design and demonstrate an integrated oven for AlN piezoelectric MEMS resonators that enables device heating from -40°C to +85°C with a power consumption as low as 368µW – the lowest ever recorded for MEMS resonators. By decoupling RF power delivery from resonator heating, a very high thermal resistance was engineered to thermally isolate the resonator from its surroundings. The new integrated oven layout also ensures high quality factors (up to 4459 @ 220MHz).

THURSDAY PROGRAM

Session Th3A
Thermal Actuators & Absorbers

TIKAHTNU A

Session Co-Chairs:
M. Maher, *SoftMEMS LLC, USA*

S. Tanaka, *Tohoku University, JAPAN*

Session Th3B
Alternative Power Sensors: Wireless & BioChem

TIKAHTNU B

Session Co-Chairs:
A. Duwel, *Draper Laboratory, USA*

E. Yeatman, *Imperial College London, UK*

Session Th3C
Chemical Sensors II

TIKAHTNU CD

Session Co-Chairs:
M. Fleischer, *Siemens AG*

S. Tadigadapa, *Pennsylvania State University, USA*

Session Th3D
Piezoelectric Actuators & RF Resonators

TIKAHTNU EF

Session Co-Chairs:
C.-Y. Kwok, *University of New South Wales, AUSTRALIA*

G. Piazza, *Carnegie Mellon University, USA*

14:30 - 14:45

Th3A.003

A ROBUST, FAST ELECTROTHERMAL MICROMIRROR WITH SYMMETRIC BIMORPH ACTUATORS MADE OF COPPER/TUNGSTEN

X. Zhang[1], B. Li[1], X. Li[2], and H. Xie[1]
[1]*University of Florida, USA and* [2]*John Hopkins University, USA*
.....912

This paper reports a robust electrothermal micromirror with a symmetric inverse-series-connected bimorph actuator design by using Cu and W for the first time. A unique backside release process is developed to keep the mirror surface intact during release. A maximum piston displacement of 169 μm is achieved with lateral shift less than 1.5 μm at only 2.3 V. The maximum optical angle is ±13°. The resonances of the piston and tip-tilt modes are 1.58 kHz and 2.74 kHz, respectively.

Th3B.003

A FULLY CAPILLARY-DRIVEN μDMFC TWIN-STACK OPERATING IN ALL ORIENTATIONS

Z. Wu[1], X. Wang[1,2,3], M. Xu[1], and L. Liu[1]
[1]*Tsinghua University, CHINA,* [2]*Tsinghua National Laboratory for Information Science and Technology, CHINA, and* [3]*Chinese Academy of Sciences, CHINA*
.....934

We present a novel concept of fully automatic fuel supply for micro direct methanol fuel cells (μDMFCs) twin-stack, a special capillary pump featured by symmetric channel array is designed to transport methanol fuel spontaneously by capillary force and allows the stack operating in all spatial orientations. The prototype exhibits a high performance in both preferred orientation (22.5 mWcm-2) and least favorable orientation (17.1 mWcm-2). As such, it is more applicable for portable devices.

Th3C.003

SELECTIVE ENVIRONMENTAL BENZENE MONITORING MICROSYSTEM BASED ON OPTIMIZED SUPRAMOLECULAR RECEPTORS

I. Elmi[1], L. Masini[1], G.C. Cardinali[1], E. Dalcanale[2], R. Pinalli[2], J.W. Trzcinski[2], F. Suriano[3], and S. Zampolli[1]
[1]*CNR - IMM, ITALY,* [2]*University of Parma, ITALY, and* [3]*Proambiente s.c.r.l., ITALY*
.....957

In the present contribution, we report of a simple miniaturized system based on a commercial photoionization detector (PID) coupled to an innovative supramolecular cavitand receptor acting as both selective pre-concentration and GC-like separation device. The use of innovative materials for pre-concentration, MEMS devices for temperature control and smart signal processing strategies allows for ppb-level selective quantification of benzene in air.

Th3D.003

THE EFFECT OF CHARGE REDISTRIBUTION ON LIMITING $K_t^2.Q$ PRODUCT OF PIEZOELECTRICALLY TRANSDUCED RESONATORS

R. Tabrizian and M. Rais-Zadeh
University of Michigan, USA
.....981

We discuss the effect of free charge redistribution on limiting the Q of piezoelectrically transduced resonators. We show that the electromagnetic energy dissipated in the anhormonic process of free charge redistribution on metallic electrodes placed on commonly used piezoelectric materials sets a limit for the resonator Q that is frequency independent and is much smaller than the Akheiser Q limit at frequencies less than 1 GHz.

THURSDAY PROGRAM

Session Th3A
Thermal Actuators & Absorbers

TIKAHTNU A

Session Co-Chairs:
M. Maher, *SoftMEMS LLC, USA*

S. Tanaka, *Tohoku University, JAPAN*

Session Th3B
Alternative Power Sensors: Wireless & BioChem

TIKAHTNU B

Session Co-Chairs:
A. Duwel, *Draper Laboratory, USA*

E. Yeatman, *Imperial College London, UK*

Session Th3C
Chemical Sensors II

TIKAHTNU CD

Session Co-Chairs:
M. Fleischer, *Siemens AG*

S. Tadigadapa, *Pennsylvania State University, USA*

Session Th3D
Piezoelectric Actuators & RF Resonators

TIKAHTNU EF

Session Co-Chairs:
C.-Y. Kwok, *University of New South Wales, AUSTRALIA*

G. Piazza, *Carnegie Mellon University, USA*

14:45 - 15:00

Th3A.004

A SILICON/SOLDER BILAYER THERMAL ACTUATOR FOR COMPENSATING THERMAL DRIFT OF SILICON SUSPENSIONS

H. Liu and W.T. Pike
Imperial College London, UK
.....916

We demonstrate a thermal actuator with solder integrated into silicon cavities to passively compensate differential thermal expansion against the temperature coefficient of Young's modulus. We apply this technique to produce a thermally compensated low frequency accelerometer without affecting the mechanical and electrical properties of the suspension.

Th3B.004

A HYDROGEL-BASED ENERGY HARVESTER WITH BROAD BANDWIDTH DRIVEN BY AMBIENT VIBRATIONS

X. Wu, G. Li, and D.W. Lee
Chonnam National University, SOUTH KOREA
.....938

In this study, a hydrogel-based energy harvester is proposed and characterized, which allows it to effectively scavenge environmental vibration energy. Compared with the water droplet based energy harvesters in literatures, not only a wide operating bandwidth can be achieved by this design, but the evaporation problem can also be overcome. In the experiment, a broad frequency range of 0-70 Hz is realized by the energy harvester while maintaining an average output voltage of ~100 mV.

Th3C.004

A VERSATILE GAS SENSOR WITH SELECTIVITY USING A SINGLE GRAPHENE TRANSISTOR

Y. Liu, S. Lin, and L. Lin
University of California, Berkeley, USA
.....961

This work reports an original technique for selectively sensing different gases by a single graphene field effect transistor (GFET). We demonstrated selective gas sensing of four types of gases, i.e. NO2, NH3, H2O and CH3OH by measuring the impurity doping and charge doping effect from gas molecule to graphene concurrently. The proposed sensing scheme and results could open up a new class of graphene-based, selective gas sensing devices for practical uses and fundamental scientific research.

Th3D.004

AN ALTERNATIVE TECHNIQUE TO PERFECTLY MATCHED LAYERS TO MODEL ANCHOR LOSSES IN MEMS RESONATORS WITH UNDERCUT SUSPENSIONS

J. Segovia-Fernandez, C. Xu, C. Cassella, and G. Piazza
Carnegie Mellon University, USA
.....985

We develop and experimentally validate a new FEM technique to accurately model anchor losses in MEMS resonator with undercut suspensions. This method is an alternative to the use of Perfectly Matched Layers (PMLs) and imposes fixed-constraint boundaries at the edges of the released region. The comparison with experiments shows that the proposed technique is more precise than PML in predicting Q when reflections from the boundaries become more relevant.

THURSDAY PROGRAM

Session Th3A
Thermal Actuators & Absorbers

TIKAHTNU A

Session Co-Chairs:
M. Maher,
SoftMEMS LLC, USA

S. Tanaka,
Tohoku University, JAPAN

Session Th3B
Alternative Power Sensors: Wireless & BioChem

TIKAHTNU B

Session Co-Chairs:
A. Duwel,
Draper Laboratory, USA

E. Yeatman,
Imperial College London, UK

Session Th3C
Chemical Sensors II

TIKAHTNU CD

Session Co-Chairs:
M. Fleischer,
Siemens AG

S. Tadigadapa, *Pennsylvania State University, USA*

Session Th3D
Piezoelectric Actuators & RF Resonators

TIKAHTNU EF

Session Co-Chairs:
C.-Y. Kwok, *University of New South Wales, AUSTRALIA*

G. Piazza, *Carnegie Mellon University, USA*

15:00 - 15:15

Th3A.005

TERAHERTZ ADDRESSED SPATIAL LIGHT MODULATOR BASED ON BI-MATERIAL CANTILEVERS ARRAY

Y. Wen[1], W. Ma[1], X. Yu[1], Y. Zhao[2], M. Liu[2], and L. Dong[2]
[1]*Peking University, CHINA and* [2]*Beijing Institute of Technology, CHINA*

.....920

This paper reports a novel spatial light modulator (SLM) addressed by terahertz radiation. The SLM was realized by integrating metamaterial absorbers into bi-material cantilever pixels and fabricated by a polyimide sacrificial layer process on a glass substrate. The device works passively in an optical reflection mode with no-electronic components and can easily achieve high resolution. A modulation sensitivity of 18.8 deg/W is experimentally obtained.

Th3B.005

PAPER BASED REVERSE ELECTRODIALYSIS POWER GENERATOR

H.K. Chang, E. Choi, J.H. Lee, and J. Park
Sogang University, SOUTH KOREA

.....942

This study represents a paper based energy generation device from mixing waters with different salinity. Because the proposed device consists of wax patterned papers that can control microflow and flexible cation exchange membranes (polycarbonate track-etched (PCTE)), the efficient pumpless reverse electrodialysis (RED) microplatform can be realized successfully.

Th3C.005

SIZE EFFECT OF ZnO-NANOWIRES ON REVERSIBLE SULFURATION-DESULFURATION REACTION FOR ULTRA-SENSITIVE DETECTION OF ppb-LEVEL H_2S GAS

Y. Chen[1], H.Y. Huang[2], P.C. Xu[1], D. Zheng[2], and X.X. Li[1]
[1]*Chinese Academy of Sciences, CHINA and* [2]*Shanghai Institute of Technology, CHINA*

.....965

This paper reports the nano-size effect of ZnO nanowire on reversible sulfuration-desulfuration reaction process. ZnO NWs are sulfurated by H2S to form ZnS, which can be latterly desulfurized This sensing mechanism is different from the conventional one. Herein higher sensitivity of ZnO-NW to ultra-low concentration H2S is expected by size shrinking. Both the 20nm ZnO-NWs sensor and the 50nm sensor are compared by experiment, resulting in good validation of the nano-size effect.

Th3D.005

PIEZOELECTRIC NONLINEARITY IN GAN LAMB MODE RESONATORS

S. Wang, L.C. Popa, and D. Weinstein
Massachusetts Institute of Technology, USA

.....989

This paper reports on experimental observation of temperature and strain dependent nonlinearities in GaN Lamb mode resonators. Frequency shift of 128ppm and increase in motional impedance of 33% are observed at +10dBm input power. Contributions from self-heating and strain-induced piezoelectric nonlinearity in Rm are decoupled to first order, revealing that strain-induced nonlinearity in piezoelectric coefficients accounts for 31% of 33% observed shift.

THURSDAY PROGRAM

Session Th3A
Thermal Actuators & Absorbers

TIKAHTNU A

Session Co-Chairs:
M. Maher, *SoftMEMS LLC, USA*

S. Tanaka, *Tohoku University, JAPAN*

Session Th3B
Alternative Power Sensors: Wireless & BioChem

TIKAHTNU B

Session Co-Chairs:
A. Duwel, *Draper Laboratory, USA*

E. Yeatman, *Imperial College London, UK*

Session Th3C
Chemical Sensors II

TIKAHTNU CD

Session Co-Chairs:
M. Fleischer, *Siemens AG*

S. Tadigadapa, *Pennsylvania State University, USA*

Session Th3D
Piezoelectric Actuators & RF Resonators

TIKAHTNU EF

Session Co-Chairs:
C.-Y. Kwok, *University of New South Wales, AUSTRALIA*

G. Piazza, *Carnegie Mellon University, USA*

15:15 - 15:30

Th3A.006

MICROHEATER MULTILAYER INTERFERENCE TO REDUCE THERMAL EMISSION FOR LOW PHOTON NUMBER LUMINESCENCE MEASUREMENT

P.R. Armstrong, M.L. Mah, K.D. Olson, and J.J. Talghader
University of Minnesota, USA

.....924

In this paper, high temperature microheaters are integrated with multilayer interference structures and demonstrated to reduce blackbody emission by almost three orders of magnitude over typical heaters so that photon counting measurements can be performed on small samples of weakly luminescent materials.

Th3B.006

ELECTRIC GENERATION USING ELECTRIC ORGANS OF ELECTRIC RAYS BY CHEMICAL STIMULATION

Y. Tanaka[1], Y. Nishizawa[1,2], N. Kamamichi[2], M. Nishinaka[3] and T. Kitamori[3]
[1]*Institute of Physical and Chemical Research (RIKEN), JAPAN,* [2]*Tokyo Denki University, JAPAN, and* [3]*University of Tokyo, JAPAN*

.....945

We have demonstrated power generation method using electric organs of electric rays by chemical stimuli and injecting systems. This system just use biological energy and easy to be controlled.

Th3C.006

PIEZOELECTRIC RESPONSE OPTIMIZATION OF MULTI ROOF TILE-SHAPED MODES IN MEMS RESONATORS BY VARIATION OF THE SUPPORT BOUNDARY CONDITIONS

G. Pfusterschmied[1], M. Kucera[1,2], E. Wistrela[1], W. Steindl[1,2], V. Ruiz-Díez[3], A. Bittner[1], J.L. Sánchez-Rojas[3], and U. Schmid[1]
[1]*Vienna University of Technology, AUSTRIA,* [2]*AC2T research GmbH, AUSTRIA, and* [3]*Universidad de Castilla-La Mancha, SPAIN*

.....969

We investigate strain related conductance peaks of advanced roof tile-shaped vibration-modes in piezoelectrically actuated resonators by variation of the support-boundary-conditions. These new vibration modes show very high Q- factors in liquid media and enhanced volume-strain, which result in high strain related conductance peaks. This outstanding feature predestinates this new class of vibration modes for a large variety of challenging resonator based sensing applications in liquid media.

15:30 - 15:45 | **Break**

THURSDAY PROGRAM

Session Th4A
Optomechanical Systems

TIKAHTNU A

Session Co-Chairs:
J.-U. Bu,
Senplus, SOUTH KOREA

A. Trusov,
Northrop Grumman, USA

Session Th4B
Energy Harvesting & Environmental Sensors

TIKAHTNU B

Session Co-Chairs:
J. Judy,
University of Florida, USA

Y.K. Yoon,
University of Florida, USA

Session Th4C
Bio Sensing Devices & Tools

TIKAHTNU CD

Session Co-Chairs:
M. Johnston,
Oregon State University, USA

Q. Lin,
Columbia University, USA

Session Th4D
Drug Delivery Devices

TIKAHTNU EF

Session Co-Chairs:
P. French, *Delft University of Technology, THE NETHERLANDS*

E. Meng, *University of Southern California, USA*

15:45 - 16:00

Th4A.001

NON-LINEAR DYNAMICS IN OPTO-MECHANICAL OSCILLATORS

S. Tallur and S.A. Bhave
Cornell University, USA
.....993

This paper presents the first reported experimental demonstration of various non-linear dynamics observed in opto-mechanical oscillators, and specifies operating conditions required to inhibit these effects. We present four non-linear effects observed in a silicon opto-mechanical oscillator viz. i) oscillations of parasitic mechanical modes, ii) chaotic oscillations, iii) multi-GHz oscillations driven by two photon absorption, and iv) coherence of the excited mechanical oscillations.

Th4B.001

AN ORIGAMI PAPER-BASED BACTERIA-POWERED BATTERY WITH AN AIR-CATHOD

H. Lee and S. Choi
State University of New York-Binghamton, USA
.....1009

We created a stackable and integrative 3-D paper-based bacteria-powered battery for potentially powering on-chip paper-based biosensors. The battery was capable of generating power from microbial metabolism, delivering, with one drop of bacteria-containing liquid, on-board energy to the next generation of paper-based systems. An inexpensive air-cathode was also created on paper for the first time with activated carbon on the sprayed Nickel electrode.

Th4C.001

A PORTABLE, PAPER-BASED MULTIPLEXING IMMUNOSENSOR FOR DETECTION OF HIV AND HCV MARKERS IN SERUM

C. Zhao and X.Y. Liu
McGill University, CANADA
.....1025

We report an integrated diagnostic platform, including a paper-based electrochemical immunosensor and a handheld potentiostat, for HIV/HCV detection in serum. The platform can perform multiplexed enzyme-linked immunesorbent assays on 8 serum samples, produce multiple data points for HIV/HCV markers, and transmit results to remote sites for telemedicine. The unique integration of paper-based microfluidics and mobile instrumentation makes our tests portable, user-friendly, and high-throughput.

Th4D.001

AN OCULAR IONTOPHORETIC DEVICE FOR LOCAL DRUG DELIVERY USING PEDOT ELECTRODE

Y. Zhang[1], Y. Chen[2], M. Yang[1], X. Yu[1], Y. Qi[1], and Z. Li[1,3]
[1]*Peking University, CHINA,* [2]*Peking University Third Hospital, CHINA, and* [3]*Tsing University, CHINA*
.....1041

An ocular iontophoretic device, using biocompatible planar PEDOT electrode is reported. In vivo experiments on rabbit eyes demonstrate the device can realize ocular iontophoresis effectively, simply and conveniently. Compared to conventional eye cups, it can be placed under the eyelid and delivery ions through the settled small part on the eyeball, reducing tissue damage during ion penetration. Using the planar electrode, the device can provide a uniform electric field in the device.

THURSDAY PROGRAM

Session Th4A Optomechanical Systems	Session Th4B Energy Harvesting & Environmental Sensors	Session Th4C Bio Sensing Devices & Tools	Session Th4D Drug Delivery Devices
TIKAHTNU A	TIKAHTNU B	TIKAHTNU CD	TIKAHTNU EF
Session Co-Chairs: J.-U. Bu, *Senplus, SOUTH KOREA* A. Trusov, *Northrop Grumman, USA*	**Session Co-Chairs:** J. Judy, *University of Florida, USA* Y.K. Yoon, *University of Florida, USA*	**Session Co-Chairs:** M. Johnston, *Oregon State University, USA* Q. Lin, *Columbia University, USA*	**Session Co-Chairs:** P. French, *Delft University of Technology, THE NETHERLANDS* E. Meng, *University of Southern California, USA*
16:00 - 16:15			
Th4A.002	**Th4B.002**	**Th4C.002**	**Th4D.002**
NEMS INTEGRATED PHOTONIC SYSTEM USING NANO-SILICON-PHOTONIC CIRCUITS B. Dong[1], M. Cai[2], M. Tang[2], Y.D. Gu[2], Z.C. Yang[3], Y.F. Jin[3], Y.L. Hao[3], D.L. Kwong[2], and A.Q. Liu[1] [1]*Nanyang Technological University, SINGAPORE,* [2]*Agency for Science, Technology and Research (A*STAR), SINGAPORE, and* [3]*Peking University, CHINA* .....997 We develop a NEMS integrated photonic system, which integrate tunable laser, variable optical attenuators and optical switches. The NEMS integrated photonic system is fabricated with nano-silicon-photonic fabrication technology to integrate various functions in a single silicon photonic circuit chip. The high light-confinement capability of the nano-silicon waveguides guarantees superior performance such as large tuning range, pure single-mode properties and high switching speed.	**OPTIMIZATION OF A HUMAN-LIMB DRIVEN, FREQUENCY UP-CONVERTING ELECTROMAGNETIC ENERGY HARVESTER FOR POWER ENHANCEMENT** M.A. Halim and J.Y. Park *Kwangwoon University, SOUTH KOREA* .....1013 The proposed electromagnetic energy harvester is designed to up-convert the vibration of human limb-motion to high-frequency vibration by mechanical impact of a freely movable ball on two optimized frequency up-converted generators (FUGs) that use reliable helical compression springs.	**FLIP CHANNEL MICROFLUIDIC DEVICE TO STUDY EMBRYOID BODY SIZE-DEPENDENT STEM CELL DIFFERNETIATION** Y.-H. Chen, C.-C. Peng, and Y.-C. Tung *Academia Sinica, TAIWAN* ..... This paper reports a polydimethysiloxane (PDMS) microfluidic device capable of forming uniform-sized embryoid bodies (EBs) and performing stem cell differentiation within the same device after flipping the channel. The device provides a useful tool to study EB size-dependent differentiation of embryonic stem (ES) cells without professional operation, complicated device fabrication and tedious cell handling under well-controlled microenvironments.	**A WIRELESS IMPLANTABLE DRUG INFUSION SYSTEM WITH INTEGRATED DOSING SENSORS** R. Sheybani and E. Meng *University of Southern California, USA* .....1045 A wireless electrolysis-based drug delivery system with integrated electrochemical dosing sensors suitable for management of chronic conditions is presented. Repeatable delivery performance for identical and variable bolus volumes and flow rates of phosphate buffer saline (PBS) was demonstrated. Successful delivery and sensing of 17.75 ± 0.48 µL boluses (1.78% of reservoir fill volume) of lidocaine was achieved.

THURSDAY PROGRAM

Session Th4A
Optomechanical Systems

TIKAHTNU A

Session Co-Chairs:
J.-U. Bu,
Senplus, SOUTH KOREA

A. Trusov,
Northrop Grumman, USA

Session Th4B
Energy Harvesting & Environmental Sensors

TIKAHTNU B

Session Co-Chairs:
J. Judy,
University of Florida, USA

Y.K. Yoon,
University of Florida, USA

Session Th4C
Bio Sensing Devices & Tools

TIKAHTNU CD

Session Co-Chairs:
M. Johnston,
Oregon State University, USA

Q. Lin,
Columbia University, USA

Session Th4D
Drug Delivery Devices

TIKAHTNU EF

Session Co-Chairs:
P. French, *Delft University of Technology, THE NETHERLANDS*

E. Meng, *University of Southern California, USA*

16:15 - 16:30

Th4A.003

A MEMS TUNABLE PHOTONIC RING RESONATOR WITH SMALL FOOTPRINT AND LARGE FREE SPECTRAL RANGE

C. Errando-Herranz, F. Niklaus, G. Stemme, and K.B. Gylfason
KTH Royal Institute of Technology, SWEDEN
.....1001

We demonstrate a MEMS tunable photonic ring resonator with a 20 µm radius and a 5 nm free spectral range (FSR). Compared to previous work, this constitutes a 4-fold increase in FSR and a 16-fold decrease in footprint area. This technology enables large scale integration of tunable photonic ring resonators for wavelength selection in reconfigurable optical networks.

Th4B.003

DEVELOPMENT OF A CAPACITIVE ICE SENSOR TO MEASURE ICE GROWTH IN A REAL TIME

H.C. Cho, X. Zhi, B. Wang, C.H. Ahn, and J.S. Go
Pusan National University, SOUTH KOREA
.....1017

We develop a capacitive type ice sensor to measure ice grow in a real time. It is consisted of a comb-type capacitance sensing part and a thermocouple to monitor temperature condition. Also, to situate icing environment, a special chamber is designed to control temperature and humidity. It is measured that as soon as ice nucleates, the capacitance rapidly decreases because water film as a medium is replaced with ice frost.

Th4C.003

PHASEGUIDE-BASED OPTOFLUIDIC ROUTER FOR PARALLEL ANALYSIS OF SERUM SAMPLES

J. Vila-Planas[1], X. Munoz-Berbel[1], P. Mueller[2], B. Ibarlucea[1], D. Kopp[2], H. Zappe[2], and A. Llobera[1]
[1]*Institut de Microelectrònica de Barcelona (IMB-CNM, CSIC), SPAIN and* [2]*University of Freiburg - IMTEK, GERMANY*
.....1029

A phaseguide-based optofluidic router (PHASOR) is presented. By using phaseguides, DI-water can be pinned in the required angle so that light incident undergoes total internal reflection and can be reflected towards one of the six output channels without movable parts. In addition, the PHASOR is coupled to two enzymatically-functionalized photonic lab on a chip (PhLoC). Using real rat serum samples, we were able to monitor in real time and using only one light source L-Lactate and Glucose.

Th4D.003

CONTROLLED DRUG DELIVERY VIA REMOTELY HEATED CORE-SHELL MAGNETIC MICROCAPSULES

X. Li, K. Iwai, F.N. Pirmoradi, Y. Chen, and L. Lin
University of California, Berkeley, USA
.....1049

We report controlled drug release by remotely heated core-shell magnetic microcapsules for the local delivery of encapsulated drug agents. Three major accomplishments are demonstrated: (1) the "thermoresponsive magnetic shell" by UV-curable PEGDA with embedded PNIPAm nanogels and iron oxide nanoparticles; (2) a multi-stage microfluidic flow-focusing scheme to construct the microcapsules; and (3) the remote release of encapsulated drug in the core via induction heating of the magnetic particles.

THURSDAY PROGRAM

Session Th4A Optomechanical Systems	Session Th4B Energy Harvesting & Environmental Sensors	Session Th4C Bio Sensing Devices & Tools	Session Th4D Drug Delivery Devices
TIKAHTNU A	**TIKAHTNU B**	**TIKAHTNU CD**	**TIKAHTNU EF**
Session Co-Chairs: J.-U. Bu, *Senplus, SOUTH KOREA* A. Trusov, *Northrop Grumman, USA*	**Session Co-Chairs:** J. Judy, *University of Florida, USA* Y.K. Yoon, *University of Florida, USA*	**Session Co-Chairs:** M. Johnston, *Oregon State University, USA* Q. Lin, *Columbia University, USA*	**Session Co-Chairs:** P. French, *Delft University of Technology, THE NETHERLANDS* E. Meng, *University of Southern California, USA*
16:30 - 16:45			
Th4A.004	**Th4B.004**	**Th4C.004**	**Th4D.004**
SELECTIVE TRANSDUCTION OF WINE-GLASS VIBRATION MODE USING DIFFERENTIAL OPTOMECHANICS M.J. Storey[1], A.K. Bhat[1], and S.A. Bhave[2] [1]*Cornell University, USA and* [2]*Analog Devices, USA* .....**1005** This paper demonstrates differential opto-mechanical transduction which selectively senses the wine-glass vibration mode of a silicon resonator. We use two waveguide arms for opto-mechanical sensing at the anti-nodes of the 21.9 MHz wine-glass mode and utilize a differential photo detector (PD) to measure the vibration. The differential PD significantly attenuates the radial "common-mode" vibration at 94.8 MHz.	**NANOSTRUCTURED SILICON FIELD EMITTER ARRAY-BASED HIGH-VACUUM MAGNETIC-LESS ION PUMP FOR MINIATURIZED ATOMIC SPECTROSCOPY SENSORS** A. Basu[1], M.A. Perez[2], and L.F. Velásquez-García[1] [1]*Massachusetts Institute of Technology, USA and* [2]*Cold Quanta, USA* .....**1021** We designed, developed and characterized a novel magnetic-less ion pump architecture for high vacuum generation. The electron impact ionization pump uses a nanostructured, high-current, low- voltage silicon field emitter array as the electron source and does not degrade when operated in Rubidium vapor. Pumping via gettering of electron impact-ionized molecules was observed in a proof-of-concept vacuum chamber. The pump will help maintain better vacuum for miniaturized atomic spectroscopy sensors.	**LONG-TERM, HIGH-SPATIOTEMPORAL RESOLUTION RECORDING FROM CULTURED ORGANOTYPIC SLICES WITH HIGH-DENSITY MICROELECTRODE ARRAYS** W. Gong[1], J. Sencar[2], D. Jäckel[1], J. Müller[1], M. Fiscella[1], M. Radivojevic[1], D. Bakkum[1], and A. Hierlemann[1] [1]*ETH Zürich, SWITZERLAND and* [2]*University of Ljubljana, SLOVENIA* .....**1037** We present a novel system to cultivate brain slices directly on high-density microelectrode arrays (HD-MEA), which then enable continuous high-resolution electrical activity recording. This system allows, for the first time, for tracing the activities of selected individual neurons while neuronal network development in slices at the same time, over extended times.	**A TENTACLE-LIKE DOUBULE SECTION CURVATURE TUNABLE ACTUATOR WITH LIGHT GUIDING/DRUG DELIVERY ABILITY FOR BIOMECIAL APPLICATIONS** G.H. Feng and S.Y. Hou *National Chung Cheng University, TAIWAN* .....**1053** We develop a biocompatible flexible actuator possessing embedded electrical and liquid transmission ability. A light-emitting diode (LED) and a cotton swab are integrated to the actuator to demonstrate electrical power and liquid drug transmission ability while the actuator performs a snake-like motion. The light emitted from an LED can be guided arbitrarily and the drug-absorbed-swab can be applied to the difficultly reached wound through manipulation of the actuator.

17:00 - 17:30	**Awards Ceremony**
17:30	**Conference Adjourns**

POSTER/ORAL PRESENTATIONS

See poster floorplan on page XX

M - Monday	13:30 - 15:30
T - Tuesday	15:30 - 17:30
W - Wednesday	10:30 - 12:30

MONDAY - Mechanical/Physical Sensors and Microsystems

M3P.001 **A MODE-MATCHING 130-KHz RING-COUPLED GYROSCOPE WITH 225 PPM INITIAL DRIVING/SENSING MODE FREQUENCY SPLITTING** 1057

J. Ren, C.-Y. Liu, M.-H. Li, C.-C. Chen, C.-Y. Chen, C.-S. Li, and S.-S. Li

National Tsing Hua University, TAIWAN

A degenerate mode 130-kHz ring-coupled gyroscope with auxiliary transducer array is designed to enhance the sensitivity as well as the mode-matching feature. The average frequency split for drive/sense modes over multiple tested devices is only 225 ppm with the mean resonance frequency of 130 kHz. The measured Q-factor is 50 in air and up to 10,000 in vacuum. The scale factor of 2.2 mV/°/s and the resolution of 0.26 °/s, respectively, are characterized in air.

M3P.002 **ULTRA-HIGH-SPEED CANTILEVER TACTILE PROBE FOR HIGH-ASPECT-RATIO MICRO METROLOGY** 1061

H.S. Wasisto[1], L. Doering[2], U. Brand[2], and E. Peiner[1]

[1]*Technische Universität Braunschweig, GERMANY and* [2]*Physikalisch-Technische Bundesanstalt (PTB), GERMANY*

A silicon cantilever-based piezoresistive tactile probe coated with aluminum oxide (Al2O3) thin film in an atomic layer deposition (ALD) process is described to detect surface irregularities of high-aspect-ratio micro holes (e.g., spray holes of fuel injector nozzles) at ultra-high speed.

M3P.003 **DESIGN AND CHARACTERIZATION OF A THERMAL SENSOR ACHIEVING SIMULTANEOUS MEASUREMENT OF THERMAL CONDUCTIVITY AND FLOW SPEED** 1065

C.J. Hepp[1], F.T. Krogmann[1], and G.A. Urban[2]

[1]*Innovative Sensor Technology IST AG, SWITZERLAND and* [2]*University of Freiburg - IMTEK, GERMANY*

In this contribution, we present a novel design and excitation procedure for a thermal flow sensor to simultaneously determine thermal conductivity and flow rate of gas in a channel. For the first time, these two parameters can be detected by using a time-independent (DC) excitation mode. Theoretical and experimental results are discussed in order to specify possible application fields.

M3P.004 **PERFORMACE IMPROVEMENT OF CMOS-MEMS PIRANI VACUUM GAUGE WITH HOLLOW HEATER DESIGN** 1069

Y.-C. Sun, K.-C. Liang, C.-L. Cheng, M.-Y. Lin, R.-S. Chen, and W. Fang

National Tsing Hua University, TAIWAN

A novel heater-with-holes design is developed to realize a CMOS-MEMS Pirani vacuum gauge. The proposed design has the following merits: (1) The holes on heater increase the thermal resistance and then improve the efficiency of heat transfer; (2) The heat-sink mesas are added to compensate the lost active area between heater and heat sink; (3) Easily integrate with other packaged CMOS-MEMS devices for pressure monitoring.

M3P.005 **A NOVEL RESONANT ACCELEROMETER BASED ON MODE LOCALIZATION OF WEAKLY COUPLED RESONATORS** 1073

H.M. Zhang[1], W.Z. Yuan[1], B.Y. Li[1], Y.C. Hao[1], M. Kraft[2], and H.L. Chang[1]

[1]*Northwestern Polytechnical University, CHINA and* [2]*University of Liege, BELGIUM*

This paper describes a novel MEMS resonant accelerometer based on two weakly coupled resonators (WCRs) using the phenomenon of mode localization. It is the first time that this principle is demonstrated experimentally for an accelerometer. The measured relative shift in amplitude ratio (~312162 ppm/g) is 302 times higher than the shift in resonance frequency (~1035 ppm/g).

M3P.006 **A PERSONAL NAVIGATION SYSTEM USING MEMS-BASED HIGH-DENSITY GROUND REACTION SENSOR ARRAY AND INERTIAL MEASUREMENT UNIT** 1077

Q. Guo[1], O. Bebek[2], M.C. Cavusoglu[3], C. Mastrangelo[1], and D.J. Young[1]

[1]*University of Utah, USA,* [2]*Ozyegin University, TURKEY, and* [3]*Case Western Reserve University, USA*

This paper presents the design, implementation and testing results of a prototype personal navigation system employing a commercial IMU assisted by a high-density error-correcting ground reaction sensor array (GRSA). An initial 10-minute walking test demonstrated an in-plane navigation accuracy of 0.4 meter and a vertical position accuracy of 1 meter.

POSTER/ORAL PRESENTATIONS

M3P.007 **A STAINLESS-STEEL-BASED CAPACITIVE PRESSURE SENSOR CHIP AND ITS MICROWELDING INTEGRATION** **1081**

X. Chen[1], D. Brox[1], B. Assadsangabi[1], M.S. Mohamed Ali[2], and K. Takahata[1]
[1]*University of British Columbia, CANADA and* [2]*Universiti Teknologi Malaysia, MALAYSIA*

This paper reports a micromachined capacitive pressure sensor based on medical-grade stainless steel that offers high chemical robustness and biocompatibility. Laser microwelding is utilized to integrate the developed sensor directly on stainless-steel platforms including a stent. This microwelding integration is shown to provide superior performance over a conductive epoxy bonding, with ~2x larger mechanical strength and ~6x higher electrical conductance in the bond.

M3P.008 **DEVELOPMENT OF A NO-BACK-PLATE SOI MEMS CONDENSER MICROPHONE** **1085**

S.-C. Lo, W.-C. Lai, C.I. Chang, Y.Y. Lo, C. Wang, M.R. Bai, and W. Fang
National Tsing Hua University, TAIWAN

This study demonstrates a SOI condenser MEMS microphone. No back-plate is required for this design, thus, the acoustic impedance is reduced. The merits of this study are: (1) the back-plate is replaced to prevent in-use pull-in and process stiction, (2) out-of-plane area-changing capacitive sensing provides a better linearity to sound pressure variation, (3) large and flat diaphragm implemented by SOI increases the acoustic sensitivity.

M3P.009 **QUAD-AXIAL PIEZORESISTIVE FORCE SENSOR PROBE BY FOUR SENSING ELEMENTS WITH SIDEWALL DOPING METHOD** **1089**

H. Takahashi, S. Hirakawa, T. Takahata, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

This paper reports a quad-axial force sensor probe which can measure tri-axial forces and one torque around the probe. By forming piezoresistors three dimensionally on the probe supporting beams, four sensing element can detect quad-axial force/torque on the probe tip. We demonstrated that the fabricated sensor had condition number of 2.6 with force resolutions under 1.0 μN and torque resolution under 1.0 nNm.

M3P.010 **HYPERELASTICALLY STRETCHABLE STRAIN GAUGES BASED ON LIQUID METALS AND PLATINUM-CATALYZED SILICONE ELASTOMERS** **1093**

S. Kim, J. Choi, B. Choi, and J. Lee
Sogang University, SOUTH KOREA

This paper reports hyperelastically stretchablestrain gauges based on a liquid metal and a platinum-catalyzed silicone elastomer. A custom liquidmetal printing setup was operated in a pressurecontrolled mode to offer improved printing qualityover the previously used flow-rate controlled mode. By engineering the orientation of solid wires placed over two terminals of the printed liquid metal resistor, we achieved the stretchability up to 800 %.

M3P.011 **LOW VELOCITY DIGITAL AIR FLOW SENSOR FROM 3D PRINTED PEDOT:PSS MICRO- HAIR STRUCTURES** **1097**

H. Devaraj, K.C. Aw, J. Travas-Sejdic, and R.N. Sharma
University of Auckland, NEW ZEALAND

This paper reports a novel method for digital sensing of low-velocity air flow using high aspect-ratio 3D printed conducting polymer (PEDOT:PSS) micro-hair structures (1000 μm long, 5.5±0.5 μm diameter). By implementing multiple micro-hair structures as micro-switches that respond to air flows of particular velocities, a low-velocity digital flow sensor capable of detecting air flow in the range of 61 mm/s to 99 mm/s is demonstrated.

M3P.012 **MEMS INERTIA SWITCH WITH FLEXIBLE CNTS/CU COMPOSITE ARRAY LAYER BETWEEN ELECTRODES FOR PROLONGING CONTACT TIME** **1101**

Y. Wang, Z. Yang, W. Chen, G. Ding, Y. Wang, C. Zhang, and X. Zhao
Shanghai Jiao Tong University, CHINA

We design, simulate and fabricate an inertia switch with flexible carbon nanotubes/copper (CNTs/Cu) composite array layer between movable and fixed electrodes, which achieves a longer contact time(112μs) compared to the traditional design(<5μs) using rigid-to-rigid impact between electrodes. The CNTs/Cu layer is fabricated using the composite electroplating method and the whole device is completed by multi-layer metal electroplating based on the micromachining process.

M3P.013 **NOVEL INSTRUMENTED TOOTH WITH TEN-FOLD INCREASE IN FORCE RESOLUTION** **1105**

F. Becker[1], M. Kuhl[1], Y. Manoli[1,2], and O. Paul[1]
[1]*University of Freiburg - IMTEK, GERMANY and* [2]*HSG - IMIT, GERMANY*

We developed an instrumented tooth that enables to measure all six force and moment components exerted on it. The improved design presented here shows a 10-fold increase in performance over previous designs. It builds on a 17-mm-long, 5.2-mm-diameter force/moment transducer based on a CMOS stress sensor system between two metal pins. The resulting resolution is better than 400 mN for forces and 2.15 Nmm for moments. The measurement ranges are at least 15 N and 30 Nmm, respectively.

M3P.014 **HIGH-PERFORMANCE PULL-IN TIME ACCELEROMETER** 1109
R.A. Dias[1], F.S. Alves[2], M. Costa[1], H. Fonseca[1], J. Cabral[2], J. Gaspar[1], and L.A. Rocha[2]
[1]*International Nanotech Laboratory (INL), PORTUGAL and* [2]*Universidade do Minho, PORTUGAL*

We present a closed-loop high-performance accelerometer based on electrostatic pull-in time. It presents a good performance in comparison to the state-of-the-art, with a simple readout mechanism, showing a sensitivity of 61.3 V^2/g, dynamic range of 110 dB and a noise level set below 3 µg/√Hz, by the mechanical-thermal noise only. The measured bias stability is better than ±250µg over 48h with temperature control of ±1ºC.

M3P.015 **A VERTICAL DRIVEN INERTIAL MICRO-SWITCH WITH DUAL SPRING TO PROLONG HOLDING TIME** 1113
W. Chen, Z. Yang, Y. Wang, G. Ding, H. Wang, and X. Zhao
Shanghai Jiao Tong University, CHINA

We propose a novel inertial micro-switch, whose electrodes are designed as two movable springs compared with the traditional model. The dynamic response processes of electrodes can be controlled by the structural parameters. The simulation indicates that the elastic contact can effectively prolong the holding time. The prototypes were tested by drop hammer system, which shows that the holding time of improved inertial micro-switch is longer than the traditional one under the same threshold.

M3P.016 **SELF-CALIBRATION COMPATIBLE Z-AXIS BULK PZT VIBRATORY GYROSCOPE** 1117
S. Nadig, S. Ardanuç, and A. Lal
Cornell University, USA

We report a laser micromachined piezoelectric bulk-PZT (Lead Zirconate Titanate) Z-axis Coriolis force gyroscope, which utilizes spring-mass resonances of the PZT in-plane bimorphs and PZT proof-mass. The gyroscope provides high dynamic range owing to elimination of micro-gaps, and is compatible to be monolithically integrated with a PZT dither stage for self-calibration. The gyroscope has unamplified sensitivity of ~1.3µV/°/sec under mode-mismatched operation.

M3P.017 **HOLLOW LAMÉ MODE MEMS MASS SENSORS 10 PPB-RANGE STABILITY FOR PARTICLES COUNTING AND WEIGHING IN FLUID** 1121
C. Hadji[1,2], I. Fukada[3], F. Baléras[1,2], Y. Taguchi[3], B. Icard[1,2], and V. Agache[1,2]
[1]*University Grenoble Alpes, FRANCE,* [2]*CEA, FRANCE, and* [3]*Keio University, JAPAN*

We report hollow MEMS plate oscillators for mass sensing in liquid with an expected mass resolution of 3 femtograms. The performances reached by our sensors – 10,000-range Q-factor and ppb-range frequency stability – make them amenable to individual particles metrology from a few 10 nm up to the micrometer diameter range. Our devices are operated in air inside a customized plug and play test platform and do not need to work in vacuum contrary to similar state-of-the-art technologies.

TUESDAY - Mechanical/Physical Sensors and Microsystems

T4P.001 **A RESONANT ACCELEROMETER BASED ON RING-DOWN MEASUREMENT** 1125
D.H. Zhai[1], D.C. Liu[1], C.H. He[1,2], R. Guan[1], L.T. Lin[1], L.G. Dong[1], Q.C. Zhao[1], Z.C. Yang[1], and G.Z. Yan[1]
[1]Peking University, CHINA and [2]Fifth Electronics Research Institute of Ministry of Industry and Information Technology, CHINA

A micromachined differential resonant accelerometer with electrostatic stiffness tuning is presented. The ring-down measurement is used for the first time to pick-up the real-time resonant frequencies of the accelerometer, which is more robust to device parameter variations and parasitic capacitances compared with the oscillation based read-out. The differential output varies only 1 Hz over the temperature range of 120°C compared with 40.9 Hz of the single one.

T4P.002 **A PASSIVE MICROMECHANICAL BROADBAND AMPLIFIER FOR ACOUSTIC EMISSION SENSING** 1129
M. Müller, V. Maiwald, M. Käch, C. Hierold, and C. Roman
ETH Zürich, SWITZERLAND

A novel mechanical amplification mechanism based on a coupled mass-spring system is presented. The mechanism effectively transduces and amplifies structural vibrations within a broad frequency range into out-of-plane motion and needs no electrical power supply. The concept is verified experimentally on two designs consisting of 4 and 8 coupled masses respectively. The main application field is structural health monitoring (e.g. cliffs and buildings).

T4P.003 **NONLINEARITY TUNING AND ITS EFFECTS ON THE PERFORMANCE OF A MEMS GYROSCOPE....1133**
E. Tatar, T. Mukherjee, and G.K. Fedder
Carnegie Mellon University, USA

A symmetric SOI-MEMS gyroscope having parasitic softening nonlinearity from drive comb and frequency tune fingers is successfully linearized through use of shaped comb fingers that introduce a tuned cubic hardening compensation, performed for the first time. The nonlinearity compensated gyroscope achieves high drive displacement (> 5μm) in a SOI-MEMS gyroscope while maintaining linear magnitude and phase frequency responses.

T4P.004 **ACOUSTIC EMISSION SENSOR USING LIQUID-ON-BEAM STRUCTURE 1137**
Q.-K. Pham, M.D. Nguyen, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

In this paper we proposed an acoustic emission (AE) sensor that can be used for structural health monitoring. The key aspect of this sensor is the liquid-on-beam structure, in which a nanoliter-droplet is placed on a 300nm-thick piezoresistive beam. Experiment results demonstrates that this structure enables the sensor to have high sensitivity and flat frequency characteristics in a broad range from a few tens kHz to a few MHz.

T4P.005 **TEMPERATURE EFFECTS ON CHARACTERISTICS OF MEMS BASED ELECTROCHEMICAL SEISMIC SENSORS FOR LINEAR MOTION DETECTING....1140**
T. Deng, D.Y. Chen, J.B. Wang, J. Chen, G.L. Li, Z.Y. Zhang, and Z.Y. Sun
Chinese Academy of Sciences, CHINA

This paper first investigates temperature effects on characteristics of MEMS based electrochemical seismic sensor for linear motion detecting by both numerical simulation and experimental methods, which respectively show an average temperature sensitivity of 1.30%/℃ and 1.88%/℃ (compared to the device sensitivity) and an identical tendency of device frequency responses under different temperatures, providing crucial information for further electronic compensation.

T4P.006 **A SINGLE CRYSTAL SILICON LOW-G SWITCH TOLERANT TO IMPACT ACCELERATIONS UP TO 24,000 G....1144**
N. Raghunathan, W. Tsutsui, W. Chen, and D. Peroulis
Purdue University, USA

This paper presents a novel MEMS single-crystal silicon low-g switch surviving acceleration loads 200 times greater than its designed trigger load. In accordance with beam dynamics theory for survivability to high-g acceleration levels (on the order of 10,000-g's), low-g (<150 g) switches were designed. Experiments have confirmed that the fabricated devices trigger in the ranges of 60-131 g and survive acceleration impacts of 24,000 g.

T4P.007 **AN AUTOMATIC MODE MATCHING SYSTEM FOR A HIGH Q-FACTOR MEMS GYROSCOPE USING A DECOUPLED PERTURBATION SIGNAL....1148**
F. Yesil, S.E. Alper, and T. Akin
Middle East Technical University (METU), TURKEY

This paper reports a closed-loop automatic mode matching system that is achieved by injecting a perturbation signal to the quadrature cancellation loop, while keeping it decoupled from the angular rate control loop. It is verified to maintain matched-mode state under changing environmental conditions. The system reduces the overall output noise of the tested MEMS gyroscope by a factor of 6; truly reaching down to the thermo-mechanical noise floor.

T4P.008 **INTEGRATED CMOS MEMS LIQUID CAPACITIVE INCLINOMETER 1152**
Y. Chiu, B.-T. Chen, and H.-C. Hong
National Chiao Tung University, TAIWAN

This paper reports a miniaturized CMOS MEMS capacitive inclinometer with dielectric liquid sensing medium. A SU-8/glass cap is bonded to the CMOS chip to form the reservoir for the sensing liquid. Rotating/tilting the sensor changes the electrode area covered by the liquid and leads to a change of capacitance. Experimental results obtained by the on-chip readout circuit showed a sensitivity of 0.48 mV/degree in the linear operation range.

T4P.009 **A NOVEL MOS RADIATION DOSIMETER BASED ON THE MEMS-MADE OXIDE LAYER** **1156**
H. Liu, Y. Yang, and J. Zhang
Peking University, CHINA

This paper reports a novel MOS dosimeter with a very thick and defect-rich oxide layer fabricated by MEMS technology. We combined deep-reactive-ion etching (DRIE), thermal oxidation and LPCVD to prepare an oxide layer, which make it possible to achieve not only much thicker oxide but also higher defect density by forming multiple and large interfaces than conventional CVD one. Results proved that this MEMS-made oxide layer can improve the characteristic of MOS dosimeters significantly.

T4P.010 **DESIGN AND IMPLEMENTATION OF A FULLY-DECOUPLED TUNING FORK (FDTF) MEMS VIBRATORY GYROSCOPE FOR ROBUSTNESS IMPROVEMENT** **1160**
F.-Y. Lee[1], K.-C. Liang[1], E. Cheng[2], and W. Fang[1]
[1]*National Tsing Hua University, TAIWAN and* [2]*Taiwan Semiconductor Manufacturing Company (TSMC) Ltd., TAIWAN*

This study demonstrates the gyroscope design, which combines the fully-decoupled architecture with the tuning fork mechanism, for robustness improvement. A compact structure consisting of the structurally forced (by rigid lever mechanism) anti-phase sense-mode and the linear-coupled anti-phase drive-mode is also presented. Preliminary results show a reduced coupling signal of near 500°/s, and the vibration resistances along different directions are also investigated.

T4P.011 **NOVEL COMPACT TWO-DIMENSIONAL CMOS VERTICAL HALL SENSOR** **1164**
C. Sander, C. Leube, and O. Paul
University of Freiburg - IMTEK, GERMANY

We report a novel CMOS sensor enabling the measurement of both in-plane magnetic field components Bx and By at the same location. The sensor consists of four n-wells arranged as square and electrically interconnected into a conducting loop. By selectively switching the interconnections among the n-wells, the device is made sensitive alternatingly to Bx and By. The sensitivity for is 5.6mV/VT. At a nominal B field of 3.7mT the RMS error of magnitude and angle are only 56μT and 0.8°.

T4P.012 **FABRICATION AND CHARACTERIZATION OF BULK MOLYBDENUM FIELD EMISSION ARRAYS** **1168**
N.L. Zhu, K.S. Xu, L. Song, X. Chen, and J. Chen
Peking Univeristy, CHINA

This paper reports a simple technology for fabricating high aspect ratio(>10) field emission tips directly in molybdenum substrate by fluorine inductive-coupled-plasma(ICP) etching for the first time. The device exhibits a low turn-on electric field of 1.21V/μm. Arrays of 1,000,000 tips with 10μm pitch are employed to emit currents of 140μA at electric field strength of 5.48V/μm. A stable, uniform emission was observed in a field emission display.

T4P.013 **A SIMPLIFIED TEST VEHICLE FOR UNDERSTANDING AND IMPROVING TILT AND ITS IMPACT ON THE PERFORMANCE OF INERTIAL SENSORS** **1172**
M. Varvara, R. Barnett, F. Avril, and P. Bennett
SPTS Technologies, UK

We present a simplified methodology to control and increase the verticality of silicon etched structures in a DRIE source. The combined analysis of polymer etching on blanket wafers and tilt of inertial sensors enables us to validate the optimized design and to identify the key parameters of the Bosch DRIE process.

T4P.014 **NOVEL TWO-STAGE CMOS-MEMS CAPACITIVE-TYPE TACTILE-SENSOR WITH ER-FLUID FILL-IN FOR SENSITIVITY AND SENSING RANGE ENHANCEMENT** **1175**
W.-C. Lai and W. Fang
National Tsing Hua University, TAIWAN

This study has presented a novel two-stage CMOS-MEMS capacitance-type tactile sensor with ER-fluid fill-in to enlarge the sensing range. Merits of the sensor are: (1) small tactile force (mN) is detected by first-stage sensing-unit with sensing range modulated by driving-voltage through ER-fluid; (2) larger tactile force (N) is detected by the second-stage sensing-unit. Moreover, sensing range and sensitivity can be further modulated using different ER-fluid.

T4P.015 **INVESTIGATION OF A BROADBAND MICROMACHINED THERMOELECTRIC MICROWAVE POWER SENSOR WITH A CANTILEVER BEAM** 1179

D.B. Wang and Y.M. Fang
Nanjing University of Posts and Telecommunication, CHINA

We propose a novel thermoelectric microwave power sensor with a MEMS cantilever beam in order to improve the measurement dynamic range and the band width. The measured results show that the MEMS cantilever beam can improve the dynamic range by increasing the top end of the range into no less than 200mW, and enhance the band width by increasing the top end of the range into no less than 36GHz.

T4P.016 **ATMOSPHERIC PRESSURE MODE LOCALIZATION COUPLED RESONATORS FORCE SENSOR** 1183

M. Montaseri[1], J. Xie[2], H. Chang[2], Z. Chao[3], G. Wood[3], and M. Kraft[4]
[1]*University of Duisburg-Essen, GERMANY,* [2]*Northwestern Polytechnical University, CHINA,*
[3]*University of Southampton, UK, and* [4]*University of Liege, BELGIUM*

This paper reports on a 3-DoF mode localization resonant sensor experimentally evaluated under atmospheric conditions. It was demonstrated that using amplitude ratio as an output signal, even when the device is operated in air, yields a higher sensitivity compared to the frequency variation sensitivity when assuming vacuum conditions.

T4P.017 **INLINE PRESSURE SENSING MECHANISMS ENABLING SCALABLE RANGE AND SENSITIVITY** 1187

D. Alveringh[1], J. Groenesteijn[1], R.J. Wiegerink[1], and J.C. Lötters[1,2]
[1]*MESA+, University of Twente, THE NETHERLANDS and* [2]*Bronkhorst High-Tech BV, THE NETHERLANDS*

We report on two novel capacitive pressure sensing mechanisms that allow measurements inline with other fluidic devices (e.g. Coriolis flow sensor) on one chip, without introducing a large internal volume to the fluid path. One sensing mechanism is based on out-of-plane bending of a U-shaped channel. The other mechanism is based on deformation of the cross-section of the tube and allows a differential capacitive readout. The sensitivity and range of both mechanisms are scalable.

WEDNESDAY - Mechanical/Physical Sensors and Microsystems

W2P.001 **A NEW EXTRACTION METHOD OF INFORMATION FOR QUANTIFICATION OF THE SENSE OF TOUCH USING A NOVEL TWO-AXIS TACTILE SENSOR** 1191

R. Kozai, K. Terao, T. Suzuki, F. Shimokawa, and H. Takao
Kagawa University, JAPAN

A new extraction method of information for quantification of the fingertip sense which is never extracted by previous tactile sensors is reported for the first time. The MEMS two-axis tactile sensor used for the purpose can get the correlation between the surface shape and the local frictional force at the same time and at the same point. A lot of information to quantify the sense of touch such as instant frictional force has been extracted using the novel MEMS tactile sensor in this study.

W2P.002 **DEVELOPMENT AND CHARACTERIZATION OF A NOVEL TWO-DIMENSIONAL POSITION SENSITIVE SILICON STRIP DETECTOR FOR ELECTRON DETECTION** 1195

Y.J. Chuang[1], Y.T. Liao[2], W.R. Lin[2], F.R. Chen[2], P.R. Chen[1], and K.Y. Hung[3]
[1]*Ming Chuan University, TAIWAN,* [2]*National Tsing Hua University, TAIWAN, and*
[3]*Ming Chi University of Technology, TAIWAN*

A novel silicon strip detector has been developed that has the necessary properties to provide two-dimensional position sensitivity with a moderate number of readouts and single-sided detector fabrication process. The concept is based on segmented pixel electrodes arranged in a projective X-Y readouts, it combines the 2-D position resolution of pixel electrode geometry with the simplicity of the projective readout of a double-sided strip detector.

W2P.003 **CROCODILE INSPIRED DOME PRESSURE SENSOR FOR HYDRODYNAMIC SENSING** 1199

E. Kanhere[1], N. Wang[1], M. Asadnia[1], A.G.P. Kottapalli[2], and J.M. Miao[1]
[1]*Nanyang Technological University, SINGAPORE and* [2]*Singapore MIT Alliance for Research and Technology, SINGAPORE*

Crocodiles have dome pressure receptors (DPRs) scattered on their skin, which assist them to locate the origin of disturbance, both on water surface and inside the water; thereby enabling them to hunt preys even in dark and turbid waters. This novel work draws inspiration from DPRs of crocodiles to form a dome structure embedded with piezoelectric pressure sensors, which will be employed to detect the direction from which the hydrodynamic disturbance originates.

W2P.004 FLOW COMPENSATION IN A MEMS DUAL-THERMAL CONDUCTIVITY DETECTOR TCD) FOR HYDROGEN SENSING IN NATURAL GAS **1203**

G. de Graaf, A. Abarca Prouza, and R.F. Wolffenbuttel
Delft University of Technology, THE NETHERLANDS

The TCD presented is based on the on-line flow compensation using two thin-film sensors on membranes in parallel on the same chip, exposed to the same flow. Differential operation at constant temperature results in a strongly reduced flow rate dependency of the thermal conductivity measurement.

W2P.005 DOUBLE-ENDED TUNING FORK RESONANT STRAIN SENSOR OPERATED IN ATMOSPHERIC ENVIRONMENT USING A GALVANIC PROTECTION TECHNIQUE **1207**

W. Wei[1,2], F. Yu[1,2], W. You[1,2], D. Liu[1,2], H. Yang[1], and X. Li[1]
[1]*Chinese Academy of Sciences, CHINA and* [2]*Graduate School of Chinese Academy of Sciences, CHINA*

This paper presents a double-ended tuning fork resonant strain sensor that can operate in an atmospheric environment. The design is based on the fact that the driving amplitude at resonance increases with the increase of the gap width in an atmospheric environment. The main cause of feed-through has been revealed, and a symmetrical design is employed to suppress it. The strain sensor presents a sensitivity of 39 Hz/με and a quality factor of 1574 in an atmospheric environment.

W2P.006 HIGH-SENSITIVITY CMUT WITH INTERLAYER METAL ARCHITECTURE FOR MEDICAL ULTRASONIC SYSTEMS **1211**

T.-C. Cheng[1], Y.-T. Liao[2], and T.-H. Tsai[1]
[1]*National Chung Cheng University, TAIWAN and* [2]*National Chiao Tung University, TAIWAN*

This paper presents an integration of the capacitive micromachined ultrasonic transducers (CMUTs) and the trans-impedance amplifier in ultrasound systems. The proposed CMUT and the sensing circuits are both fabricated on the same chip in a 0.18 μm CMOS MEMS technology. Two interlayer metal structures are proposed to improve the sensitivity. The CMUTs are designed with 2.25 MHz cells for medical diagnosis. The conversion efficiency of the CMUTs is improved 4 times.

W2P.007 A SELF-POWERED WIRELESS SENSING NODE FOR EVENT-DRIVEN ALERTING BASED ON A BI-STABLE VIBRATION ENERGY HARVESTER **1215**

Q.C. Tang[1], Q.S. He[1], M.Y. Li[2], C. Dong[2], D.C. Xu[2], and X. Li[1]
[1]*Chinese Academy of Sciences, CHINA and* [2]*Soochow University, CHINA*

This paper reports a fully self-powered wireless node for sensor-network that monitors the kinetic amount of mechanical vibration. The self-powered sensing function is enabled by a newly developed energy-harvester that can generate considerable electric-power only when the monitored amplitude of the vibratory acceleration reaches or exceeds a pre-set threshold. The node wirelessly sends a notification signal only when the concerned amount of motion reaches a certain threshold.

W2P.008 DUAL FOUCAULT PENDULUM GYROSCOPE **1219**

D. Senkal, A. Efimovskaya, and A.M. Shkel
University of California, Irvine, USA

This paper reports a new type of MEMS degenerate mode gyroscope. The Dual Foucault Pendulum (DFP) gyroscope consists of two dynamically equivalent, mechanically coupled proof masses, oscillating in anti-phase motion, creating a dynamically balanced resonator with x-y symmetry in frequency and damping. Dual axis tuning fork behavior provides vibration immunity and anchor loss mitigation. We believe Dual Foucault Pendulum is the minimal realization of a dynamically balanced lumped mass gyroscope.

W2P.009 A MICROMACHINED FLUIDIC REDUCED INERTIAL MEASUREMENT UNIT USING THERMAL EXPANSION FLOW PRINCIPLE **1223**

S.S. Wang, X.H. Gong, B. Nie, W.Z. Yuan, and H.L. Chang
Northwestern Polytechnical University, CHINA

This paper presents a micromachined fluidic integrated reduced inertial measurement unit based on the thermal expansion flow principle. The proposed multi-axis gas sensor can achieve the simultaneous detection of single-axis angular rate and dual-axis acceleration using one chamber. A large measurement range has been demonstrated, e.g., the Z-axis gyroscope can achieve a sensitivity of 0.548 mV/°/s with a nonlinearity less than 3.87% within the input range of ±2160 °/s.

W2P.010 INVESTIGATION OF WAVE PROPAGATION PHENOMENA IN MICROFABRICATED ARRAYS OF NONLINEARLY COUPLED OSCILLATORS 1227

R.E. Carroll[1], N. Garraud[1], J.A. Little[2], M.J. Mazzoleni[2], B.P. Mann[2], and D.P. Arnold[1]
[1]*University of Florida, USA and* [2]*Duke University, USA*

We demonstrate a MEMS platform for the investigation of wave propagation behavior in an array of nonlinearly coupled oscillators. The long-term objective is to experimentally demonstrate behaviors such as reconfiguring bandgaps, energy localization, and chimera states. Improved fundamental understanding and engineering of these phenomena could offer new capabilities for vibration/acoustic control in sensors, filters, shock mitigation, and energy conversion systems.

W2P.011 DEVELOPMENT OF HIGH RESOLUTION AND HIGH SHOCKPROOF MEMS ACCELEROMETER FOR MONITORING OF STRUCTURES 1231

D. Morihara, Y. Tatara, Y. Nakagawa, K. Hosoya, and T. Seki
Omron Corporation, JAPAN

We developed MEMS accelerometer which has high resolution, flat characteristic at low frequency range, and high resistance to shock. Decreasing noise and making mass heavier improve a resolution performance which is 0.05gal. Additionally resistance to shock is 20000G to optimize stopper size. In this paper, we describe the improvement of low frequency noise and flattering frequency characteristic.

W2P.012 CONTACT STIFFNESS CALIBRATION PLATFORM FOR NANOMECHANICAL PROPERTY MEASUREMENTS WITH CONTACT RESONANCE ATOMIC FORCE MICROSCOPY 1235

M.R. Rosenberger[1], S. Chen[1], C.B. Prater[2], and W.P. King[1]
[1]*University of Illinois, Urbana-Champaign, USA and* [2]*Anasys Instruments, USA*

We developed a micromechanical calibration platform and methodology for determining contact stiffness in atomic force microscope (AFM)-based mechanical property measurements. We present a calibration of cantilever contact resonance frequency vs. contact stiffness obtained using our calibration platform. Our experimental calibration of resonance frequency vs. contact stiffness overcomes a major limitation in AFM, which is the reliable determination of tip-sample contact stiffness.

W2P.013 HIGHLY SENSITIVE STRAIN SENSORS USING A SURFACE ACOUSTIC WAVE ON THE ALUMINUM NITRIDE THIN FILM FOR WIRELESS SENSOR NETWORKS 1239

Z. Bao, M. Hara, and H. Kuwano
Tohoku University, JAPAN

We developed SAW based strain sensors using AlN films to obtain high-dense integration with oscillator circuits. An IDT was fabricated on layered structures consisted of AlN, Pt/Ti, and SiO_2. The resonant frequency was linearly changed under 10^{-6} order strain with a sensitivity of 107 MHz/ε. The sensor can be fabricated under the low temperature. It can be embedded to the one-chip oscillator with post-IC-process, and be easily expanded to multisensor modules for wireless sensor networks.

W2P.014 A 2-AXIS GYROSCOPE WITH A SYNCHRONOUSLY-DRIVEN DUAL MASS 1243

T. Akashi, H. Funabashi, Y. Omura, M. Fujiyoshi, Y. Hata, and Y. Nonomura
Toyota Central R&D Labs., Inc., JAPAN

We report a detuned gyroscope with a single sensor element for detecting 2-axis rates. We designed and fabricated a novel structure composed of two synchronously-driven masses and three kinds of supporting beams to limit the movable direction of each mass, resulting in low cross-axis sensitivity. The fabricated gyroscope showed a cross-axis sensitivity of +/-2.7%. The test results demonstrated that the gyroscope detects both yaw and roll rates with low cross-axis sensitivity.

W2P.015 A HIGH RESOLUTION RESONANT MEMS ACCELEROMETER 1247

X. Zou and A.A. Seshia
University of Cambridge, UK

We report a vacuum packaged resonant MEMS accelerometer that demonstrates some of the highest sensitivities reported to-date and a ~7x scale factor enhancement relative to a recently reported prototype. The experimentally measured electronic noise spectral density is less than 150 ng/$\sqrt{\text{Hz}}$ in the frequency range from < 1 Hz up to 50 Hz.

MONDAY - Materials, Fabrication and Packaging Technologies

M3P.018 RAPID 3D-PRINT-AND-SHRINK FABRICATION OF BIODEGRADABLE MICRONEEDLES WITH COMPLEX GEOMETRIES 1251
M. Ochoa, J. Zhou, R. Rahimi, V. Badwaik, D. Thompson, and B. Ziaie
Purdue University, USA

We have developed a simple technique for fabricating polymeric microneedles of complex geometries by coupling 3D printing technology with an isotropic shrinkage technique, which effectively enhances the current resolution limits of 3D printing by at least five fold. The resulting needles are sufficiently sharp to penetrate porcine skin and deliver loaded/embedded chemicals.

M3P.019 SIMULATION OF MICROLOADING AND ARDE IN DRIE 1255
M.A. Gosalvez[1], Y. Zhou[2], Y. Zhang[2], G. Zhang[3], Y. Li[3], and Y. Xing[3]
[1]*University of the Basque Country, SPAIN,* [2]*IntelliSense Corp., CHINA, and* [3]*Southeast University, CHINA*

An atomistic etching model is combined with a continuum concentration solver to realistically simulate Deep Reactive Ion Etching (DRIE), including microloading (or loading effect) and Aspect Ratio Dependent Etching (ARDE or lag effect). The model strongly differs from current simulation approaches where the local etch rate depends markedly on a complex integral over the ion flux with an elaborate visibility function and re-emission. Instead, we focus on the description of the etchant depletion.

M3P.020 A HEAT INDUCED BI-LAYER LIFT-OFF METHOD FOR FLEXIBLE SUBSTRATES 1259
Y. Jia, H. Cai, and Q. Lin
Columbia University, USA

This paper presents a novel rapid lift-off method that uses the reflow (i.e., heat induced photoresist deformation) of bi-layer sacrificial photoresists to allow complete lift-off of thick films. The simplicity and versatility of the method enables lift-off processing of thick thin-films (> 50% thicker than the undercut photoresist layer) to enable the fabrication of low-electric-resistance components in MEMS devices for applications such as power generation and wireless communication.

M3P.021 HIGHLY ALIGNED P(VDF-TrFE) NANOFIBERS WITH ANISOTROPIC PIEZOELECTRICITY FABRICATED BY ELECTROSPINNING FOR PHYSICAL SENSING DEVICES 1263
Y.G. Jiang, X.J. Sun, and D.Y. Zhang
Beihang University, CHINA

This paper reports an electrospinning method for fabrication of highly aligned poly(vinylidene fluoride-trifluoroethylene) copolymer (P(VDF-TrFE)) nanofibers by using micro-patterned parallel electrodes to modify the electric field nearby the collector.The P(VDF-TrFE) fibers demonstrate anisotropic piezoelectricity, which means higher charge output with a strain in the axial direction of the nanofibers than that under a strain in other directions.

M3P.022 DYNAMIC STRUCTURAL TRANSFORMATION OF SELF-ASSEMBLED JANUS HYDROGEL MICROPARTICLES UNDER PERIODICALLY-CHANGED MAGNETIC FIELD 1267
S. Yoshida[1], M. Takinoue[2], and H. Onoe[1]
[1]*Keio University, JAPAN and* [2]*Tokyo Institute of Technology, JAPAN*

This study presents self-assembly of Janus hydrogel microparticles, which enables to transform the assembled structures dynamically. We fabricated Janus hydrogel microparticles encapsulating superparamagnetic materials in one side to respond to magnetic field. We succeeded in dynamic construction of structures using hydrogel microparticles and in acquiring three different self-assembled structures that can transform to other structures dynamically by controlling precessional magnetic field.

M3P.023 LOW STRESS FLIP-CHIP PACKAGE FOR PRESSURE SENSORS OPERATING AT 500 °C 1271
R. Zeiser[1], S. Ayub[1], P. Wagner[1], J. Müller[3], S. Henneck[2], and J. Wilde[1]
[1]*University of Freiburg - IMTEK, GERMANY,* [2]*Robert Bosch GmbH, GERMANY, and* [3]*University of Ilmenau, GERMANY*

This work presents a novel method for a reliable assembly and interconnection of MEMS for very high temperatures. The stress in micromechanical pressure sensors, induced by the packaging process due to material-dependent mismatches, is analyzed with optical ESPI-deformation measurements up to 500 °C. The comparison of the obtained results with finite element analysis (FEA) revealed a strong influence of the applied substrate on the thermal-mechanical stresses in the sensor.

M3P.024 MAGNETICALLY ALIGNED 2D RECTANGULAR MICRO MAGNETS WITH UNIAXIAL IN-PLANE ANISOTROPY FOR HIGH FREQUENCY MAGNETIC DEVICES 1275
K. Koh[1], K.P. O'Brien[2], D.S. Gardner[2], N. Tayebi[2], C. Yang[1], and L. Lin[1]
[1]*University of California, Berkeley, USA and* [2]*Intel Inc., USA*

We developed micromachined thin rectangular magnets fabricated and aligned under an external magnetic field to exhibit uniaxial in-plane anisotropy for microwave frequency applications in wireless communication systems, such as inductors and filters. To achieve uniaxial in-plane anisotropy, ultra-thin rectangular magnets which have 1:5 aspect ratio were lithography-defined and self-aligned under the external magnetic field.

M3P.025 IC-FOUNDRY COMPATIBLE FABRICATION OF LOW-COST AND TINY-SIZED DOG-BONE RESONANT CHEMICAL SENSORS IN NON-SOI SINGLE-WAFER 1279
F. Yu, C.J. Wang, P. Xu, and X. Li
Chinese Academy of Sciences, CHINA

The paper reports a single-side micromachining technology for batch-fabrication of dog-bone resonant gas sensors in single non-SOI wafer. The process has been transferred to the standard IC-foundry company of ASMC, showing advantage in low-cost volume production. The dog-bone structured resonant chemical sensors are designed and fabricated with the novel micro-machining technology, and high sensing performances for ppm-level chemical gas are achieved.

M3P.026 THE WAFER-LEVEL VACUUM SEALING AND ELECTRICAL INTERCONNECTION USING ELECTROPLATED GOLD BUMPS PLANARIZED BY SINGLE-POINT DIAMOND FLY CUTTING 1283
H. Hirano, K. Hikichi, and S. Tanaka
Tohoku University, JAPAN

We have developed the vacuum packaging and integration technology which is applicable to non-planer and temperature-sensitive wafers by means of single-point diamond fly cutting of electroplated Au bumps and Au-Au diffusion bonding. Formation of nano-crystal with many lattice defects beneath the planarized Au bump surface caused by stress of fly cutting enhances yield of vacuum-sealing and bonding shear strength.

M3P.027 RAPID PROTOTYPING OF PIEZORESISTIVE MEMS SENSORS VIA A SINGLE-STEP LASER CARBONIZATION AND MICROMACHINING PROCESS 1287
Z.B. Hughes, R. Rahimi, M. Ochoa, and B. Ziaie
Purdue University, USA

This paper reports on a rapid and low cost single step fabrication method for MEMS piezoresistive force sensors using laser carbonization and micromachining. The technique uses a CO2 laser to pyrolyze a polyimide film and create piezoresistive nano/micro porous carbon patterns followed by a mechanical shape definition step using the same setup. Double-clamped cantilever force sensors show a sensitivity of 1.06 Ω/g with a range of 0-110g.

TUESDAY - Materials, Fabrication and Packaging Technologies

T4P.018 ALUMINIUM NITRIDE MEMBRANES WITH EMBEDDED BURIED IDT ELECTRODES FOR NOVEL FLEXURAL PLATE WAVE DEVICES 1291
M. Reusch[1], P. Katus[1], K. Holc[2], W. Pletschen[2], L. Kirste[2], V. Zürbig[1], D. Iankov[1], L. Reindl[1], O. Ambacher[2], and V. Lebedev[2]
[1]*University of Freiburg, GERMANY and* [2]*Fraunhofer Institute, GERMANY*

We fabricate and evaluate reactively sputtered piezoelectric AlN membranes designed for novel flexural plate wave (FPW) electroacoustic sensors equipped with buried interdigital transducers (IDT) for sensing in liquids. Bimorph AlN membranes containing buried IDT electrodes were fabricated. Electro-acoustical properties of resonators and delay lines were assessed by laser vibrometry and S-parameter analyses. Structural properties were investigated by confocal Raman spectroscopy and XRD.

T4P.019 DEVELOPMENT OF A SAPPHIRE OPTICAL WALL SHEAR STRESS SENSOR FOR HIGH-TEMPERATURE APPLICATIONS 1295
D. Mills[1], D. Blood[1,2], and M. Sheplak[1]
[1]*University of Florida, USA and* [2]*Valparaiso University, USA*

This paper presents the development of the first sapphire micromachined wall shear stress sensor for high-temperature applications utilizing geometric moiré optical transduction. Ultra-short pulse laser micromachining processes are developed for patterning of mechanical structures in sapphire, and a four-channel alumina fiber array with sapphire optical fibers is used to interrogate the moiré fringe. Platinum gratings and a high-temperature package enable a theoretical operating limit of 800°C.

T4P.020 RAPID FABRICATION OF 3D ELASTOMERIC STRUCTURES VIA LASER-MACHINING AND VACUUM DEFORMATION 1299
L. Ben-Yehoshua, M. Ochoa, and B. Ziaie
Purdue University, USA

This paper reports on a fabrication technique for creating three-dimensional soft elastomeric structures via a vacuum-assisted auto-shaping process. The structures are fabricated by a planar layer-by-layer fashion using laser machining to define channels and chambers in selected layers. Upon placing in a vacuum, the evacuation of the chambers deforms the structure into a pre-determined 3D shape, which is then locked in place by subsequent deposition of Parylene-C.

T4P.021 MASKLESS METHOD TO SELECTIVELY ETCH PARYLENE-C FROM HIGH ASPECT RATIO NEURAL DEVICES 1303
M. Leber[1], M.M.H. Shandhi[1], R. Bhandari[2], and S. Negi[1]
[1]*University of Utah, USA and* [2]*Blackrock Microsystems, USA*

This paper presents a maskless method of selectively desinsulating the tips of the Utah Electrode Array (UEA) by using the unique architecture of the UEA (aspect ratio 15:1) in its favor and biasing its back-plane to the DC bias voltage resulting from the reactive ion etching (RIE) process. The Parylene is etched in oxygen plasma. During the RIE the electric field distribution concentrates around the tip of the electrode, leading to higher concentration of the oxygen plasma at the tip.

T4P.022 STUDY OF PARYLENE PENERTRATION INTO MICROCHANNEL.....1307
W. Wang, D.Y. Kang, and Y.C. Tai
California Institute of Technology, USA

This study reports the penetration of various Parylenes inside long PDMS microchannels. This work broadly covers the effects of the dimer type, loaded dimer mass, substrate temperature and channel size on the penetration length, i.e., the length that Parylene can be deposited into the microchannel from the inlet.

T4P.023 MICROMACHINED HIGH-*Q* FUSED SILICA BELL RESONATOR WITH COMPLEX PROFILE CURVATURE REALIZED USING 3D MICRO BLOWTORCH MOLDING 1311
T. Nagourney, J. Cho, A. Darvishian, B. Shiari, and K. Najafi
University of Michigan, USA

We demonstrate controlled fabrication of axisymmetric 3D fused silica micro shell resonators with complex sidewall profiles, including a bell-shaped sidewall. The shell profile and geometry can be customized by the shape of the mold and applied through the micro blowtorch reflow molding process. Shell profile plays a key role in performance of a micro gyroscope by determining the frequencies of the wineglass and parasitic modes and potentially reducing anchor loss.

T4P.024 ACCELERATED LIFETIME AND RELIABILITY TESTING OF LARGE-DEFLECTION PIEZOELECTRIC MICROSYSTEMS 1315
R.Q. Rudy[1], L.M. Sanchez[1], M. Tellers[2], and R.G. Polcawich[1]
[1]*US Army Research Laboratory, USA and* [2]*University of Maryland, USA*

We report accelerated lifetime testing and reliability of large displacement piezoelectric micro-electromechanical systems over trillions of cycles. Electrical, mechanical, and piezoelectric properties of cantilevers have been monitored over time and the surface topology has been observed through scanning electron microscopy.

T4P.025 DESIGN AND FABRICATION OF A SANDWICH FRAMED FOCAL PLANE ARRAY FOR UNCOOLED INFRARED IMAGING.....1318
R. Zhao[1], W. Ma[1], S. Wang[1], X. Yu[1], Y. Feng[2], and Y. Zhao[2]
[1]*Peking University, CHINA and* [2]*Beijing Institute of Technology, CHINA*

We report a novel design and fabrication processes for an IR FPA by using SiNx/SiO2/SiNx sandwich structure as the frame of bimaterial cantilever pixels. To reduce the fracture and bending of the focal plane, the FPA pixels were arranged in staggered arrangement. The device was fabricated with a bulk silicon process, where a trench backfill technique was employed to form the sandwich frame. The fill factor, reliability and uniformity of FPA were improved by the fabrication process optimization.

T4P.026 COMPACT MULTIFUNCTIONAL TEST STRUCTURE TO MEASURE THE IN-PLANE THERMOELECTRIC FIGURE OF MERIT ZT OF THIN FILMS 1322
D. Moser, D. Mueller, and O. Paul
University of Freiburg, *GERMANY*

We report a novel compact, multifunctional test structure to measure the in-plane thermoelectric figure of merit ZT of thin films. All material parameters contributing to ZT are determined on a single sample with dimensions of about 500 µm × 500 µm. These are the Seebeck coefficient, the thermal conductivity, and the electrical resistivity. The method can be applied to thin-films deposited at high temperature, such as poly-Si, and at low temperature, such as metal layers.

T4P.027 **A UNIFIED EPI-SEAL PROCESS FOR RESONATORS AND INERTIAL SENSORS** **1326**
Y. Yang, E.J. Ng, Y. Chen, I.B. Flader, C.H. Ahn, V.A. Hong, and T.W. Kenny
Stanford University, USA

We present a thin-film wafer-level encapsulation process which incorporates both narrow (0.7µm) and wide (50µm) lateral transduction gaps, in-plane and out-of-plane electrodes, and does not require release etch-holes is presented. High stability, high quality factor resonant devices as well as inertial sensors are fabricated in the process.

WEDNESDAY - Materials, Fabrication and Packaging Technologies

W2P.016 **LARGE DISPLACEMENT NANOPOSITIONING FLEXURE FABRICATED BY DIRECT 3D PRINTING OF TITANIUM** **1330**
H.S. Fiaz and K. Hoshino
University of Connecticut, USA

A XY nanopositioning flexure made up of titanium alloy fabricated through a 3D printing, namely Electron Beam Additive Manufacturing (EBAM), is reported. Titanium alloy excels in mechanical dynamic properties and EBAM allows for the formation of a complex framed structure reducing the mass of the system. Integrated with piezoelectric actuators, the flexure demonstrated a high frequency (1.8 kHz) and a large displacement (50µm). The system has been implemented as an optical laser scanner.

W2P.017 **INVESTIGATING THIN FILM PASSIVATIONS FOR IGZO DUAL GATE PH SENSORS FABRICATED AT LOW TEMPERATURE** **1334**
S. Pavlidis[1], P. Getz[1], J. Hagen[2], N. Kelley-Loughnane[2], B. Bayraktaroglu[2], and O. Brand[1]
[1]*Georgia Institute of Technology, USA and* [2]*Air Force Research Laboratory, USA*

Dual-gate IGZO TFTs fabricated using high-k dielectrics deposited via ALD at low temperature (<180 °C) are proposed for chemical and biosensor applications, leading to an investigation of suitable passivation films for such devices. Tested as pH sensors, sensitivities of 76 mV/pH - beyond the Nernst limit - have been demonstrated.

W2P.018 **LARGE FIGURE-OF-MERIT EPITAXIAL $Pb(Mn,Nb)O_3$-$Pb(Zr,Ti)O_3$/Si TRANSDUCER FOR PIEZOELECTRIC MEMS SENSORS** **1338**
H. Hanzawa[1], S. Yoshida[1], K. Wasa[2], and S. Tanaka[1]
[1]*Tohoku University, JAPAN and* [2]*Yokohama City University, JAPAN*

We fabricated an epitaxial $Pb(Mn,Nb)O_3$-$Pb(Zr,Ti)O_3$ film on a Si substrate as a large figure-of-merit (FOM) piezoelectric transducer film. This film had both a large piezoelectric coefficient and a small dielectric constant due to the predominant c-axis orientation and excellent crystallinity. Thus, a FOM for piezoelectric MEMS gyroscope reached 100 GPa, which is 5 times larger than those of conventional PZT films. This film has a great potential to provide an ultrahigh performance gyroscope.

W2P.019 **PROCESS PLATFORM FOR HIGH ASPECT-RATIO SELF-ALIGNED VERTICAL COMB ACTUATORS** **1342**
H.T. Su[1], G.L. Luo[1], J. Hsieh[1], Y.C. Fu[2], and W. Fang[3]
[1]*Asia Pacific Microsystems, Inc., TAIWAN,* [2]*Ultimems, Inc., TAIWAN, and* [3]*National Tsing Hua University, TAIWAN*

This paper reports a novel process to fabricate self-aligned Vertical comb-drive actuator with aspect-ratio up to 40. With this process platform, some process limitations can be lifted, while a Vertical comb-drive actuator with non-resonant scan angle larger than 20° can be obtained. A 2D optical scanner with large scan angle is taken as an example to demonstrate this platform.

W2P.020 **RECOVERABLE/STRETCHABLE POLYMER SPRING WITH EMBEDDED CNTS ELECTRICAL ROUTING FOR LARGE-AREA ELECTRONIC APPLICATIONS** **1346**
W.L. Sung[1], C.L. Cheng[1], C. Hong[2], and W. Fang[1]
[1]*National Tsing Hua University, TAIWAN and* [2]*National Synchrotron Radiation Research Center, TAIWAN*

This study presents a large-area chip-network using polymer stretchable spring with embedded carbon nanotubes (CNTs). Merits of this approach: (1) polymer stretchable spring with large fracture strain acts as mechanical connection; (2) the polymer spring has better recoverability after stretching; (3) vertically-aligned CNTs are exploited as electrical routing and promising sensing material for different stress state; (4) the chip-network with flexibility can apply to curved surfaces.

W2P.021 **A LOW-COST FABRICATION TECHNIQUE FOR DIRECT SEWING STRETCHABLE INTERCONNETIONS FOR WEARABLE ELECTRONICS** **1350**

R. Rahimi, W. Yu, S. Parupudi, M. Ochoa, and B. Ziaie
Purdue University, USA

Here we present a facile method for rapid fabrication of low-cost electrical interconnections for wearable electronics. Using a commercial sewing machine, thin metallic wires are sewn onto the wearable materials in a double-stitch zigzag pattern, with the second stitch being a water-soluble thread. As a proof of concept implementation, we sewed interconnects and a soft capacitive force sensor onto a latex glove to create a wearable tactile sensor with a linear sensitivity of 96fF/N.

W2P.022 **MICRO WELDING OF ALUMINUM FOR POST PROCESS ELECTRODE GAP REDUCTION USING FEMTOSECOND LASER** **1354**

C.R. Meinecke[1], M. Müller[2], M. Rennau[1], A. Bertz[1], R. Ebert[2], D. Reuter[1], H. Exner[2], and T. Geßner[1]
[1]*Technische Universität Chemnitz, GERMANY and* [2]*Laserinstitut Hochschule Mittweida, GERMANY*

We develop a new technology to reduce the micro-dimensional trench width below the technological limitations of the Deep Reactive Ion Etching process. The high-accuracy femto-second laser-micro-welding of aluminum was used for the first time by MEMS fabrication to realize this permanent gap reduction. We realized an electrode gap reduction of a high precision vibration sensors, resulting in a fourfold improvement of the sensitivity without changing the size of the sensor chip itself.

W2P.023 **CNC-LITHOGRAPHY: COMPUTER-CONTROLLED MULTIDIRECTIONAL LIGHT-MOTION-SYNCHRONIZED LITHOGRAPHY FOR 3-D MICROFABRICATION** **1358**

J.K. Kim[1], Y.K. Yoon[2], T.C. Mier[1], and M.G. Allen[1]
[1]*University of Pennsylvania, USA and* [2]*University of Florida, USA*

We report computer-controlled (CNC) multidirectional UV-LED lithography for 3-D microfabrication. This system combines an inclined rotational and translational sample holder with illumination synchronization of light source to sample position, achieving the rapid formation of fine features with no layering artifacts, at the expense of the completely arbitrary shape fabrication capability of stereolithography. New 3-D lithographic structures such as a micro-'thumb's-up' are demonstrated.

W2P.024 **FABRICATION OF MICROTIP ELECTRODE ARRAY INTEGRATED WITH SELF-ALIGNED REFERENCE ELECTRODE** **1362**

B.R. Maeng, S.K. Lee, S.J. Bai, and J.H. Park
Dankook University, SOUTH KOREA

This paper presents a novel microtip-based electrode array with the reference electrode around tips. The conductive microtip with high aspect ratio, small apex radius and the height of tens of micron scale is insulated except the tip ends. The tips are closely surrounded by the self-aligned reference electrode. The whole process was completed with a single photography mask. The fabricated microtip-based electrode array was successfully verified with the cyclic voltammetry measurements.

W2P.025 **"CRACK-PHOTOLITHOGRAPHY" FOR HIGH-THROUGHPUT NANOPATTERNING AND NANOFLUIDIC APPLICATIONS** **1366**

M. Kim, D. Ha, and T. Kim
Ulsan National Institute of Science & Technology (UNIST), SOUTH KOREA

We present an innovative cracking-assisted nanofabrication technique that relies only on a standard photolithography process. This novel technique produces arbitrary-shaped nanopatterns with well-controlled, various geometric dimensions in a large-area and high-throughput manner. In addition, we show that mixed-scale patterns fabricated using the technique can be used as a master mold for replicating numerous nanofluidic devices via soft lithography.

W2P.026 ***IN VITRO* DEGRADATION OF BIODEGRADABLE METAL ZN AND ZN/FE-COUPLES AND THEIR APPLICATION AS CONDUCTORS IN BIODEGRADABLE SENSORS** **1370**

M. Luo[1], W. Shen[2], Y. Wang[1], and M.G. Allen[2]
[1]*Georgia Institute of Technology, USA and* [2]*University of Pennsylvania, USA*

We report an in vitro degradation study of biodegradable metal Zn and Zn/Fe couples, and explore their application as conductors in completely biodegradable sensors. By electrically connecting a micromachined Zn conductor to small, discontinuous, more electrochemically active Fe regions, the degradation rate of the entire metal conductor can be accelerated in a controllable manner by galvanic corrosion. This approach may expand the number of candidate metals for biodegradable conductors.

MONDAY - Nanoscale Materials, Devices and Fabrication

M3P.028 **CONSTRUCTION OF GRAPHENE-BASED ENZYME SYSTEM FOR RAPID PHOTO-ASSISTED PROTEOLYSIS.....1374**
G. Cheng, S.J. Hao, and S.Y. Zheng
Pennsylvania State University, USA

A novel porous graphene-silica composite material was prepared. After further immobilization of enzyme in the nanopores, a photo-assisted digestion system was constructed. It realized rapid proteolysis in 1 minute under near-infrared radiation, which is ~103 faster than the widely used overnight in-solution digestion. It's expected that this work would contribute to the rapid and high throughput protein digestion in proteomics.

M3P.029 **THREE DIMENSIONAL MONOLAYER GRAPHENE FOAM FOR ULTRA-SENSITIVE PH SENSING.....1378**
S.K. Ameri, P.K. Singh, and S.R. Sonkusale
Tufts University, USA

In this work, we present a liquid gated three-dimensional graphene transistor for pH sensing. The active layer of this transistor is made of mono to double layer graphene foam, which is liquid-gated for pH-dependent field effect conduction. Three-dimensional configuration provides high surface area and higher electrostatic gate control of graphene channel, which results in superior sensitivity to the local pH environment.

M3P.030 **IMPEDANCE SPECTROSCOPIC ANALYSIS OF FUNCTIONALIZED GRAPHENE/SILICON SCHOTTKY DIODE SENSOR 1381**
M.A. Uddin[1], A.K. Singh[1], K.M. Daniels[2], M.V.S. Chandrashekhar[1], and G. Koley[1,3]
[1]*University of South Carolina, USA,* [2]*Naval Research Laboratory, USA, and* [3]*Clemson University, USA*

The sensor response of Functionalized Graphene/p-Si Schottky Diode has been analyzed by DC amperometric measurement and AC impedance spectroscopy (IS) for the first time. With Pt nano-particle functionalization, the sensor performance enhanced by 4 times for NH3. To understand the diode sensing mechanism, the AC IS response was analyzed using an equivalent circuit model, and the extracted equivalent parameters at different conditions has been evaluated.

M3P.031 **SPECIFIC HEAT CAPACITY OF ULTRA-THIN ATOMIC LAYER DEPOSITION NANOBRIDGES FOR MICROBOLOMETERS 1385**
N.T. Eigenfeld[1], J.M. Gray[1], J.C. Gertsch[1], G.D. Skidmore[2], S.M. George[1], and V.M. Bright[1]
[1]*University of Colorado, Boulder, USA and* [2]*DRS Technologies, USA*

This paper reports on the first ever specific heat capacity (SHC) measurements of ultra-thin atomic layer deposition (ALD) W/Al2O3 nanobridges. The thermal time constants of suspended ALD nanobridges were measured and a new model was derived to fit the data and extract the SHC. The accuracy of the model and the application of these ultra-thin materials for microbolometers are discussed.

M3P.032 **SELECTIVE ASSEMBLY OF DNA NANOSTRUCTURE BRIDGING ONTO A TRENCHED SILICON SUBSTRATE.....1389**
Y. Mori, Z. Ma, S. Park, Y. Hirai, T. Tsuchiya, and O. Tabata
Kyoto University, JAPAN

We demonstrated for the first time the versatility of the previously proposed concept of DNA nanostructure integration on MEMS by selectively assembling DNA nanostructures to form a bridge over a trenched silicon. A DNA origami (30 × 150 nm) was fixed to bridge the trench (100 nm width) using the hybridization between ssDNA on the DNA origami and immobilized ssDNA-pattern at the edges of trench. An ODS-SAM was utilized as a masking layer for a SPL with better process stability than a TMS-SAM.

M3P.033 **HEXAGONAL BORON NITRIDE (H-BN) NANOMECHANICAL RESONATORS WITH TEMPERATURE-DEPENDENT MULTIMODE OPERATIONS.....1393**
X.Q. Zheng, J. Lee, and P.X.-L. Feng
Case Western Reserve University, USA

We report on the first experimental demonstration of hexagonal boron nitride (h-BN) nanomechanical resonators operating in wide environmental temperature range from -4°C to 141°C, with spatially-resolved mapping of multiple mode shapes and their temperature dependence. We fabricate h-BN resonators as thin as 10nm, using a facile, wet-chemistry-free, dry-transfer technique. We observe distinct multimode resonances and study their interesting temperature coefficients of frequencies (TCfs).

TUESDAY - Nanoscale Materials, Devices and Fabrication

T4P.028 **FABRICATION OF NANOWIRES FROM POLYIMIDE FOR TRANSPARENT SERS DEVICES** 1397

L.C. Tang[1,2], H.Y. Mao[1], Y. Wang[1], W. Ou[1], W.G. Wu[3], Q.L. Tan[2], and J.J. Xiong[2]
[1]*Chinese Academy of Sciences, CHINA,* [2]*North University of China, CHINA, and* [3]*Peking University, CHINA*

Free-standing nanowires with high transparency are fabricated from Polyimide (PI), adopting a lithography-free and micromachining-compatible process. By sputtering a thin layer of noble metal on the nanowires, surface-enhanced Raman scattering (SERS) devices with high enhancement capabilities can be obtained. Also, nanowires are able to be generated on glass, which allow penetration of laser from the back side, thus transparent SERS devices are achieved.

T4P.029 **FABRICATION OF VERTICALLY ALIGNED SILICON NANOTUBES USING NANOSPHERE BEADS AS THE MASK AND BOSCH PROCESS** 1401

Y. He, X.C. Che, and L. Que
Iowa State University, USA

Silicon nanotubes have been fabricated by a series of standard microfabrication processes, specifically by an ambient temperature Bosch process using the nanosphere beads as the mask. The dimensions of the Si nanotubes can be tuned, with a diameter from 10s of nanometers to 100s of nanometers with a high aspect ratio. The as-fabricated Si nanotube surfaces assume super hydrophobicity and have an excellent optical trapping capability, suggesting their potential applications in the fields.

T4P.030 **A GRAPHENE-BASED AFFINITY GLUCOSE NANOSENSOR** 1405

Y. Zhu[1], J. Yan[2], C. Wang[1,3], X. Wang[1,4], K. Xu[5], D. Li[5], Q. Wang[2], and Q. Lin[1]
[1]*Columbia University, USA,* [2]*University of South Carolina, USA,* [3]*Tsinghua University, CHINA*
[4]*Xi'an Jiaotong University, CHINA, and* [5]*Tianjin University, CHINA*

This paper presents a synthetic graphene affinity nanosensor for glucose measurements. The nanosensor exploits affinity binding of a novel, surface-immobilized synthetic polymer with glucose to induce changes in the bulk properties of graphene for sensitive glucose detection without the use of physical barriers commonly employed by existing sensors.

T4P.031 **CUBIC PLATINUM-TUNGSTEN ALLOY NANOCRYSTALS IN-SITU GROWN ON MOLYBDENUM DISULFIDE NANOSHEETS FOR HIGH SPECIFIC AND ULTRA SENSITIVE DETECTION OF HYDROGEN PEROXIDE** 1409

Z.F. Chen[1], Y. Zhang[1,2], J.Q. Xu[1], P.C. Xu[2], and X.X. Li[2]
[1]*Shanghai University, CHINA and* [2]*Chinese Academy of Sciences, CHINA*

This work reports a novel nanocomposites material, PtW nanocrystals modified MoS2 nanosheets. The incorporation of two different nanomaterials in conjunction with each other to form novel composites improves the selective interaction of hydrogen peroxide with sensing material surface, achieviachieving efficient transport of reactant species, and further increases the sensitivity and selectivity of electrochemical sensor.

T4P.032 **MULTI TIPS ATOMIC FORCE MICROSCOPY FOR DYNAMIC NANOMOVEMENT DETECTION** 1413

Y.K. Chiou[1], J.M. Chang[2], Y.C. Chen[1], F.G. Tseng[1], and P.C. Wang[1]
[1]*National Tsing Hua University, TAIWAN and* [2]*Institute of Nuclear Energy Research, TAIWAN*

We nano-engineered commercial atomic force microscope (AFM) probes with multi nano-tip structures for high speed/resolution dynamic nanodetection. The tip radius could be shrunk down to 2.5 nm, and the time resolution could be less than 10 ms for measuring particle movement. The multi-tip AFM can be applicable for detecting the dynamic movement of bio-molecules in situ.

T4P.033 **INKJET-PRINTING-BASED STRUCTURAL COLORING FOR ANTI-COUNTERFEIT APPLICATIONS** 1417

H. Nam[1], K. Song[2], D. Ha[1], and T. Kim[1]
[1]*Ulsan National Institute of Science & Technology (UNIST), SOUTH KOREA and*
[2]*Korea Institute of Machinery & Materials (KIMM), SOUTH KOREA*

We show a novel anti-counterfeiting technique using mono-layered self-assembled photonic crystals (SAPCs) These patterned photonic crystal layers not only provide stealth ability to avoid pattern detection from counterfeiters but also generate multiple colorful holograms under strong illumination on different viewing angles for complex cryptography.

POSTER/ORAL PRESENTATIONS

WEDNESDAY - Nanoscale Materials, Devices and Fabrication

W2P.027 **SULFUR-DOPING IN GRAPHENE AND ITS HIGH SELECTIVITY GAS SENSING IN NO_2** **1421**

C. Liang[1,2], Y.L. Wang[1], and T. Li[1]
[1]*Chinese Academy of Sciences, CHINA and* [2]*University of Chinese Academy of Sciences, CHINA*

In this paper, a simple but efficient strategy was demonstrated to dope S in graphene by introducing hydrogen sulfide gas flow as sulfur source at 1000°C. It is confirmed by transmission electron microscopy (TEM) and Raman spectrum that S atoms were doped successfully by surface adsorption forming honeycomb carbon–sulfur compound crystal domains. Gas sensing test indicated that S-doped graphene showed high selectivity gas sensing to NO2 compared with NH3, CH4, SO2 and CO.

W2P.028 **MODIFICATION OF ADHESION FORCES IN MULTIPLE LAYERS OF TRANSITION METAL DICHALCOGENIDES USING ILLUMINATION FOR MICRO-ACTUATORS** **1425**

N.I. Mou and M. Tabib-Azar
University of Utah, USA

Surface adhesion forces in few layers of layered transition metal dichalcogenides (ReS2, NbS2, n-type WSe2, MoS2, p-type MoSe2, TaS2) hexagonal BN (hBN) and graphene were determined using atomic force microscope in dark and under illumination to identify suitable materials for opto-mechanical actuators. In all cases the surface adhesion forces increased under illumination and varied from 8.4% to 165% depending on the energy bandgap of the material being largest for highest energy gap material.

W2P.029 **1.27 GHZ GRAPHENE-ALUMINUM NITRIDE NANO PLATE RESONANT INFRARED DETECTOR** **1429**

Z. Qian, Y. Hui, F. Liu, S. Kai, and M. Rinaldi
Northeastern University, USA

This paper reports on the first demonstration of a Graphene-Aluminum Nitride nano-plate resonant Infrared sensor. For the first time we demonstrate that by using a virtually massless and high electrical conductivity graphene electrode, floating at the van der Waals separation of a few angstroms from a piezoelectric nano-plate, it is possible to implement ultra-thin piezoelectric nanomechanical resonant structures operating in the GHz range with largely improved f*Q and IR detection capabilities.

W2P.030 **INORGANIC MATERIAL-BASED FLEXIBLE CMOS CIRCUIT AND OPTICAL SENSOR** **1433**

W. Honda, T. Arie, S. Akita, and K. Takei
Osaka Prefecture University, JAPAN

We demonstrate a mechanically flexible complementary metal-oxide-semiconductor inverter and optical sensor are developed by integrating p-type carbon nanotubes (CNTs) network thin-film transistors (TFTs) and n-type InGaZnO TFTs with relatively high field-effect mobility and an optical sensor using CNT and InGaZnO on a polyimide substrate. Furthermore, we experimentally confirmed that these devices are mechanically stable by comparing electrical properties under flat and bending states.

W2P.031 **INFLUENCE OF Au/Ag NANOSTARS AND CdTe QUANTUM DOTS ON PHOTON MANIPULATION** **1436**

A. Ayon[1], U. Tronco-Jurado[2], R. López-Delgado[3], M. Sharma[1], E. Saucedo-Flores[2], and E. Alvarez-Ramos[3]
[1]*University of Texas, San Antonio, USA,* [2]*Universidad de Guadalajara, MEXICO, and* [3]*Universidad de Sonora, MEXICO*

We report a newly developed synthesis-method and the extensive characterization of highly monodisperse, stable, multipode Au/Ag bimetallic-nanostars using an inorganic additive as a ligand. This new method evolves the nano-alloys in one solution rather than the utilization of parallel solutions employed in the state-of-the-art. Additionally, we discuss the synergistic effects of nanostars when employed in conjunction with CdTe quantum-dots that have enabled demonstrating photovoltaic efficiencies greater than 15% when applied to substrates with a thickness ≤200µm, a result that has not been reported to date.

MONDAY - Chemical Sensors and Microsystems

M3P.034 **NEMS GAS SENSORS FOR BREAKTHROUGH GC MULTIGAS ANALYSIS SYSTEMS** **1440**

E. Ollier[1,2], R. Barattin[3], C. Ladner[1,2], M. Petitjean[3], A. Bellemin-Compte[1,2], V. Goutenoire[3], K. Benedetto[1,2], A. Salette[3], N. David[1,2], V. Jousseaume[1,2], P. Puget[3], L. Duraffourg[1,2], and E. Colinet[3]
[1]*CEA-LETI, FRANCE,* [2]*University Grenoble Alpes, FRANCE, and* [3]*APIX Analytics, FRANCE*

This paper reports a NEMS gravimetric gas sensor functionalized and packaged collectively at the wafer level and its implementation in a breakthrough GC multigas analyzer system. The performances reported demonstrate the capability of the system to analyze complex gas mixtures for Industrial applications (alkanes mixture) or Indoor Air Quality monitoring (BTEX mixture), with real-time measurements, portable system and Limit Of Detection (LOD) in the ppm-ppb range.

M3P.035 RAPID CIGARETTE DETECTION BY USING SURFACE ACOUSTIC WAVE GAS SENSOR WITH NON-POLYMER SENSING FILM 1444
C.Y. Cheng, H.C. Hao, S.S. Huang, C.M. Yang, K.T. Tang, and D.J. Yao
National Tsing Hua University, TAIWAN

A surface acoustic wave (SAW) gas sensor is coated with modified hollow meso-porous carbon nano-sphere to replace generally used polymer as new type sensing material, used to detect the secondhand smoke marker, 3-ethenylpyridine. This non-polymer sensing layer is more sensitive than poly-acrylic acid due to the much more carboxyl group bonded by treating with HNO3 and the large surface area caused by porous structure is leading to rapid detection at low flow rate. Finally, the SAW sensor success

M3P.036 MULTI-VARIABLE MICRO OPTO-FLUIDIC RING RESONATOR SENSING WITH PLASMONIC NANOPARTICLE FILMS 1448
C. Zhang, L.K. Wright, K.W. Scholten, X. Fan, and E.T. Zellers
University of Michigan, USA

Localized surface plasmon resonance (LSPR) in films of monolayer-protected gold nanoparticles (MPN) probed at three visible wavelengths, has been exploited to discriminate among 6 vapors with a single sensing film. Arrays of just two MPN films were also remarkably selective even with just a single wavelength response from each film. Initial results obtained from the first-ever MPN-coated microfabricated optofluidic ring resonator sensor used as a µGC detector are also promising.

M3P.037 COLORIMETRIC MATERIALS FOR GAS SELCTIVE SENSING IN LOW-POWER APPLICATIONS 1452
C. Pannek[1], K. Schmitt[1], and J. Wöllenstein[2]
[1]*Fraunhofer Institute for Physical Measurement Techniques, GERMANY and* [2]*University of Freiburg - IMTEK, GERMANY*

One approach to realize selective chemical sensors is the integration of colorimetric materials as gas sensitive substances. Color changes, due to the reaction with the target gas, can be detected optically. These kinds of sensors offer various advantages, such as fast response times and the use of simple instrumentation. Being selective, reliable and energy-saving, the integration into different low-power applications such as fire detectors, RFID-labels or energy autarkic systems and sensor net

M3P.038 DEVELOPMENT OF NEW MICRO GAS PRECONCENTRATOR USING NOVEL ELECTROLESS GOLD PLATING PROCES 1456
C.-Y. Kuo[1], P.-S. Chen[1], K.-J. Chiu[1], C.-J. Lu[2], and W.-C. Tian[1,3]
[1]*National Taiwan University, TAIWAN,* [2]*National Taiwan Normal University, TAIWAN, and* [3]*Delta Research Center, SINGAPORE*

This article presents a novel electroless gold plating method to fabricate a thin film heater for a new micro preconcentrator utilized in a micro gas chromatograph. The thin gold heating film with a high porosity is fabricated within the surface of the µPCT channel. The µPCT can be heated to >300°C repeatedly with a rapid heating rate of 75 °C/sec. Four volatile organic compounds are successfully concentrated, and separated through a commercial GC.

M3P.039 A MICROCALORIMETER WITH A CARBON NANOTUBE FOREST AS A PRECONCENTRATOR FOR TRACE CHEMICAL DETECTION 1460
B. Xu and Z. Wang
Tsinghua University, CHINA

We develop a microcalorimeter with an in-situ synthesized carbon nanotube (CNT) forest for detection of trace energetic chemical vapors (ECV). The CNT forest and the preconcentrator provide high-efficiency preconcentration for target chemicals, and their preconcentration factors (PF) are 2.5 and 10, respectively. We have achieved a low limit of detection (LOD) and a short detection time for ECV with concentrations far below the capability of conventional microcalorimeters.

M3P.040 SHARK-INSPIRED MEMS CHEMICAL SENSOR WITH EPITHELIUM-LIKE MICROPILLAR ELECTRODE ARRAY FOR LEAD DETECTION 1464
N. Wang[1], E. Kanhere[1], M.S. Triantafyllou[2], and J.M. Miao[1]
[1]*Nanyang Technological University, SINGAPORE and* [2]*Massachusetts Institute of Technology, USA*

We design, fabricate and characterize a miniaturized MEMS chemical sensor with micropillar electrode array, which mimics the biological function of shark's olfactory sensor. Electrochemical experiments with our biomimetic chemical sensor show excellent redox repeatability and accuracy under wide range of scan rates. Measurement of Pb yields undistorted, well-defined stripping peaks with good linearity. Limit of detection (LOD) down to 0.8 ppb is obtained.

TUESDAY - Chemical Sensors and Microsystems

T4P.034 **A FULLY INTEGRATED ON-CHIP ELECTROCHEMICAL MICROREACTOR FOR THE DETECTION OF TOTAL PHOSPHORUS IN FRESHWATER** **1468**

F.F. Wang[1,2], J.H. Tong[1], C. Bian[1], Y. Li[1], J.Z. Sun[1], and S.H. Xia[1]
[1]*Chinese Academy of Sciences, CHINA and* [2]*University of Chinese Academy of Sciences, CHINA*

A fully integrated on-chip electrochemical microreactor fabricated by MEMS technique is reported for the detection of total phosphorus (TP) in freshwater. Both a ultra-violet (UV) photocatalytic digestion unit and an electrochemical three-electrode unit are integrated on a chip to realize the microreactor. Since no additional oxidizing reagent is needed, a fully compatible electrochemical detection of TP can be achieved.

T4P.035 **NON-CONTACT SENSOR FOR MEASUREMENT OF LIQUID CONCENTRATION BASED ON QUARTZ OSCILLATOR** **1472**

T. Susa, T. Watanabe, M. Sohgawa, and T. Abe
Niigata University, JAPAN

In this paper, the non-contact sensor for measurement of liquid concentration based on quartz oscillator is reported. The non-contact sensing can be realized by using a leaked electric field of a planer sensing capacitor for sensing liquid on a spacer. This sensor measures capacitance changes of the sensing capacitor (SC) as frequency changes of the quartz oscillator. This sensor can be used with general IC and electronic component, which takes low cost.

T4P.036 **POROUS SILICON BASED INFRARED PHOTONIC-SENSOR FOR HIGH SENSITIVE HEAVY METAL ION DETECTION** **1476**

J.-R. Lai[1], J.-K. Wu[1], M.-H. Nguyen[2], and F.-G. Tseng[1,3]
[1]*National Tsing Hua University, TAIWAN,* [2]*Center for Microelectronics and Informatics Technology, VIETNAM, and* [3]*Academia Sinica, TAIWAN*

In this paper we report the development of ultra-sensitive photonic sensor based on nanoporous silicon (NPS) substrate for heavy metal ions detection in a FTIR reflection system. A one-demensional photonic crystal with disturbed Bragg reflector (DBR) fabricated by successive electrochemical etchings (ECE) is able to enhance the reflected IR signals.

T4P.037 **HIGHLY SELECTIVE ELECTROCHEMICAL APPROACH FOR DETECTION OF DA, AA AND 5-HT USING MATERIAL DIVERSITY WITH CHEMOMETRICS ON PAPER** **1479**

P. Mostafalu[1], S. Mostafalu[2], J.K. Mann[1], M. Punjiya[1], and S. Sonkusale[1]
[1]*Tufts University, USA and* [2]*University of Massachusetts, USA*

Selective detection of coexisting species with similar reduction potentials using electrochemical approaches is very challenging. As a novel solution to this problem, we employ material diversity with a data-driven chemometric approach for selective detection of coexisting redox species such as dopamine, ascorbic acid and serotonin. A simple and low-cost paper-based platform, containing four different electrodes and microfluidic channels, was used to implement our approach.

T4P.038 **LOW POWER MICROHEATER-BASED COMBUSTIBLE GAS SENSOR WITH GRAPHENE AEROGEL CATALYST SUPPORT** **1483**

A. Harley-Trochimczyk[1], J. Chang[1], T. Pham[1], J. Dong[1], M.A. Worsley[2], A. Zettl[1], W. Mickelson[1], and R. Maboudian[1]
[1]*University of California, Berkeley, USA and* [2]*Lawrence Livermore National Laboratory, USA*

This paper reports a microheater-based combustible gas sensor with low power consumption and using novel sensing materials. High surface area graphene aerogel is used as a support for platinum and palladium nanoparticles. Sensing response to hydrogen and propane gas of the two materials show promising selectivity and fast response and recovery times. The results indicate high level of flexibility in creating selective low power combustible gas sensors.

T4P.039 **TRACE LEVEL DETECTION OF NERVE AGENT SIMULANT BY USING CANTILEVER-BASED APTASENSOR** **1487**

R. Zhao, Y. Wen, and X. Yu
Peking University, CHINA

We report a cantilever-based aptasensor for a sensitive and specific detection of DMMP in neutral solution. By improving the fabrication processes, the output fluctuation of piezoresistive sensor has been decreased to 1μV at a 3V bias voltage. The aptasensor, functionalized by a 78-mer biotinylated aptamer, realized the trace detection of DMMP with a LOD of 80nM and showed excellent specificity. Finally, a pseudo-first-order kinetic model was developed to analyze the aptamer/DMMP interaction.

WEDNESDAY - Chemical Sensors and Microsystems

W2P.032 PYROLYTIC DEPOSITED GRAPHITE ELECTRODES FOR VOLTAMMETRIC SENSORS: AN ALTERNATIVE TO NANO STRCTURED ELECTRODES 1491

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[1] *Dresden University of Technology, GERMANY and* [2] *Kurt-Schwabe Research Institute Meinsberg, GERMANY*

The paper presents optimized preparation conditions for highly sensitive electrode materials as an alternative to carbon nano tubes electrodes. Pyrolytic deposited graphite electrodes can be produced uniformly in high quality. They are suitable for voltammetric determination of dissolved nitroaromates and dopamine in concentrations of about 2 ppb. They have similar or better performance respecting sensitivity, cross sensitivity and reproducibility as electrodes made of nanotubes.

W2P.033 MICRO CATALTYIC METHANE SENSOR ON BULK QUARTZ SUBSTRATE 1495

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[1] *Tsinghua University, CHINA and* [2] *University of Minnesota, USA*

A micro catalytic methane sensor was designed and fabricated on a bulk quartz substrate for the first time. This sensor was designed using finite element method (FEM) and fabricated on top of a bulk quartz substrate to achieve lower power consumption. Such sensors was uniformly fabricated by two simple MEMS processes.

W2P.034 COMPARATIVE STUDY OF LARGE AREA PULSED LASER DEPOSITED METAL OXIDES FOR GAS SENSORS APPLICATIONS 1499

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[1] *Robert Bosch GmbH, GERMANY and* [2] *Saarland University, GERMANY*

Large-area pulsed laser deposition was used to deposit various metal oxide thin films on 150 mm wafers, aiming to find materials for batch-processing of miniaturized gas sensors. Fundamental properties of these materials such as sheet resistance and morphology were investigated. Layers were structured by a silicon-based shadow mask. Gas responses of contacted layers down to ppm concentrations of CO were compared. Tin oxide and indium oxide layers showed good sensitivity and short response time.

W2P.035 NON-ENZYMATIC SPECIFIC DETECTION OF CARBAMATE PESTICIDES BASED ON MONODISPERSE GOLD-RHODIUM ALLOY NANOCRYSTALS 1503

Z.F. Chen[1], Y. Zhang[1,2], J.Q. Xu[1], P.C. Xu[2], and X.X. Li[2]
[1] *Shanghai University, CHINA and* [2] *Chinese Academy of Sciences, CHINA*

Monodisperse AuRh bimetallic nanocrystals are employed for the non-enzymatic specific detection of carbamate pesticides. Compared with state of the art, other Au based bimetallic nanocrystals and monometallic analogues, AuRh nanocrystals show their advances in specific electrocatalytic reaction toward carbamate pesticides at nano-molar (nM) level without the assistance of acetylcholinesterase (AchE) or other biochemical recognition elements.

W2P.036 A FLEXIBLE ROOM TEMPERATURE NO_2 SENSOR BASED ON MULTI-WALLED CARBON NANOTUBES-WO_3 NANOPARTICLES MATRIX ON PET SUBSTRATE 1507

U. Yaqoob and G.-S. Chung
University of Ulsan, SOUTH KOREA

The fabrication and characterization of flexible NO_2 gas sensor based on multi walled carbon nanotube-WO_3 nanoparticles (MWCNTs-WO_3 NPs) on PET substrate have been investigated. The fabricated sensor showed high sensitivity (~ 14% at 5 ppm) with relatively fast recovery time (27 min) and excellent mechanical flexibility. The implemented device also showed good repeatability and low limit of detection (LOD) of 100 ppb.

W2P.037 CANTILEVER-BASED RESONANT MICROSENSORS WITH INTEGRATED TEMPERATURE MODULATION FOR TRANSIENT CHEMICAL ANALYSIS 1511

C. Carron[1], P. Getz[1], S.M. Heinrich[2], F. Josse[2], and O. Brand[1]
[1] *Georgia Institute of Technology, USA and* [2] *Marquette University, USA*

This work introduces a resonant cantilever platform with integrated temperature modulation for real-time chemical sensing. Embedded heaters allow for rapid thermal cycling of individual sensors, thereby enabling real-time transient signal analysis without the need for a microfluidic setup to switch between analyte and reference gases. Compared to traditional mass-sensitive micro-sensors operating in steady-state, the on-chip generation of signal transients improves analyte discrimination.

W2P.038 **INTEGRATION OF RING NANOELECTRODES INTO MICROWELL FOR THE BIOELECTROCHEMICAL ANALYSIS IN SUB-PICOLITER VOLUMES**

F. Sékli Belaïdi, W. Tiddi, M. Polverel, G. Lemercier, A. Lecestre, P. Dubreuil, J. Launay, and P. Temple-Boyer
LAAS-CNRS, FRANCE

We present the technological integration of platinum (Pt) ring nanoelectrodes (RNE) into silicon dioxide (SiO2) based microwells for electrochemical analysis in sub-picoliter volumes. Thanks to the realization of functional microdevices on glass substrate, electrochemical characterizations are performed in order to study the detection principles of single RNE and RNE arrays, and to compare them to theory and simulation, aiming to single cell/mitochondria analysis.

MONDAY - Bio-Sensors and Bio-Microsystems

M3P.041 **DUAL-FUNCTION MICROELECTRODE ARRAY SYSTEM FOR SIMULTANEOUSLY MONITORING ELECTROMECHANICAL INTEGRATION STATUS OF CARDIOMYOCYTES** 1519

N. Hu, J. Fang, H. Li, K. Su, and P. Wang
Zhejiang University, CHINA

A novel dual-function cardiomyocyte-based biosensor system is developed based on microelectrode array (MEA). MEA is employed to recording the extracellular potential and beating status of cardiomyocytes cultured in vitro. It was the first time to monitor these two parameters of cardiomyocyte by one sensors rather than integrated sensors. Based on this electromechanical integration detection function, this dual-function cardiomyocyte-based biosensor system will be a utility platform to study the

M3P.042 **RAPID, LABEL FREE, HIGH THROUGHPUT, MINIARURUIZED, AND INEXPENSIVE NANOELECTRONIC ARRAY AS A CANCER DIAGNOSIS TOOL** 1523

R. Esfandyarpour[2], Z. Koochak[1,2], J.S. Harris[1], and R. W. Davis[2]
[1]*Stanford University, USA and* [2]*Stanford Genome Technology Center, USA*

Described in here are the design, fabrication, and testing of a miniaturized, rapid, label free, high throughput and inexpensive nanoelectronic array in a microfluidic channel, which can be used to detect and quantify different biomarkers. We have fabricated different geometrical designs of the array and demonstrated label free and real time electrical detection of nucleic acids, proteins and cells using our fabricated nanoarray.

M3P.043 **HBA1C RATIO DETECTION USING THE MICROFLUIDIC BIOSENSOR BASED ON DEVELOPED SANDWICH IMMUNOASSAY AND IMPEDANCE MEASUREMENT** 1527

C.H. Yeh[1], K.C. Mou[1], I.Y. Huang[2], and Y.C. Lin[1]
[1]*National Cheng Kung University, TAIWAN and* [2]*National Sun Yat-sen University, TAIWAN*

The proposed microfluidic biosensor successfully detected the impedance signals of the various hemoglobin (Hb) and glycated hemoglobin (HbA1c) concentrations to obtain the HbA1c ratio. This microfluidic biosensor has advantages including small sample volumes (10 μL) and rapid quantitative measurement, and works with wider detection range of concentration in clinical diagnosis.

M3P.044 **RAPID SIZE DETERMINATION OF PCR AMPLIFED DNA BY BEADS-BASED DIELECTRPHORETIC IMPEDANCE SPECTROSCOPY** 1530

M. Nakano, Z. Ding, H. Kasahara, and J. Suehiro
Kyushu University, JAPAN

This paper reports a new method to determine the size of DNA amplified by polymerase chain reaction (PCR). After PCR, the amplified DNA was attached on dielectric microbeads, then, the DNA labeled microbeads were trapped on a microelectrode by dielectrophoresis (DEP). Thesize of the DNA was determined by measuring frequency dependent impedance of the trapped microbeads as an impedance spectroscopy.

M3P.045 **ELECTRICAL IMPEDANCE SPECTROSCOPY FOR BIOTISSUE DIFFERENTIATION USING BIPOLAR ELECTRODES POSITIONED AT THE END OF A HYPODERMIC NEEDLE** 1533

J. Yun, G. Kang, Y. Park, S. Moon, J. Lim, J.-J. Cha, and J.-H. Lee
Gwangju Institute of Science and Technology (GIST), SOUTH KOREA

This paper reports EIS (Electrical Impedance Spectroscopy) on a hypodermic needle for the first time. This EoN (EIS-on-a-Needle) has bipolar interdigitated electrodes at the end of round surface, which can be used to find the accurate position for drug delivery and/or tissue characterization prior to biopsy. To evaluate the performance of the fabricated EoN, electrical impedance of chicken leg (fat, muscle) was measured. The experimental result was in good agreement with the known permittivity.

M3P.046 **HIGH SENSITIVE DETECTIONS OF NOROVIRUS DNA AND IGG BY USING MULTI-SINW-FET BIOSENSORS 1537**
X. Gong, R. Zhao, and X. Yu
Peking University, CHINA

This paper reports ultrasensitive detections of DNA and protein by multi-silicon-nanowire field-effect-transistor biosensors. Compared with single-SiNW-FET, the multi-SiNW-FETs biosensor shows a higher ability of decreasing the noise by averaging the fluctuation of source-drain currents. Both Norovirus DNA and IgG have been detected with the sensors at concentrations as low as 1 fM and 10 fM.

M3P.047 **IN-VIVO SINGLE CELL PROTEIN INTERACTION INVESTIGATION USING MICROFLUIDIC PLATFORM 1541**
B. Davaji[1], G. Biener[2], V. Raicu[2], and C.H. Lee[1]
[1]*Marquette University, USA and* [2]*University of Wisconsin Milwaukee, USA*

We designed and developed a microfluidic platform to investigate protein interaction on the membrane of a single cell. The developed microfluidic platform is able to capture and release a single cell while also allowing the captured cell to be subjected to various media. The device structure is designed to adopt the two photon excitation microscopy with high spectral resolution to investigate protein-protein and protein-ligand interaction on a cell membrane.

M3P.048 **AN ELECTROCHEMICAL ASSAY FOR DNA METHYLATION BASED ON 3D NANOSTRUCTURED GOLD ELECTRODE AND METHYL BINDING DOMAIN PROTEIN 1545**
S.A. Hong, S.W. Jung, H.J. Cho, and S. Yang
Gwangju Institute of Science and Technology (GIST), SOUTH KOREA

We develop an electrochemical detection of methylated DNA using 3D nanostructured gold electrode and methyl binding domain protein. For sensitive detection, the 3D nanostructured gold electrode which has 22-fold larger surface area is developed. In addition, label-free detection is developed by the DPV response with a methyl binding domain protein. The proposed detection method can detect methyltransferase activity from 0.1 to 50 U/mL.

M3P.049 **MICROFLUIDIC DEVICE TO INTERCONNECT MULTIPLE ORGANS VIA FLUIDIC CIRCULATION: TOWARDS BODY-ON-A-CHIP 1549**
Y. Kato, Y. Hirai, K. Kamei, T. Tsuchiya, and O. Tabata
Kyoto University, JAPAN

We developed a simplified microfluidic device (1) assembling multiple organs within a device and (2) integrating a closed-loop medium circulation system to investigate the effects of drug candidates and their metabolites on two organs, namely body-on-a-chip. For its fabrication, simple and reliable 3D lithography was applied to improve the PDMS molding. The fabricated PDMS microfluidic device was successfully applied to evaluate the effects of an anti-cancer drug (Doxorubicin) on cell survival.

M3P.050 **ELECTROCHEMICAL REAL-TIME MONITORING OF ISOTHERMAL NUCLEIC ACID AMPLIFICATION FOR QUANTITATIVE ANALYSIS 1553**
M. Tabata[1], H. Yang[2], F. Mannan[3], Y. Katayama[1], T. Goda[1], A. Matsumoto[1], A. Seichi[4], K. Suzuki[4], and Y. Miyahara[1]
[1]*Tokyo Medical and Dental University, JAPAN,* [2]*Huaqiao University, CHINA,* [3]*Imperial College London, UK, and* [4]*Keio Univerisity, JAPAN*

We have developed label-free miniaturized electrochemical devices for monitoring nucleic acid amplification. We successfully monitored released protons during amplification reaction in real-time manner using miniaturized pH sensors and demonstrated quantitative detection of nucleic acid. The proposed system would be cost-effective and portable and potentially implemented in clinical use such as diagnosis of infectious disease and cancer.

M3P.051 **A HANDHELD DEVICE FOR RAPID VIABLE CIRCULATING TUMOR CELL ISOLATION USING MICROFABRICATED TAPERED-SLIT FILTERS 1557**
Y.T. Kang, I. Doh, and Y.H. Cho
Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA

We present a handheld device for the simple, stable, high-throughput, and viable circulating tumor cell (CTC) isolation. The handheld device used the microfabricated tapered-slit membrane filters, and verified the performance using the 4 different lung cancer cells and 5 different lung cancer patients' blood.

M3P.052 **MEASUREMENT OF REACTIVE OXYGEN SPECIES RELEASE FROM STIMULATED CELL CULTURE WITH FULLY INTEGRATED MICROSENSOR SYSTEM BY ADVANCED ELECTROCHEMICAL DETECTION PRINCIPLE** **1561**

H. Flamm, A. Weltin, J. Kieninger, and G.A. Urban
University of Freiburg - IMTEK, GERMANY

We present an integrated microsystem and a new method to detect reactive oxygen species superoxide from cultivated cancer cell culture. The system comprises electrochemical superoxide sensors, based on the direct oxidation of superoxide on polymer covered gold microelectrodes, without the need for biological recognition elements. That enhances the sensor performance dramatically by increasing the long term stability and sensor sensitivity.

M3P.053 **PROPOSITION AND DEMONSTRATION OF 3TR. TYPE ION IMAGE SENSOR PIXEL STRUCTURE FOR HIGHLY RESOLUTION BIO-IMAGING** **1565**

M. Fujita[1], K. Shimizu[1], S. Watanabe[1], F. Dasai[1], M. Futagawa[2], M. Ishida[1], and K. Sawada[1,3]
[1]*Toyohashi University of Technology, JAPAN,* [2]*Shizuoka University, JAPAN, and*
[3]*Japan Science and Technology Agency (JST), JAPAN*

We propose a pH-sensor with a new measurement method that spills charge to a potential wall under sensing area. The sensor pixel with 3 transistors has more advantages for fabricating a sensor array with high spatial resolution than a conventional ISFET type sensor pixel with 4 transistors. The sensor pixel is 2 μm pixel pitch that is fabricated in a conventional 4-metal 0.34 μm CMOS process. The sensor has a distinguishable spatial resolution at cells individually.

M3P.054 **GLUCOSE MEASUREMENT USING SURFACE PLASMON RESONANCE SENSOR WITH AFFINITY BASED SURFACE MODIFICATION BY BORATE POLYMER** **1569**

D.C. Li[1], J.W. Wu[1], P. Wu[1], Y. Lin[2], Y.J. Sun[2], R. Zhu[1], J. Yang[1], and K.X. Xu[1]
[1]*Tianjin University, CHINA and* [2]*Chinese Academy of Sciences, CHINA*

We proposed an affinity based method of implantable continuous glucose monitoring using a fiber optic SPR sensor modified by borate polymer. The proposed sensor avoids the impact of the bioelectricity from viable tissues by detecting the optical refractive index. It also realizes non-consumption measurement of glucose due to the dynamic association and dissociation between the polymer and the glucose. Thus, the defects of conventional enzyme electrode based glucose sensor are overcome.

M3P.055 **HIGHLY SENSITIVE PLASMONIC GRATING PLATFORM FOR THE DETECTION OF A WIDE RANGE OF INFECTIOUS DISEASES** **1573**

S. Bok, S. Pathan, A.J. Wood, B. Chen, C.J. Mathai, K. Gangopadhyay, S. Grant, C. McArthur, and S. Gangopadhyay
University of Missouri, USA

We report the cost-effective fabrication of a plasmonic grating for improved light coupling in a fluorescence-based sensor platform by simple micro-contact printing technique. The fluorescence of Rhodamine 6G film on gratings was enhanced by up to 239-fold with respect to glass using a fluorescence microplate reader. The platform has been optimized to detect Interferon-gamma, an indicator of M. tuberculosis infection, by immunofluorescence assay demonstrating 500 fg/ml limit of detection.

TUESDAY - Bio-Sensors and Bio-Microsystems

T4P.040 **FABRICATION OF NON LABEL ATP IMAGE SENSOR WITH MIXED LAYERED TECHNIQUE** **1577**

H. Doi[1], T. Horio[1], K. Okumura[1], T. Hattori[1,2], M. Ishida[1], and K. Sawada[1,2]
[1]*Toyohashi University of Technology, JAPAN and* [2]*Japan Science and Technology Agency (JST), JAPAN*

128 × 128 ATP (Adenosine Triphosphate) image sensors using charge-coupled device ion image sensor and mixed layer technique of polyion complex were successfully fabricated to obtain 2D real time ATP image, and was carried out in a non-label manner. We obtained the diffusion image of ATP with the mixed layer method at the concentration as low as 100 μM. The sensitivity of the sensor was calculated to be 14.6 mV/decade.

T4P.041 **AN INTEGRATED CHIP COIL SENSOR AND INSTRUMENTATION AMPLIFIER FOR BIO-MAGNETIC SIGNAL ACQUISITION** **1581**

V.V. Nair, J.H. Youn, and J.R. Choi
Kyungpook National University, SOUTH KOREA

An on-chip high inductance coil sensor and instrumentation amplifier is designed and fabricated for highly sensitive bio-signal acquisition. The developed system is accounted for its portability and cost-effectiveness. The fabricated high-inductance coil aids to better sensitivity and reduced size in comparison to prior artworks. The acquired signal is amplified flawlessly with an instrumentation amplifier, which operates with low power thus devising an energy efficient system.

T4P.042 **HIERARCHICAL PLATINUM NANOSTRUCTURE FOR THE NON-ENZYMATIC DETECTION OF GLUCOSE BY AMPEROMETRY AND IMPEDANCE ANALYSIS** 1585

T. Unmüssig[1], P. Daubinger[1,2], J. Kieninger[1], and G. Urban[1]
[1]*University of Freiburg, GERMANY and* [2]*Johnson Matthey Piezo Products, GmbH, GERMANY*

High sensitivity, selectivity and stability of a non-enzymatic glucose sensor were achieved by the combination of hierarchical platinum nanostructures with a sophisticated measurement scheme. The selectivity towards glucose can be enhanced beyond the contribution of the nanostructure itself by the unique combination of the hierarchical nanostructure and low frequency impedance analysis. Additionally the long-time stability of the sensor was improved by using a chronoamperometric protocol.

T4P.043 **LABEL-FREE DETECTION OF LEUKEMIA CELLS WITH A LAB-ON-A-CHIP SYSTEM INTEGRATING DIELECTROPHORESIS AND CMOS IMAGING** 1589

Y. Demircan[1], S. Örgüç[1], J. Musayev[1], E. Özgür[1], M. Erdem[1], U. Gündüz[1], S. Eminoğlu[2], H. Külah[1], and T. Akin[1]
[1]*Middle East Technical University (METU), TURKEY and* [2]*Mikro-Tasarim San. ve Tic. Ltd. Sti., TURKEY*

This paper presents a fully-integrated LOC for label-free detection and real-time counting of dielectrophoretically trapped multidrug resistant (MDR) K562 cells. The system integrates a parylene-based microfluidic DEP channel on top of a CMOS image sensor for the first time in the literature.

T4P.044 **A NOVEL BIOCOMPATIBLE BIOMATERIAL FOR ON-DEMAND GENERATION OF THREE-DIMENSIONAL OXYGEN GRADIENTS IN VITRO** 1593

C. Mozayan[1], R. Chabra[2], P. Wu[3], R. Narayan[1,3], and C. Li[1,3]
[1]*Hofstra North Shore-LIJ School of Medicine, USA,* [2]*Rensselaer Polytechnic Institute, USA, and*
[3]*Feinstein Institute for Medical Research, USA*

This paper reports a novel biocompatible biomaterial for on-demand generation of three-dimensional oxygen gradients in vitro. By exposing the oxygen-consuming biomaterial consisting of glucose oxidase and chitosan enzymes to the cell culture media, precisely controlled oxygen gradients (2.5 mmHg per 100 µm distance) that closely mimic in vivo hypoxia can be generated.

T4P.045 **A GAS-LIQUID SEPARATED IN-PLANE SWING-MODE RESONATOR WITH HIGH Q-FACTOR IN SOLUTION FOR REAL-TIME BIO-SENSING** 1597

H.T. Yu, Y. Chen, P.C. Xu, T.G. Xu, Y.Y. Bao, and X.X. Li
Chinese Academy of Sciences, CHINA

This paper reports that high Q-factor is achieved in liquid by using an in-plane swing-mode micro-resonator that is specific-designed with a gas-liquid separated structure. With design of an anti-leakage narrow 'hydrophobic-slit' to protect the resonator still in air for high-Q vibration, while only the sensing-region of the device contacts the analyte solution. In addition, the in-plane vibrated resonator works in a swing-mode that helps to gain high-Q by largely decreasing liquid damping.

T4P.046 **SIGNAL AMPLIFICATION USING MAGNETIC BEAD CHAINS IN MICROFLUIDIC ELECTROCHEMICAL BIOSENSORS** 1601

L. Armbrecht[1], C. Dincer[1], A. Kling[1], J. Horak[1,2], J. Kieninger[1], and G. Urban[1]
[1]*University of Freiburg, GERMANY and* [2]*KTH Stockholm, SWEDEN*

We present a novel approach to increase the sensitivity of a microfluidic immunosensing platform using magnetic micro-beads. Sensitivity enhancement is achieved by means of a soft-magnetic lattice, which induces self-assembly of the magnetic beads in chains. This facile strategy allows for complete independence of traditional sensor materials and channel geometries. Validation was conducted with optical microscopy and with electrochemical measurements on an integrated microfluidic chip.

T4P.047 **DEVELOPMENT OF BIOTRANDCUSERS DRIVEN BY PHOTOSTIMULATION** 1605

T. Asano[1], T. Ishizuka[2], H. Yawo[2], and K. Morishima[1]
[1]*Osaka University, JAPAN and* [2]*Tohoku University, JAPAN*

We develop a photosensitive skeletal muscle driven by biochemical energy reaction, as an efficient novel biotransducer. To improve spatial and temporal resolution, energy efficiency, flexibility for manipulating the contractile activity, we have made the optically controllable muscle cells by introducing the gene of light-gated ion channels, ChR.

T4P.048 **A LOW-COST NANOPARTICLE-BASED SPECTROPHOTOMETRIC TRANSDUCER USING COMMON ELECTRONICS COMPONENTS FOR IMMUNOSENSING** **1609**

H.J. Chun, Y.D. Han, and H.C. Yoon
Ajou University, SOUTH KOREA

We developed a low-cost optical transducer for the gold nanoparticle-based immunosensing by reassembling common electronics components including laser diode, solar-cell and multimeter. For the versatile biosensing, two types of gold nanoparticles and laser sources were introduced and used. For the simple immunoassay without washing procedures, superparamagnetic microparticles (MPs) were introduced as an immunosensing substrate in the developed optical immunosensing system.

T4P.049 **FAST MECHANICAL BIOSENSING IN LIQUID USING MEMS FABRY-PEROT INTERFEROMETRIC SURFACE-STRESS SENSOR** **1613**

Y. Masuya[1], R. Ozawa[1], M. Ishida[1,2], K. Sawada[1,2,3], and K. Takahashi[1,3]
[1]*Toyohashi University of Technology, JAPAN,* [2]*Japan Science and Technology Agency (JST), JAPAN, and*
[3]*Electronics Inspired - Interdisciplinary Research Institute (EIIRIS), JAPAN*

We developed an optical interferometeric surface-stress sensor which utilizes the nonlinear optical transmittance change in the Fabry–Perot interference to enhance the sensitivity of the surface-stress, integrated with a microfluidic channel for fast biosensing. Photocurrent change of 8 nA was obtained when an anti-bovine serum albumin (BSA) with concentration of 100 ng/ml was injected with flow rate of 1 µl/min. Response time was successfully improved to be several tens of seconds.

T4P.050 **DIELECTROPHORETIC SORTING OF LIPID-CONTAINING MICROORGANISMS USING HIGH FREQUENCY ELECTRIC FIELDS PRODUCED BY CONDUCTING POST ARRAYS** **1617**

A.R. Schor and C.R. Buie
Massachusetts Institute of Technology, USA

We have fabricated and validated a dielectrophoretic cell sorter comprised of arrays of conductive microposts. This sorter is used to identify high-lipid-content organisms, which have commercial value as oil feedstock. Cell sorting based on dielectrophoresis (DEP) has been shown in the literature, but not to investigate lipid content. The geometry, fabrication, and selection criteria are also unique among flow-through sorters.

T4P.051 **LIGHT EMITTING DEVICES AND INTEGRATED ELECTROCHEMICAL SENSORS ON LAB-ON-CHIP FOR TOXICITY BIOASSAYS BASED ON ALGAL PHYSIOLOGY** **1621**

A. Tsopela[1,2], A. Laborde[1,2], L. Salvagnac[1,2], I. Séguy[1,2], R. Izquierdo[3], P. Juneau[3], P. Temple-Boyer[1,2], and J. Launay[1,2]
[1]*LAAS-CNRS, FRANCE,* [2]*Université de Toulouse, FRANCE, and* [3]*Université du Québec à Montréal, CANADA*

This study focuses on assembling integrated electrochemical sensors and light-emitting devices on a glass-based fluidic platform for the detection of toxicants. The fabricated lab-on-chip sensor could monitor herbicide-induced modifications in algal photosynthetic activity and be an efficient indicator of water pollution. The innovative OLED -based integrated system demonstrates high detection characteristics and is highly promising for further integration of optical and electrochemical sensors.

T4P.052 **REAL-TIME MULTI-ANALYTE ONLINE MONITORING OF 3D CELL CULTURES BY INTEGRATED ENZYME-BASED BIOSENSORS IN HANGING DROP NETWORKS** **1625**

P.M. Misun, J. Rothe, A. Hierlemann, and O. Frey
ETH Zürich, SWITZERLAND

We present the integration of enzyme-based lactate and glucose biosensors into hanging drop networks. This technique enables continuous in-situ online monitoring of effects of different culturing conditions and compound dosages on the microtissues. A hybrid approach including glass sensor modules embedded into a microfluidic PDMS chip facilitates system integration. The biosensors enabled real-time recording of lactate production and glucose consumption of human colon carcinoma spheroids.

T4P.053 **USING MAGNETIC MARKED PEGDA-BASED CELL SHEETS FOR THREE DIMENSIONAL LOBULE-MIMICKING CHIP** **1629**

Y.-S. Chen, L.-Y. Ke, H.-H. Lo, and C.-H. Liu
National Tsing Hua University, TAIWAN

We propose lobule-mimicking three dimensional chips by using magnetic marked PEGDA-based cell sheets. It consists of four cell sheet chambers and one stacking chamber. We had used hydrogel material with few magnetic beads which to form magnetic mark and form MP cell sheets. The stacking chamber was drilled by UV laser. By using magnetic field to manipulate MP cell sheets moving and rotating. Finally, we had stacked MP cell sheets to the stacking chamber to achieve lobule-mimetic regeneration.

T4P.054 **A PAPER-BASED 3D SENSOR ARRAY FOR ELECTROMICROBIOLOGY 1633**
G. Choi and S. Choi
State University of New York, Binghamton, USA

We provided a strategy for high-throughput monitoring of temporal and spatial gradients of electrons/protons in electrogenic bacterial biofilms by utilizing 3D multi-laminate structures of papers as a scaffold to support bacterial biofilms and/or media. Assembly of a 3D paper stack can be modular and allows us to control the thickness of the overall biofilm construct and diffusion of nutrients/redox mediators through the stack and the shapes of gradients in the stacks can be modulated.

T4P.055 **PRECISION PROTEIN ASSAYS ON COMPARTMENTALIZED BIOSENSOR ARRAYS 1637**
D.J.B. Bechstein, J.-R. Lee, E. Ng, and S.X. Wang
Stanford University, USA

We report a biological measurement microsystem capable of performing precision protein assays by compartmentalization of biosensors in a sensor array. Our technique performs all required measurements, including biological references, on a single sensor chip and thus yields assays that quantify the protein concentrations precisely. Our compartmentalization technique also enables sample multiplexing on large-scale solid-state sensor arrays.

WEDNESDAY - Bio-Sensors and Bio-Microsystems

W2P.039 **IRRADIATING LOW-TEMPERATURE ATMOSPHERIC PRESSURE PLASMA TO CELLS USING MEMS NOZZLE 1641**
Y. Nakayama[1], R. Shimane[1], S. Kumagai[1], H. Hashizume[2], T. Ohta[3], M. Ito[3], M. Hori[2], and M. Sasaki[1]
[1] *Toyota Technological Institute, JAPAN,* [2] *Nagoya University, JAPAN, and* [3] *Miejo University, JAPAN*

A MEMS nozzle device achieved low-temperature atmospheric pressure plasma irradiation for individual cell treatment. The device had sample trapping/releasing function, which enabled stable plasma treatment. Biological sample of pollen (100-140um) was plasma-treated with the device. The pollen surface was etched locally (10-20um). During the treatment, nozzle temperature was 40 deg., almost the same as human body. The low-temperature treatment is useful to keep the activity of biological sample.

W2P.040 **A NOVEL PROBE FOR MULTIPLEXED DETECTION OF INTRACELLULAR PROTEASES BASED ON FRET AND FLUORESCENCE POLARIZATION 1645**
D. Ren, J. Wang, and Z. You
Tsinghua Universiy, CHINA

At present, FRET probes used to characterize the target molecules were usually based on the change in the fluorescent molecule's volume and mass. Based on resonance energy transfer, we constructed fluorescent probes using streptavidin labeled Alexa488, nanogold and biotinylated substrate peptide. Using the probe, trypsin and biotin were detected by the change in luorescence intensity and fluorescence polarization, showing higher reliability and higher sensitivity.

W2P.041 **A HIGHLY PERFORMED ENZYMATIC BIOSENSOR USING DISTRIBUTED ELECTRODES DECORATED WITH HYDROTHERMALLY TREATED REDUCED GRAPHENE OXIDE AND PLATINUM NANOPARTICLES 1649**
M.F. Hossain, H.S. Yoon, and J.Y. Park
Kwangwoon University, SOUTH KOREA

In this work, two distributed working electrodes connected in series are decorated with reduced graphene oxide-platinum nanoparticles and added enzyme composites with nafion, which integrated on a single chip for effectively glucose sensing. Since each electrode is modified and electrochemical properties gradually increase, thus electrochemical properties of total system also increases owing to the series connection within electrodes.

W2P.042 **A LIGHT GUIDE PLATE BASED FLEXIBLE OPTICAL CUFF FOR OPTOGENETIC STIMULATION OF MOTOR UNITS 1653**
M.S. Kim[1], M.K. Kim[1], J. Hwang[1], C. Joo[1], J.Y. Kang[2], and Y.J. Kim[1]
[1] *Yonsei University, SOUTH KOREA and* [2] *Korea Institute of Science Technology, SOUTH KOREA*

This paper reports a light guide plate based flexible optical cuff for optogenetic stimulation of motor units. We propose the optical cuff based on a single-sheet PDMS light guide plate (LGP). It has good flexibility, and can be improved the efficiency of the light source by distributing the light globally through the LGP. Moreover, the possibility of cell necrosis due to heat can help to reduce by preventing direct contact between the μ-LED and neurons.

W2P.043 A CMOS-BASED POLY-SILICON SUB-MICRON WIRE BIOSENSOR FOR MULTIPLE BIOMARKER DETECTIONS IN CLINICAL SAMPLES 1657
I.-S. Wang, J.-K. Lee, H.-H. Lin, Y.-H. Sun, G.-Y. Chen, and C.-T. Lin
National Taiwan University, TAIWAN

This paper reports an integrated poly-silicon sub-micron wire biosensor for multiple biomarker detections in clinical samples. In this work, a series of anemia/diabetes biomarkers, such as low-density lipoprotein (LDL), hemoglobin (Hb), glycated hemoglobin (HbA1c), and ferritin are examined by the developed CMOS poly-silicon biosensors. The experimental results indicate differences of biomarker concentrations between sick and healty people.

W2P.044 MEASUREMENT OF VISCOSITY OF ADULT ZEBRAFISH BLOOD USING A CAPILLARY PRESSURE-DRIVEN VISCOMETER 1661
D. Kang[1], W. Wang[2], J. Lee[3], Y.C. Tai[1], and T.K. Hsiai[3]
[1]*California Institute of Technology, USA,* [2]*Peking University, CHINA, and* [3]*University of California, Los Angeles, USA*

This paper reports the first experimental work onthe measurement of adult zebrafish blood viscosity. Theproposed approach is uniquely applicable for smallsample volume (<1μL) and short measurement time (<2min). As a calibration, the measurements for waterand human whole blood are done and in good agreementwith published data, demonstrating the reliability of thismethod. Power law and Carreau-Yasuda models are usedto model the non-Newtonian behavior of zebrafish blood.

W2P.045 HIGH-Q ON-CHIP MICROWAVE RESONATOR FOR SENSITIVE PERMITTIVITY DETECTION IN NANOLITER VOLUMES 1665
A.M. Watson[1], A. Padilla[2], V.M. Bright[1], C.L. Holloway[2], and J.C. Booth[2]
[1]*University of Colorado, Boulder, USA and* [2]*National Institute of Standards and Technology (NIST), USA*

We design, fabricate and test a thick coplanar waveguide RF resonator with high Q. Integrated microfluidics allow measurement of 0.8% changes in permittivity in nanoliter liquid sample volumes. By measuring the phase shift of the S21 transmission parameter at resonance, we estimate a lower detection limit of 500 ppm with this device.

W2P.046 A RAPID ON-CHIP SINGLE NUCLEOTIDE POLYMORPHISM DETECTION DIRECTLY FROM HUMAN BLOOD 1669
L. Zhang[1], Q. Cai[1], B. Jones[1], P. Fiorini[1], T. Stakenborg[1], M. Tsukuda[2], and L. Lagae[1,3]
[1]*imec, BELGIUM,* [2]*Panasonic, JAPAN, and* [3]*KU Leuven, BELGIUM*

We develop a silicon/glass based microsystem for the fast detection of single nucleotide polymorphisms (SNPs) directly from on-chip filtered human blood. A cross-flow micro-pillar filter is used for purifying lysed blood. The purified DNA solution is then tested for the detection of specific SNPs in a micro-cavity by polymerase chain reaction. A successful on-chip detection of two SNPs in human CYP2C9 gene is demonstrated. The SNP profiling took less than 40 minutes from sample to result.

W2P.047 MICROMECHANICAL STIMULATION CHIPS FOR STUDYING MECHANOTRANSDUCTION IN MICTURITION 1672
K. Svennersten[1], A. Maziz[2], K. Hallén-Grufman[1], and E.W.H. Jager[2]
[1]*Karolinska Institute, SWEDEN and* [2]*Linköping University, SWEDEN*

We developed a micro-mechanostimulation chip that applies physiologically relevant mechanical stimuli to single cells to study mechanosensitive cells in the urinary tract. The chips comprise arrays of electroactive polymer microactuators that provide individual mechanical stimulation to single cells, including controls, all integrated on one single chip. The chips are easily integrated in existing cell biology equipment and allow for in situ stimulation during live imaging studies.

W2P.048 FINGER-TIP SIZE MULTIPLE REVERSE TRANSCRIPTION DEVICE FOR EARLY DETECTION OF DISEASES 1676
Y. Kimura, M. Ikeuchi, and K. Ikuta
University of Tokyo, JAPAN

We have developed a portable device for accurate reverse transcription which enable early detection of diseases. This micro device was fabricated by 3D micro stereolithography. The size is only a finger-tip scale, but can perform multiple analysis all at once. This device needs only 1 μl reagent for inspection that is much smaller than that of conventional devices. Basic performance for precise measurement of reverse transcription was verified experimentally.

W2P.049 NATURAL SHELLAC FOR GREEN MICROFLUIDIC APPLICATIONS 1680
R. Lausecker, V. Badilita, and U. Wallrabe
University of Freiburg - IMTEK, GERMANY

We introduce the biomaterial shellac as a new player in the field of sustainable microfluidics. To address drawbacks from traditional microfabrication, e.g. high energy and resource consumption and generation of non-degradable end products, we demonstrate a green process for wafer-level fabrication of microstructures by means of shellac hot embossing. The implementation capability is demonstrated through successful fabrication of basic fluidic building blocks as channels, reservoirs and mixers.

W2P.050 SENSOR-ARRAY FOR CONTINOUS MONITORING OF BIOCHEMICALS FOR BIOPROCESS CONTROL 1684
T. Nguyen[1], S. Cho[1,2], V. Bhola[1,2], S. Ko[1], R. Sharma[1], J. Magda[1], and P. Tathireddy[1,2]
[1]*University of Utah, USA and* [2]*Applied Biosensors, USA*

We present a sensor that utilizes novel stimuli- responsive hydrogels intended for use as the sensing elements of disposable sensors in single use bioreactors. The response of hydrogels to changes in environmental concentration of a specific analyte is transduced using a magnetic or pressure sensor. Here we present recent results from glucose, lactate and osmolality sensor measured using a pressure and magnetic sensors.

W2P.051 D_2O BASED MICROFLUIDICS FOR IN VITRO IR CELL ANALYSIS 1688
R. Ebrahimifard, S. van den Driesche, W. Lang, and M.J. Vellekoop
University of Bremen, GERMANY

We present the use of D_2O (deuterium oxide) as a liquid medium for infrared analysis of biological cells in microfluidic devices. In contradiction to standard buffer liquids, D_2O shows a low infrared absorption in the range of 3 to 4 µm wavelength, which makes it suitable for infrared analysis methods in that range. We illustrate the performance by the measurement of CH_2 and CH_3 stretch vibrations of phospholipid bilayer of the cell membrane of yeast, in a microfluidic chip.

W2P.052 MICROBIAL PRODUCTION INSIDE MICROFABRICATED HYDROGEL MICROTUBES 1692
M. Ogawa, K. Higashi, and N. Miki
Keio University, JAPAN

We propose to use microtubes to encapsulate, protect, and culture microbes. Tubes can be micro- and mass-fabricated and prevent competitive microbes from intruding inside. The byproducts can be collected together with the tubes. In this paper, we demonstrate the proof-of-concepts experiments: we fabricated hydrogel microtube and cultured lactic acid producing microbes inside. The microbes increased and produced lactic acid, which was later successfully collected with the microtubes. This concept

W2P.053 CONTINUOUS LACTATE MONITORING BY MICROSENSORS IN SPHEROID 3D TUMOR CELL CULTURES 1695
A. Weltin[1], S. Hammer[1], Y. Kaminski[2], S. Klein[2], F. Noor[2], J. Kieninger[1], and G.A. Urban[1]
[1]*University of Freiburg - IMTEK, GERMANY and* [2]*Saarland University, GERMANY*

We report the application of an electrochemical metabolic monitoring system in a spheroid 3D tumor cell culture environment. Microsensors allow the online, in situ measurement of metabolic parameters of increasingly relevant organotypic cultures. Precise lactate production from single human hepatocyte spheroids was continuously monitored, also in combination with drug exposure. The approach enhances and simplifies the determination of metabolic rates, e.g. in drug discovery and toxicology.

W2P.054 CELL BASED MICROACTUATOR WITH CONTROLLED ROUGHNESS OF THIN FILM 1699
Y. Inoue and K. Ikuta
University of Tokyo, JAPAN

We succeeded higher adhesion force between cells and base materials. A hybrid actuators were composed of both artificial material and biological driving source. In this report, we focused on surface roughness of the materials and revised energy transmission on the hybrid actuators to increase generative force. We revealed that controlled rough surface made higher efficiency than flat surface. A 3.2mm/min swimming robot was succeeded by this method and cell viability was maintained.

MONDAY - Medical Microsystems

M3P.056 DETECTION OF NEUROENDOCRINE MARKER IN BLOOD SAMPLES USING AN OPTOFLUIDIC CHIP.....1703
S. Alzghoul[1], M. Hailat[2], S. Zivanovic[1], G. Shah[2], and L. Que[3]
[1]*Louisiana Tech University, USA,* [2]*University of Louisiana-Monroe, USA, and* [3]*Iowa State University, USA*

An optofluidic chip has been fabricated and used for detecting a newly discovered prostate cancer (PC) biomarker neuroendocrine marker (NEM). Different from prostate-specific antigen (PSA), NEM is produced by prostate tumor cells and is released in blood. Hence, NEM is tumor-specific and more reliable biomarker than PSA. We have detected 10pg/mL NEM in BSA solution and NEM in blood serum from a patient using the optofluidic chip with high specificity.

M3P.057 MICRODEVICE FOR THE MEASUREMENT OF NEUTROPHIL ACTIVITY FOR STRESS MONITORING.....1707
K. Tanabe[1], A. Yamagishi[1], M. Yokokawa[1], Y. Morimoto[2], M. Kinoshita[2], and H. Suzuki[1]
[1]*University of Tsukuba, JAPAN and* [2]*National Defense Medical College, JAPAN*

This paper describes a device that measures the activity of neutrophils that is seems to have close relation to psychological stress. A microfabricated Clark-type oxygen electrode that measures the respiratory activity of cells was formed along with a microfluidic channel. This device can measure the phagocytosis process with a trace of neutrophil cells. We also demonstrate the measurement of immune activity with 30μL mouse blood sample.

M3P.058 128-CHANNEL DEEP BRAIN RECORDING PROBE WITH HETEROGENOUSLY INTEGRATED ANALOG CMOS READOUT FOR FOCAL EPILEPSY LOCALIZATION.....1711
F. Pothof, T. Galchev, M. Patel, A. Sayed Herbawi, O. Paul, and P. Ruther
University of Freiburg - IMTEK, GERMANY

This paper presents a novel stereoelectroencephalography probe with CMOS electronics that allow simultaneous recording of 128 channels. It comprises 8 macro electrodes and 120 microelectrodes (diameter: 35 μm; impedance: 332 kΩ at 1 kHz) for recording single neurons. We employ micro fabrication- and assembly-techniques to obtain cylindrical probes with heterogeneously integrated electronics. Each output channel is buffered to drive the output leads at a power consumption of 12 μW/ch.

M3P.059 SHARP TIP-SEPARABLE MICRONEEDLES DEVICE FOR TRANS-DERMAL DRUG DELIVERY SYSTEMS.....1715
K. Imaeda[1], K. Bessho[1], and M. Shikida[2]
[1]*Nagoya University, JAPAN and* [2]*Hiroshima City University, JAPAN*

We challenged to develop a sharp tip-separable microneedle for trans-dermal drug delivery systems. Firstly, two different shapes Si-sharp-pyramids, eight-sided and rhombic pyramids, were fabricated by anisotropic wet etching. Then, tip-separable biodegradable microneedles with the tip radius of less than 1.0 μm were produced by applying molding process. Finally, the tip-separable microneedle was successfully penetrated and instantly placed the tip into the mouse skin by the separation.

M3P.060 THE BLOOD PRESSURE MEASUREMENT DEVICE WITH CONVEX MICRO SENSOR ARRAY FOR REDUCING A CROSS TALK.....1719
Y. Endo and T. Dohi
Chuo University, JAPAN

We fabricated the blood pressure measurement device based on the arterial tonometry method with the convex micro pressure sensor array for reducing a cross talk. The size of our device is 30_30_5.8 mm3 which has 11 pressure sensors of 130_250_20 μm3 in size. Since each pressure sensor has a convex shape surface, the pressure measured by each sensor element has little effect on each other. As a result, the clear pulse wave of blood pressure can be measured by reducing a cross talk.

M3P.061 CMOS-BASED NEURAL PROBE WITH ENHANCED ELECTRONIC DEPTH CONTROL.....1723
A. Sayed Herbawi, F. Larramendy, T. Galchev, T. Holzhammer, B. Mildenberger, O. Paul, and P. Ruther
University of Freiburg - IMTEK, GERMANY

This paper reports on the design, fabrication, and testing of CMOS-based high-density neural probes. An enhanced electronic depth control concept is implemented on the probe shaft, enabling uninterrupted probe reconfiguration. Up to 334 electrodes are addressable using 16 channels. The probes are realized using a commercial 0.18 μm CMOS process combined with in-house post processing. Probe functionality has been verified demonstrating Pt electrode impedances of 1.4±0.2 MΩ at 1 kHz.

M3P.062 **MINIATURIZED MAGNETIC FORCE SENSOR ON A CATHETER TIP** **1727**
G. Chatzipirpiridis[1], S. Gervasoni[1], F. Berlinger[1], S. Blaž[2], O. Ergeneman[1], S. Pané[1], and B.J. Nelson[1]
[1]*ETH Zürich, SWITZERLAND and* [2]*RLS merilna tehnika d.o.o, SLOVENIA*

We report the smallest magnetic force sensor integrated on a catheter tip. The sensor is capable of high sensitivity and robust force measurements suitable for in-vivo applications. It utilizes a magnet mounted on a flexible membrane encapsulating the catheter and a Hall sensor to detect the magnetic field generated by the magnet. This device can be used in applications of minimally invasive surgery to detect forces applied on tissue or to characterize different types of tissue for diagnosis.

TUESDAY - Medical Microsystems

T4P.056 **NOVEL DESIGN AND FABRICATION OF DOUBLE SIDE PENETRATING NEURAL ELECTRODE ARRAY** **1731**
S. Negi[1], A. Hogan[2], M. Leber[1], M.M.H. Shandhi[1], and R. Bhandari[2]
[1]*University of Utah, USA and* [2]*Blackrock Microsystems, USA*

For the neuroprosthetic applications, there are many laminar neural interface electrodes having active sites (for recording and stimulation) on only one side of the shaft. Having active sites on one side of the probe poses inherent disadvantage of not able to communicate with the neurons, which are at the other (back) side of the shaft. We have developed neural probes which have electrodes on both side of the shaft.

T4P.057 **MINIATURIZED PORTABLE IMAGE-RECORDING DEVICE FOR PAPER-BASED NUCLEOTIDE ASSAYS WITH NANOPARTICLES** **1735**
S.J. Lo[1], D.H. Wan[1], C.M. Cheng[1], K. Keränen[2], R. Korhonen[2], H. Kopola[2], and D.J. Yao[1]
[1]*National Tsing Hua University, TAIWAN and* [2]*VTT Technical Research Center of Finland, FINLAND*

This study describes the development of a portable image-recording device that is light, inexpensive, and compatible with commercial smartphone and paper-based analytical devices. Here, we attempted to miniaturize the portable image-recording device by using a thin-film LED strip and minimize the cost of the device by using colored glassine as a light filter. Finally, we demonstrated the capacity to measure DNA-AuNP concentration by using a paper-based device.

T4P.058 **DESIGN AND FABRICATION OF MULTI-CONTACT FLEXIBLE SILICON PROBES FOR INTRACORTICAL FLOATING IMPLANTATION** **1739**
A. Schander, E. Tolstosheeva, V. Biefeld, L. Kempen, H. Stemmann, A. Kreiter, and W. Lang
University of Bremen, GERMANY

This paper reports on a novel design and process flow development for the fabrication of multi-contact silicon probes with monolithically integrated highly flexible ribbon cables on wafer level. Compared to the state of the art silicon probes, this novel development allows for the first time a floating intracortical implantation with reduced destructive forces applied to the brain tissue.

T4P.059 **BASKET FORCEPS WITH FLOW SENSOR FOR EVALUATING BREATHING CHARACTERISTICS IN SMALL AIRWAY** **1743**
N. Harada[1], R. Ono[2], M. Matsushima[2], T. Kawabe[2], and M. Shikida[1]
[1]*Hiroshima City University, JAPAN and* [2]*Nagoya University, JAPAN*

This paper challenged to develop a basket forceps with flow sensor for evaluating the breathing characteristics in small airway, for the first time. The MEMS flow sensor was integrated onto a guide wire with a simulated basket forceps. The sensor was successfully fixed in the inside surface of a small tube by bending arms in the basket forceps, and we finally confirmed that the breathing properties of rat was successfully detected by the integrated flow sensor.

T4P.060 **FAILURE MODE ANALYSIS OF AL_2O_3 - PARYLENE C BILAYER ENCAPSULATION FOR IMPLANTABLE DEVICES AND APPLICATION TO PENETRATING NEURAL ARRAYS** **1747**
R. Caldwell[1], L. Rieth[1], X. Xie[2], R. Sharma[1], F. Solzbacher[1], and P. Tathireddy[1]
[1]*University of Utah, USA and* [2]*Blackrock Microsystems, USA*

We develop and characterize a strategy for incorporating atomic-layer-deposited aluminum oxide underneath parylene C as a bilayer encapsulation technique for implantable neural devices. Impedance spectra of devices subject to in vitro lifetime testing are analyzed to evaluate benefits of bilayer encapsulation versus parylene C alone. Failure modes associated with device features and topographies are identified and solutions are presented that promote stability of device impedance.

T4P.061 **A THIN FILM FLEXIBLE ANTENNA WITH CMOS RECTIFIER CHIP FOR RF-POWERED IMPLANTABLE NEURAL INTERFACES.....1751**
K. Okabe, I. Akita, S. Yamagiwa, T. Kawano, and M. Ishida
Toyohashi University of Technology, JAPAN

We propose a parylene film antenna integrating a CMOS rectifier chip for wireless neural recording devices. An implanted antenna requires the flexibility to fit the shape of brain surface. In addition, an integrating technology with solid-state and flexible substrate is needed because a silicon chip can provide high-performance and multi-functionality. The fabricated device that packages antenna, transformer, and rectifier generates more than 1.5V and achieves a power transmission efficiency of 0.086%.

WEDNESDAY - Medical Microsystems

W2P.055 **DETECTION OF BOTH HEARTBEAT AND RESPIRATION SIGNALS FROM AIRFLOW AT MOUTH BY SINGLE CATHETER FLOW SENSOR.....1755**
H. Kawaoka[1], T. Yamada[2], M. Matsushima[2], T. Kawabe[2], and M. Shikida[1]
[1]Hiroshima City University, JAPAN and [2]Nagoya University, JAPAN

This paper challenged to detect both heartbeat and respiration signals from the airflow at mouth by a single catheter flow sensor, for the first time. An endotracheal intubation tube with the flow sensor was developed, and it was applied to an airway in rat. At first, the airflow rate mostly dominated by the respiration signal was measured. Then, the both heartbeat and respiration signals were successfully extracted from the airflow waveform by filters.

W2P.056 **A NOVEL METHOD OF FABRICATING HIGH CHANNEL DENSITY NEURAL ARRAY FOR LARGE NEURONAL MAPPING.....1759**
M.M.H. Shandhi[1], M. Leber[1], A. Hogan[2], R. Bhandari[2], and S. Negi[1]
[1]University of Utah, USA and [2]Blackrock Microsystems, USA

We are presenting a technology to fabricate high channel density neural array. This new array, Utah Multi-sites Electrode Array (UMEA), is capable to have 9 channels per shaft with channel density of 56.25 sites/mm2, which is 9 times more than that of the conventional Utah Electrode Array (UEA). The UMEA will have 900 active sites. With the UMEA we will not only map large area of brain but also will be able to access different layers of human cortex.

W2P.057 **POLYDIMETHYLSILOXANE STRAIN GAUGES FOR BIOMEDICAL APPLICATIONS.....1763**
M. Zens[1], J. Ruhhammer[1], F. Goldschmidtboeing[1], M.J. Feucht[2], A. Bernstein[2], P. Niemeyer[2], H.O. Mayr[2], and P. Woias[1]
[1]*University of Freiburg - IMTEK, GERMANY and* [2]*University Medical Center Freiburg, GERMANY*

This paper reports on novel, fully polymericcapacitive strain gauges and their biomedical applications. Specifically the determination of ligament and tendon elongation at the human knee is shown here. The concept, fabrication, testing and successful application of these sensors is described, together with results of a first clinical study. Further applications and the possible impact for biomechanical studies are discussed.

W2P.058 **FILTRATION MEMBRANE WITH ULTRA-HIGH POROSITY AND PORE SIZE CONTROLLABILITY FABRICATED BY PARYLENE C MOLDING TECHNIQUE FOR TARGETED CELL SEPARATION FROM BRONCHOALVEOLAR LAVAGE FLUID (BALF) 1767**
Y. Liu, W. Wang, W. Wu, H. Li, F. Yang, and W. Wang
Peking University, CHINA

This paper presented an effective Parylene C molding technique to prepare micropore arrayed membrane with an ultra-high porosity up to 90.9% and pore size controllability. Bronchoalveolar lavage fluid (BALF) with spiked rare cancer cells was sequentially filtrated through membranes with different pore sizes. The preliminary results indicated that the present multiplex filtration device can get a high targeted cell separation yield of 96.5% and purity of 100% with throughput as high as 2 mL/min.

W2P.059 **IMPLANTABLE ENZYME FREE GLUCOSE SENSOR BASED ON FLEXIBLE STAINLESS STEEL FOR CONTINUOUS MONITORING AND MASS PRODUCTION.....1770**
H.S. Yoon, X. Xuan, and J.Y. Park
Kwangwoon University, SOUTH KOREA

We develop implantable and non-enzymatic sensor for continuous glucose monitoring based on flexible and medical grade stainless steel. The proposed glucose sensor provides better reliability and lower production cost since all the materials used are metals and there is low residual stress between has simple fabrication steps which are compatible to mass-production. It also has much larger active surface area resulting in smaller size and higher sensitivity.

W2P.060 **HIGH-RESOLUTION NEURAL DEPTH PROBE WITH INTEGRATED 460 NM LIGHT EMITTING DIODE FOR OPTOGENETIC APPLICATIONS** **1774**

M. Schwaerzle, F. Pothof, O. Paul, and P. Ruther
University of Freiburg - IMTEK, GERMANY

We report on the design, assembly, and optical as well as thermal characterization of a polymer-based optrode with an integrated light source for optogenetics. The novel depth probe allows to optically stimulate neural activity in deeper brain regions and simultaneously record brain activity using integrated macro- and microelectrodes. The optrode is based on a cylindrical polyimide probe carrying electrodes and the integration of a bare light emitting diode chip within this cylindrical probe.

MONDAY - Microfluidics

M3P.063 **A TUBING-FREE MICROFLUIDIC WOUND-HEALING ASSAY QUANTIFYING VASCULAR SMOOTH MUSCLE CELL MIGRATION** **1778**

Y.C. Wei[1], F. Chen[2], T. Zhang[3], D.Y. Chen[1], X. Jia[2], J.H. Tong[1], J.B. Wang[1], W. Guo[2], and J. Chen[1]
[1]*Chinese Academy of Sciences, CHINA,* [2]*Chinese PLA General Hospital, CHINA, and*
[3]*Peking University People's Hospital, CHINA*

In this study, we proposed a microfluidic wound healing assay enabling the quantification of migration of vascular smooth muscle cells where gravity was used to facilitate cell seeding and culture, wound generation, cell migration and on-chip staining of alpha actin.

M3P.064 **SIMPLE VALVES ON A PDMS MICROCHIP BONDED VIA PATTERNED OXYGEN PLASMA** **1782**

T. Kawai[1,2], H. Moriguchi[1], and Y. Tanaka[1,3]
[1]*Institute of Physical and Chemical Research (RIKEN), JAPAN,*
[2]*Japan Science and Technology Agency (JST), JAPAN, and* [3]*Osaka University, JAPAN*

The simplest form of microfluidic valve was fabricated via oxygen plasma patterning on a PDMS chip. New plasma patterning method based on a ''shielding effect'' of sacrificial metal layer was investigated in detail, which indicates the superior performance to the “deactivation effect” of conventional stamp method. Due to its simplicity, long term injection was easily carried out. The 3D valve-opening mechanism was finally examined both experimentally and theoretically.

M3P.065 **ELECTROCHEMICAL BIDIRECTIONAL MICROPUMP FOR PROCESSING OF LIQUID PLUGS** **1786**

H. Obata, T. Kuji, M. Yokokawa, and H. Suzuki
University of Tsukuba, JAPAN

This paper introduces an electrochemical micropump and a novel method for autonomous programmed operation of the micropump. Bidirectional movement of a solution in a microfluidic channel was realized by producing and shrinking hydrogen bubbles on a platinum black electrode. The pump could be operated autonomously by changing the mixed potential, which was realized by coupling the reduction and oxidation of protons/hydrogen with the oxidation (dissolution) of zinc and deposition of silver on elec

M3P.066 **MAGNETIC DROPLET MANIPULATION INCORPORATED WITH ACOUSTIC EXCITATION** **1790**

K.Y. Lee, Y.R. Lee, and S.K. Chung
Myongji University, SOUTH KOREA

This paper reports a new type of magnetic droplet manipulation method incorporated with acoustic excitation, which will allow not only the enhancement of mixing performance but also usability based on the selective droplet oscillation technique for point-of-care molecular diagnostic systems.

M3P.067 **HIGH-THROUGHPUT MANUFACTURING OF POLYMER NANOFIBERS VIA ELECTROHYDRODYNAMIC JETTING FROM PLANAR ARRAYS OF MICROFABRICATED EXTERNALLY-FED EMITTERS** **1794**

P.J. Ponce de Leon, F.A. Hill, E.V. Heubel, and L.F. Velásquez-García
Massachusetts Institute of Technology, USA

We designed, fabricated, and characterized novel high-throughput MEMS polymer nanofiber sources. The devices are planar arrays of high-aspect-ratio silicon emitters with surfaces covered by an array of micropillars that enable surface tension-driven feed of liquid to the emitter tips. The sources are assembled from monolithic linear arrays of emitters etched out of a silicon wafer using deep reactive-ion etching. Experimental data show the design can be scaled up with no loss of productivity.

M3P.068 **FULLY INTEGRATED MICROFLUIDIC MEASUREMENT SYSTEM FOR REAL-TIME DETERMINATION OF GAS AND LIQUID MIXTURES COMPOSITION** 1798

J.C. Lötters[1,2], J. Groenesteijn[2], E.J. van der Wouden[1], W. Sparreboom[1], T.S.J. Lammerink[2], and R.J. Wiegerink[2]
[1]*Bronkhorst High-Tech BV, THE NETHERLANDS and* [2]*MESA+ University of Twente, THE NETHERLANDS*

We have designed and realised a fully integrated microfluidic measurement system for real-time determination of both flow rate and composition of gas- and liquid mixtures. The system comprises electrical impedance sensors, a Coriolis flow and density sensor, a thermal flow sensor, pressure sensors, a thermal conductivity sensor and a sensor for the dielectric constant. We demonstrated the feasibility to determine the composition of several different mixtures of nitrogen, water and IPA.

M3P.069 **BACTERIAL CELL TRANSPORTATION IN PAPER-BASED MICROFLUIDICS** 1802

G. Choi and S. Choi
State University of New York, Binghamton, USA

We provided a new technique to monitor the flow of bacterial cells in paper. This was based on real-time measuring of the electricity generated from bacterial metabolism. Our device contained three hydrophilic spots linked through hydrophilic channels on paper and each spot came into contact with an anode electrically connected to a cathode through an external load. When bacterial cells were transported to each spot by capillary force, the current generated from bacteria was monitored.

TUESDAY - Microfluidics

T4P.062 **AUTONOMOUS MICROFLUIDICS REALIZED WITH ACTIVE HYDROPHOBIC VALVES** 1806

G.C. Biswas, T. Watanabe, E.T. Carlen, M. Yokokawa, and H. Suzuki
University of Tsukuba, JAPAN

Efficient sophisticated microfluidic systems can be realized using simple valves based on switching from a hydrophobic state to a hydrophilic state. A hydrophobic self-assembled monolayer (SAM) was formed on a platinum electrode in a flow channel surrounded by hydrophobic walls of poly (dimethylsiloxane) (PDMS). A solution moves in parts of the flow channel other than the valve region by capillary action but stops at the valve.

T4P.063 **A CONTINUOUS FLOW MICROFLUIDIC CHIP WITH INTEGRATED CONCENTRATION GRADIENT GENERATOR FOR CELL CULTURING** 1810

H. Kreher, I.N. Dahmke, H. Seidel, and D. Feili
Saarland University, GERMANY

In this work a continuous flow microfluidic Si-glass chip is fabricated for passive generation of a binary logarithmic concentration profile with ten dilutions of an arbitrary fluid in a buffer, including ten integrated cell culture wells. Two designs with different etch depths and different surface coatings are compared regarding their fluidic resistances and performance. For analysis three methods were used for measuring the concentration profile at the outlets.

T4P.064 **BANDPASS PARTICLE SORTING IN CASCADE ACOUSTOFLUIDIC SYSTEM FOR DRINKING WATER MONITORING** 1814

Y. Xia[1], L. Lei[1], E.P.H. Yap[1], H.D. Sun[1], Y. Liu[1], Z.C. Yang[2], and A.Q. Liu[1]
[1]Nanyang Technological University, SINGAPORE and [2]Peking University, CHINA

This paper demonstrates the bandpass particle sorting by using a cascade acoustofluidic system, in which the targeting particle size is tunable by adjusting the applied voltage. The relationship of particle motion, particle size and applied voltage is discussed. The sorting of 10-μm and 5-μm particles are experimentally demonstrated with a recovery as high as 90% and 80% elimination rate of undesired particles. It shows a high potential for different microbial sorting in drinking water monitor.

T4P.065 **VISUALIZATION OF SELF-LIMITING ELECTROCHEMICAL GAS GENERATION TO RECOVER UNDERWATER SUPERHYDROPHOBICITY** 1818

R.T. Freeman[1], A.C. Houck[2], and C.J. Kim[1]
[1]*University of California, Los Angeles, USA and* [2]*Massachusetts Institute of Technology, USA*

We investigate an electrochemical gas recovery mechanism that enables long-term superhydrophobic state underwater. In addition to directly visualizing the self-initiation and self-termination of electrochemical gas generation at liquid impalement and full gas recovery of a microtrench, respectively, we characterize the recovery mechanism at varying initial wetting states and hydrostatic pressures.

T4P.066 **ENCAPSULATION OF INTEGRATED CIRCUITS IN PLASTIC MICROFLUIDIC SYSTEMS USING HOT EMBOSSING** **1822**

V. Iyer[1], P. Murali[1], J. Paredes[2], D. Liepmann[1], and B. Boser[1]
[1]*University of California, Berkeley, USA and* [2]*Tecnun, University of Navarra, SPAIN*

This paper reports a novel method of fabricating thermoplastic microfluidic cartridges with integrated electronic circuits and microelectrodes compatible with standard connectors using a hot embossing process. The fabrication methodolgy is used to demonstrate the effectiveness of on chip magnetophoretic focusing applied to a chip scale magnetic label flow cytometer.

T4P.067 **ON-CHIP SEPARATION METHOD USING A BUBBLE FOR BIO/MICRO-OBJECT MANIPULATION** **1826**

J.H. Seo, S.H. Oh, J.P. Jeon, and S.K. Chung
Myongji University, SOUTH KOREA

This paper presents a novel on-chip microseparator where microparticles in aqueous medium are separated and collected by size using an acoustically excited bubble as a mechanical filter.

T4P.068 **A VISCOMETER ARRAY BASED ON DYNAMIC RESPONSE OF DROPLETS DRIVEN BY DIELECTRIC FORCE** **1830**

K.W. Liao[1], R.C. Luo[1], M.T. Hou[2], and J.A. Yeh[1,3]
[1]*National Tsing Hua University, TAIWAN,* [2]*National United University, TAIWAN, and*
[3]*Instrument Technology Research Center, TAIWAN*

We present a novel viscometer array based on dynamic response of droplets driven by dielectric force. Each sensing element contains a small testing droplet. When applying a bias voltage between the electrodes, the droplet would change its shape due to the dielectric force. The capacity between the upper electrodes changes. The viscosity of droplet was measured from the time constant of the step response. The results show the sensing range of viscometer array is 10 to 200 cSt less than 1000 ms.

T4P.069 **MAGNETIC LIQUID METAL MARBLE: WIRELESS MANIPULATION OF LIQUID METAL DROPLET FOR ELECTRICAL SWITCHING APPLICATIONS** **1834**

J.P. Jeon[1], J.-B. Lee[2], S.K. Chung[1], and D. Kim[3]
[1]*Myongji University, SOUTH KOREA,* [2]*University of Texas at Dallas, USA, and*
[3]*Korea Army Academy at Yeongcheon, SOUTH KOREA*

We report a magnetic liquid metal marble which enables the wireless on-demand manipulation of a liquid metal droplet for electrical switching applications with an applied magnetic field.

WEDNESDAY - Microfluidics

W2P.061 **GENERATION OF LOW-TEMPERATURE ATMOSPHERIC PRESSURE PLASMA-JET PATTERNABLE ARRAY AT A 320μM PITCH CHANNEL ARRAY** **1838**

T. Ihara, H. Yamasaki, K. Terao, T. Suzuki, F. Shimokawa, and H. Takao
Kagawa University, JAPAN

In this study, a novel device to create patternable atmospheric-pressure plasma-jet array at a fine-pitch has been developed, and the evaluation results of the fabricated devices are reported. Micro plasma jet array are created by multi-channel gas discharges individually controlled in microfluidic channels on a silicon chip, and 320μm pitch plasma jet array has been demonstrated. A photoresist sample was exposed to two plasma jets, and 1.0μm/min etching rate was obtained at a 30mW.

W2P.062 **ENRICHMENT AND SEPARATION OF MICRODROPLET CONTENTS** **1842**

M. Fukuyama[1,2] and A. Hibara[1]
[1]*Tokyo Institute of Technology, JAPAN and* [2]*Kyoto Institute of Technology, JAPAN*

Microdroplet operations based on spontaneous nanodroplet formation (spontaneous emulsification) seem feasible for the selective enrichment and separation. In a recent paper, the enrichment characteristics have been verified. In this paper, selectivity of the method is discussed, and its application to biological enrichment / separation is demonstrated.

W2P.063 **ON DEMAND EWOD DROPLET FORMATION AT A MICROFLUIDIC T-JUNCTION** **1846**

K. He, A. Ahmadi, K. Walus, and B. Stoeber
University of British Columbia, CANADA

This paper illustrates a new method for creating air separated droplets on demand at a microfluidic T-junction in a microchannel using electrowetting-on-dielectric (EWOD). This new mechanism enables digital control that is not achievable by conventional continuous flow T-junction systems. The developed system can be used for dispensing droplets of different materials for numerous biomedical applications including high throughput screening without further liquid processing.

W2P.064 ENHANCEMENT OF RADIOACTIVE DECONTAMINATION IN MICROALGAE USING DIELECTROPHORESIS BASED SCREENING 1850
C. Wang[1], K.A. Lee[1], E. Choi[1], K.-Y. Lee[2], S.-Y. Lee[1], K.-H. Jung[1], and J. Park[1]
[1]*Sogang University, SOUTH KOREA and* [2]*Korea Atomic Energy Research Institute, SOUTH KOREA*

This paper reports a dielectrophoresis (DEP) based screening microplatform to select the specific microalgae, which have the enhanced potential for removing radioactive nuclide. Microalgae Chlorella vulgaris which has high contents of strontium, can be collected by finding the particular crossover frequency over the other that has relatively low strontium contents. Based on this, we design a novel screening microplatform considering easy separation and collection.

W2P.065 SIZE AND DEFORMABILITY-BASED PARTICLE SORTING BY STRATEGIC DESIGN OF OBSTACLE ARRAYS IN CONTINUOUS CENTRIFUGAL SEDIMENTATION MODE 1854
C.E. Nwankire, I. Maguire, D. Kernan, M. Glynn, D. Kirby, and J. Ducrée
Dublin City University, IRELAND

We describe a novel, smart grid technique for isolating, sorting and capturing cancer cells based on size and deformability by deterministic lateral displacement (DLD). In stopped-flow, centrifugal sedimentation mode, the bioparticles (5 - 30 µm) are size-selectively displaced in a deterministic fashion along dynamically spaced grid of the micro-structures. Following displacement, the particles and cells are subsequently captured in claw-like structures for onward processing.

W2P.066 FLOATING-FLOWER INSPIRED CELL CULTURE PLATFORM FOR SIMPIFYING MEDIUM EXCHANGE BASED ON ELASTO-CAPILLARITY 1857
H. Hong, S.J. Park, M.H. Na, S.M. Park, and D.S. Kim
Pohang University of Science and Technology (POSTECH), SOUTH KOREA

We developed a floating flower-inspired cell culture platform based on elasto-capillarity. This flower shaped PDMS platform can capture and dispense a medium with simple motions of pulling up and dipping down. Thus, this platform can simplified the cell culture medium exchange process without use of containers and pipettes.

W2P.067 MICROFLUIDIC CHIP FOR RAPID ELECTROFUSION OF HOMOGENEOUS AND HETEROGENEOUS CELLS 1861
G.P. Pendharkar[1], C.-H. Lu[1], Y.-T. Lu[2], A. Chang[2], and C.-H. Liu[1]
[1]National Tsing Hua University, TAIWAN and [2]Mackay Memorial Hospital, TAIWAN

We present a cell electrofusion chip fabricated using soft lithography technique, which combines the rapid and precise cell pairing microstructures and the high yield electrofusion micro-electrodes for the cell fusion. The design uses hydrodynamic trapping in combination with positive dielectrophoretic force (pDEP) to achieve cell fusion. We observe pairing efficiency of 68% with fusion efficiency of64%.

W2P.068 CONSTRUCTUNG 3D CELL-LADEN HYDROGELS ON ELECTROMOLDING 1865
Y.-H. Lai and S.-K. Fan
National Taiwan University, TAIWAN

We proposed an electro-microfluidic lithography technique instead of convection lithography. Simultaneously manipulating multi pre-polymer solution and forming microstructures. Constructing cells laden hydrogels for 3D scaffolds and culturing cells. Compare with convection, cells will growth in 3D and aligned hydrogel boundary. Which approaching bio-environment for cells growing in vitro environment.

W2P.069 CHARACTERISTIC PARAMETER ESTIMATION FOR SINGLE-PARTICLE BASED ON DIELECTROPHORETIC AND HYDRODYNAMIC EFFECTS 1869
J. Xu, R. Zhu, and X.L. Guo
Tsinghua University, CHINA

We reports a micro-electrode-array chip and a novel methodology to characterize parameters of single particle in virtue of the equilibrium between dielectrophoretic(DEP) force and Stokes' drag force by using the microchip and microfluidic control. Compared to conventional ways of particle measurement, the proposed method is superior in simplicity, precision, single particle sensitivity and high throughput.

POSTER/ORAL PRESENTATIONS

MONDAY - Composite Materials/ Polymers, Devices and Fabrication

M3P.070 **THERMAL ELASTOMER COMPOSITES FOR SOFT TRANSDUCERS** **1873**

S.H. Jeong[1], S. Chen[2], J. Huo[1], L. Gravier[3], K. Gamstedt[1], J. Liu[2],
S.-L. Zhang[1], Z.-B. Zhang[1], Z.G. Wu[1,4], and K. Hjort[1]
[1]*Uppsala University, SWEDEN,* [2]*Chalmers University of Technology, SWEDEN,*
[3]*Haute École d'Ingénierie et de Gestion (HEIG-VD), SWITZERLAND, and*
[4]*Huazhong University of Science and Technology, CHINA*

A thermal elastomer composite that is electrically insulating has potential uses in soft transducers targeted at thermal sensors and actuators, or thermoelectric generators. In this work, such composites were prepared by dispersing a gallium based liquid alloy (Galinstan) in polydimethysiloxane (PDMS). The composites were highly elastic and showed an up to three fold increase in thermal conductivity from that of PDMS. A thermoelectric device with TEC packaging was demonstrated.

M3P.071 **MICROMANIPULATION TOOL REPLACEABLE SOFT ACTUATOR WITH GRIPPING FORCE ENHANCING AND OUTPUT MOTION CONVERTING MECHANISMS** **1877**

G.H. Feng and S.C. Yen
National Chung Cheng University, TAIWAN

We develop an arched ionic polymer metal composite (IPMC) actuator for micromanipulating soft matters (e.g. cells). With a unique design, versatile designed micro-tools can be individually installed onto and replaced from the actuator. Two micro-tools of scissor-type gripper and elastic pin structure are demonstrated to strengthen the clamping force of the gripper and convert a squeeze/pull motion to forward/backward motion.

M3P.072 **LASER MICROFABRICATION OF GOLD NANOPARTICLES DISPERSED POLYMER FILM WITH NANOPARTICLE SIZE CONTROL** **1881**

T. Kikitsu, Y. Yagoto, M. Ogawa, and H. Yagyu
Kanto Gakuin University, JAPAN

We report laser microfabrication technique of a polymer film using absorbance of Au nanoparticles for realizing nano-microstructure. Four size of Au nanoparticles was prepared using liquid-phase reduction method and newly developed size control technique. The polymer films with Au nanoparticles of different size was processed by Nd:YVO4-SHG laser. In this paper, optimal nanoparticle size and laser processing condition was demonstrated for realizing fine micropattern on the polymer film.

TUESDAY - Composite Materials/ Polymers, Devices and Fabrication

T4P.070 **SOLVATO-MORPHOLOGICALLY CONTROLLED, REVERSIBLE PHOTO-ACTUATED HYDROGELS, OPERATIVE IN NEUTRAL ENVIRONMENTS** **1885**

A.C.M. Dunne, L. Florea, and D. Diamond
Dublin City University, IRELAND

In this study, solvato-morphologically controlled photo-responsive hydrogel actuators were generated. These hydrogels consisted of a copolymer of N-isopropylacrylamide, acrylic acid and spiropyran photochromic molecule in a 100-5-1 mole ratio. The hydrogel morphology was controlled by changing the polymerisation solvent, which resulted in each hydrogel consisting of different pore densities thus showing different photo-actuation responses.

T4P.071 **WIRELESS SCREENNING OF DEGRADATION KINETICS IN PHARMACEUTICAL GELATIN FILMS** **1889**

H. Jiang, M. Ochoa, J.H. Park, A. Otte, R. Pinal, and B. Ziaie
Purdue University, USA

We have developed a wireless sensing scheme for rapid screening of gelatin film degradation. The technique imparts dissolution-dependent magnetic properties by incorporating ferromagnetic nanoparticles into the gelatin film. The degradation kinetic is then measured wirelessly to identify the swelling and dissolution phases of the gelatin film.

T4P.072 **MOVEMENT OF MAGNETORHEOLOGICAL FLUID USING THE ROTATION OF CHAINLIKE MAGNETIC-PARTICLES DRIVEN BY ROTATION MAGNETIC FIELD** **1893**

F.-M. Hsu, C.-E. Lu, and W. Fang
National Tsing Hua University, TAIWAN

We present a novel technology to move the MR fluid using the rotation of magnetic-particles. While driven by in-plane dynamic magnetic field, the chainlike magnetic particles inside MR fluid are rotated out-of-plane and further cause the motion of MR fluid. In application, we measured the MR fluid movement speed and direction by varying the following conditions: weight fraction and length of magnetic powders, strength and angular speed of applied magnetic field, and pattern of spiral channel.

POSTER/ORAL PRESENTATIONS

WEDNESDAY - Composite Materials/ Polymers, Devices and Fabrication

W2P.070 **A HIGHLY STRETCHABLE pH SENSOR ARRAY USING ELASTOMER-EMBEDDED LASER CARBONIZED PATTERNS** **1897**

R. Rahimi, M. Ochoa, W. Yu, and B. Ziaie

Purdue University, USA

This paper reports on a facile and low cost method to fabricate highly stretchable pH sensor arrays for biomedical applications. The technique uses laser carbonization of a thermoset polymer followed by its transfer and embedment onto an elastomeric matrix. The process combines selective laser carbonization with meander interconnects methodology to fabricate stretchable conductive composites. The stretchable pH sensors display a sensitivity of -51mV/pH and stable for strains of up to 50%.

W2P.071 **FLEXIBLE SCREEN-PRINTED PIEZOELECTRIC P(VDF-TRFE) COPOLYMER MICROGENERATORS FOR ENERGY HARVESTING** **1901**

E. Gusarova[1], B. Viala[1], A. Plihon[1], B. Gusarov[2], L. Gimeno[2], and O. Cugat[2]

[1]*CEA, FRANCE and* [2]*University of Grenoble, FRANCE*

We present a fabrication method and characterization results showing energy harvesting capabilities of screen-printed polyvinylidene fluoride trifluoroethylene (P(VDF-TrFE)) flexible microgenerators. Remarkably high voltage is measured in open-circuit quasi-static conditions and the direct g31 voltage coefficient of P(VDF-TrFE) thin films is reported for the first time. High flexibility of the device is demonstrated.

W2P.072 **VERSATILE FABRICATION OF PDMS-CARBON ELECTRODES FOR SILICONE DIELECTRIC ELASTOMER TRANSDUCERS** **1905**

O.A. Araromi, S. Rosset, and H.R. Shea

École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We report a novel method for the fabrication of poly(dimethylsiloxane) (PDMS)-carbon composite electrodes for silicone dielectric elastomer transducers. The methodology combines patterning by laser ablation and oxygen plasma induced bonding, producing stretchable devices with exceptional electrode adhesion and high mechanical robustness. The methodology also offers great flexibility in device design, being able to realize large electrodes (> 100 cm^2) whilst maintaining micro-scale resolution.

MONDAY - Energy and Power MEMS/ Magnetic Sensors

M3P.073 **BETAVOLTAIC MICROBATTERIES USING TIO_2 NANOTUBE ARRAYS** **1909**

Q. Zhang[1], R.B. Chen[1], H.S. San[1], G.H. Liu[2], and K.Y. Wang[2]

[1]*Xiamen University, CHINA and* [2]*Buskerud and Vestfold University College, NORWAY*

A sandwich-type metal/TiO2 nanotube(TNT)array/metal structure under build-in contact potential difference was presented. The sandwiched structure is constructed by integrating a radioisotope 63Ni planar source on Ni substrate to the TNT arrays on Ti foil. Under irradiation of the 63Ni source with activity of 8 mCi, the TNT- betavoltaic presents optimum energy conversion with open-circuit voltage of 1.54V, short-circuit current of 12.43 nA, and effective energy conversion efficiency of 7.30%.

M3P.074 **INDIRECT IMPACT BASED PIEZOELECTRIC ENERGY HARVESTER FOR LOW FREQUENCY VIBRATION** **1913**

S. Ju and C.-H. Ji

Ewha Womans University, SOUTH KOREA

This paper presents an impact based piezoelectric vibration energy harvester using freely movable metal spheres as proof mass and an MFC beam as a piezoelectric cantilever. External vibration is transformed into free motion of metal spheres inside the channels and impact between the metal sphere and channel end induces a vibration of the MFC beam to generate electric power. Maximum open circuit voltage of 38.8V and RMS output power of 316μW have been achieved.

M3P.075 **3D CNT-GRAPHENE NETWORKS AND THEIR APPLICATION IN SUPERCAPACITORS** **1917**

X. Zang and L. Lin

University of California, Berkeley, USA

We develop a two-step CVD process to fabricate 3D CNT-Graphene electrode which further enhanced the performance in supercapacitors. Results show the enhancements of capacitance after the graphene and second CNT synthesis processes by 2.24 and 3.19 times, respectively, as compared with the electrodes made of CNT/Ni forests or 16.1 and 25.5 time as compared with the electrodes made of bare CNT forests.

M3P.076 **A BIOLOGICAL SOLAR PANEL** 1921
H. Lee and S. Choi
State University of New York, Binghamton, USA

We report a proto-type scalable and stackable biological solar panel by installing miniature bio-solar cells in an array format. Nine small-scale bio-solar cells were integrated in a panel along with a common feed microfluidic channel. The bio-solar panel continuously generated electricity from microbial photosynthetic and respiratory activities under day-night cycles.

TUESDAY - Energy and Power MEMS/ Magnetic Sensors

T4P.073 **IN-PLANE GAP-CLOSING MEMS VIBRATION ELECTRET ENERGY HARVESTER ON THICK BOX LAYER** 1925
Q.Y. Fu and Y. Suzuki
University of Tokyo, JAPAN

In this report, an improved in-plane electret energy harvester with gap-closing comb drives has been developed with a single-mask SOI process. By using 150 µm-thick device layer for increasing the seismic mass and 15 µm-thick buried oxide layer for reducing the parasitic capacitance, up to 5.3 µW output power has been obtained at 503 Hz, which is equivalent of five times higher power output than our previous prototype.

T4P.074 **IMPLEMENTATION OF STACKABLE PHOTOSYNTHETIC MICROBIAL FUEL CELL STRUCTURE USING STAINLESS STEEL MESH MEMBRANE ELECTRODE ASSEMBLY** 1929
J.G. Ha[1], S.K. Lee[2], S.J. Bai[2], Y.S. Song[2], Y.K. Kim[1], Y.M. Shin[1], and J.H. Park[2]
[1]*Seoul National University, SOUTH KOREA and* [2]*Dankook University, SOUTH KOREA*

This paper presents a fabrication and measurement of stackable photosynthetic microbial fuel cell with integrating two cathode chambers in unit cell that increases surface power density compared to conventional photosynthetic MFC structures. Stackable MFC is realized by newly proposed membrane electrode assembly structure which includes proton exchange membrane and stainless steel mesh anode.

T4P.075 **NOVEL ENERGY HARVESTING USING ACOUSTICALLY OSCILLATING MICROBUBBLES** 1933
J.P. Jeon[1], J. Hong[2], Y.R. Lee[1], J.H. Seo[1], S.H. Oh[1], and S.K. Chung[1]
[1]*Myongji University, SOUTH KOREA and* [2]*Pohang University of Science and Technology (POSTECH), SOUTH KOREA*

This paper reports a novel actuator for energy harvesting from ambient acoustic noise using acoustically oscillating bubbles in an aqueous medium. When a bubble sitting on a piezocantilever is excited by an acoustic wave, it generates cavitational microstreaming. The microstreaming bends the piezocantilever, resulting in electric power generation from the piezocantilever. It is a simple but useful tool not only for the energy harvesting but also potential acoustic wave sensors and actuators.

T4P.076 **CHARGE TRANSPORT IN SiO_2/Si_3N_4 AND SiO_2/Si-RICH SiN ELECTRETS FOR HIGH-TEMPERATURE ELECTROSTATIC ENERGY MICRO-HARVESTERS** 1937
K. Goda[1], T. Yoshioka[1], K. Ao[1], R. Abe[1], and O. Paul[2]
[1]*DENSO Corporation, JAPAN and* [2]*University of Freiburg - IMTEK, GERMANY*

We develop SiO_2/Si_3N_4 and SiO_2/Si-rich nitride electrets which has a high surface charge density, good thermal and long-term stability. In order to understand the charge retention characteristics of these electrets from the point of view of lateral and vertical charge transport, current density-electric field (J-E) analysis and partial charging experiments are conducted.

T4P.077 **A SMART ENERGY-HARVESTER WITH THE ACTION OF ELECTRIC-POWER GENERATING TRIGGERED BY PRE-SET VIBRATION THRESHOLD** 1941
Q.C. Tang[1,2], Q. He[1,2], and X. Li[1,2]
[1]*Chinese Academy of Sciences, CHINA and* [2]*University of Chinese Academy of Sciences, CHINA*

We reports a novel piezoelectricenergy-harvesting device that generateselectric-power only when the concerned vibrationlevel reaches a critical threshold. The thresholdtriggering function (equivalent to that of a sensingswitch) is achieved by magnetic repulsive couplingbetween two vibratory stages (namely sensing-stageand generating-stage) integrated in the device. Thethreshold can be pre-set by adjusting thegap-distance between the two stages.

POSTER/ORAL PRESENTATIONS

WEDNESDAY - Energy and Power MEMS/ Magnetic Sensors

W2P.073 **FREQUENCY-TUNABLE AIRFLOW ENERGY HARVESTER USING VARIABLE APERTURE HELMHOLTZ RESONATOR AND PIEZOELECTRIC CANTILEVER** **1945**

K.X. Wang[1], L. Bu[1], J.M. Chen[1], and L. Song[2]
[1]*China University of Geosciences, CHINA and* [2]*State Grid Jibei Electric Power Co., Ltd., CHINA*

A novel airflow energy harvester using variable aperture Helmholtz resonator and piezoelectric cantilever is presented. At 15m/s airflow velocity, the 0.8-11mm variable aperture achieves 76-328Hz resonant frequency range. The harvester achieves maximally 1.6V at 6mm optimal aperture diameter @221Hz frequency. Peak-to-peak voltage and optimal aperture diameter change as the airflow velocity changes. An active tuning circuit is presented to improve output voltage at varying airflow velocity.

W2P.074 **A WRIST-BAND COUPLED, HUMAN SKIN BASED TRIBOELECTRIC GENERATOR FOR HARVESTING BIOMECHANICAL ENERGY** **1949**

M.S. Rasel, M.A. Halim, H.O. Cho, and J.Y. Park
Kwangwoon University, SOUTH KOREA

This paper presents a human skin based Triboelectric Generator (TEG) coupled to a light and flexible wrist-band to be used for wearable smart device applications. It introduces a cost effective and feasible fabrication method of a micro-structured thin Polydimethylsiloxane (PDMS) film as one of the triboelectric layers, the other layer being the human skin. The fabricated prototype is capable of generating an open circuit voltage of 28.2V and 12μW peak power by mild finger pressing.

W2P.075 **A BUCKLED MEMBRANE SENSOR FOR *IN SITU* MECHANICAL AND MICROSTRUCTURE ANALYSIS OF LI-ION BATTERY ELECTRODES** **1953**

H. Jung, C.-F. Lin, K. Gerasopoulos, G. Rubloff, and R. Ghodssi
University of Maryland, USA

This work presents the first demonstration of a buckled membrane sensor for *in-situ*, simultaneous characterization of stress and microstructure evolutions in a V_2O_5 lithium-ion battery cathode during cycling. The thin membrane is coated with V_2O_5 on the backside and enables atomic force microscopy (AFM) and Raman spectroscopy from the topside. Using dual-mode measurements, both the induced stress and Raman intensity changes due to lithium cycling are successfully observed.

W2P.076 **A NOVEL CIRCULAR MICRO-PLASMA MAGNETIC FIELD SENSOR** **1957**

O. Fawole and M. Tabib-Azar
University of Utah, USA

We report a new device that uses the angular frequency of a rotating plasma beam by a magnetic field to measure the strength of that field. To the best of our knowledge, this is the first time that the rotation of plasma beam by a magnetic field has been used to systematically measure magnetic fields, and also carrier mobility. Our micro-fabricated device consists of a dot electrode at the dead center of a ring electrode. We calibrated our device to measure magnetic fields from 40 mT up to 5T.

W2P.077 **WIRELESS DRIVE OF A MEMS CILIARY MOTION ACTUATOR VIA COUPLED MAGNETIC RESONANCES USING MICRO INDUCTORS** **1961**

N. Sakamoto[1], A. Frappé[2], B. Stefanelli[2], A. Kaiser[2], and Y. Mita[1]
[1]*University of Tokyo, JAPAN and* [2]*ISEN, FRANCE*

We succeed in wireless drive of a 100 μm × 500 μm × 5 μm MEMS thermal actuator via micro-scale coupled magnetic resonances. Receiver inductor is 500 μm × 500 μm, which is the same scale as the micro-actuator. There is no need for rectifier circuit to drive the actuator, enabling power transmission with zero conversion loss. The transmission efficiency of the system was evaluated and the efficacy of magnetic resonant coupling for micro-scale power transmission was verified.

MONDAY - RF MEMS, Resonators, and Oscillators

M3P.077 **STATISTICAL CHARACTERIZATION OF A CMOS-MEMS RESONATOR FOR MONOLITHIC OVENIZED OSCILLATOR APPLICATIONS** **1965**

C.-Y. Chen, C.-H. Chin, M.-H. Li, and S.-S. Li
National Tsing Hua University, TAIWAN

A statistical study on the resonance frequency, Q-factor, electrostatic frequency tuning coefficient, and thermal resistance of a CMOS-MEMS resonator is carried out in this work to evaluate the practical utility for ovenized MEMS oscillator applications. The mean frequency of 1.195 MHz, Q of 1,190, and Rth of 295 K/mW are obtained from 12 resonator chips. The measured 1-sigma frequency tolerance of 7,560 ppm is characterized.

M3P.078 **FREQUENCY STABILITY OF RF OSCILLATOR WITH MEMS–BASED ENCAPSULATED RESONATOR.....1969**
Q. Yuan[1,2], B.H. Peng[1,2], W. Luo[1,2], J.C. Zhao[1,2], J.L. Yang[1,2], and F.H. Yang[1,2]
[1]*Chinese Academy of Sciences, CHINA and* [2]*State Key Laboratory of Transducer Technology, CHINA*

We present a RF MEMS oscillator consisting of MEMS disk resonator and low noise feedback circuits, which has high frequency stability and low phase noise. The two-port resonator was hermetically encapsulated using Au-Sn solder bonding and low noise oscillator circuit was designed with two-stage amplifying architecture and AGC loop. The phase noise is -96 dBc/Hz at 1 kHz offset and noise floor is -128 dBc/Hz. Short-term and medium-term frequency stability are ±0.5 ppm and ±4 ppm, respectively.

M3P.079 **50Ω-TERMINATED ALN MEMS FILTERS BASED ON LAMB WAVE RESONATORS.....1973**
J. Liang, H.X. Zhang, D.H. Zhang, H. Zhang, and W. Pang
Tianjin University, CHINA

This paper reports on an implementation of a miniature 140 MHz narrowband filter based on aluminum nitride Lamb wave resonators (LWRs). Monolithically integrated with a pair of on-chip capacitors and cascaded with a pair of SMT inductors, the filter is well matched to 50 ohm, showing a remarkably high performance. A low pass-band insertion loss of 2.78 dB and steep filter skirts are achieved, offering significant size savings.

M3P.080 **MODAL ANALYSIS OF OUT-OF-PLANE VIBRATIONS IN SWITCHABLE PIEZOELECTRIC GALLIUM NITRIDE MICROMECHANICAL RESONATORS.....1977**
C. Tu[1], X.-L. Guo[2], and J.E.-Y. Lee[1]
[1]*City University of Hong Kong, HONG KONG and* [2]*Nantong University, CHINA*

We analyze out-of-plane vibrations in a 12MHz piezoelectric Gallium Nitride MEMS resonator that utilizes two-dimensional electron gas (2DEG) as the embedded electrodes. The out-of-plane vibration mode that provides the strongest electromechanical transduction has a strain field that allows charges generated by the piezoelectric coupling from the orthogonal lateral strains to add up constructively. The resonator exhibits a Q of 4000 and resonance suppression of 41dB when 2DEG layer is depleted.

M3P.081 **CMOS MEMS RESONATOR OSCILLATOR WITH AN ON-CHIP BOOST DC/DC CONVERTER.....1981**
S.-H. Tseng, Y.-T. Hsieh, C.-C. Lin, H.-H. Tsai, and Y.-Z. Juang
National Applied Research Laboratories, TAIWAN

We present a CMOS MEMS resonator oscillator with an on-chip boost DC-DC converter based on an integrated Bipolar-CMOS-DMOS MEMS process. The maximum boost DC voltage can be up to 60 V, which is used to provide the DC bias voltage on the MEMS resonator. The oscillation frequency is 32.76 kHz while the DC bias voltage is 51.5 V under 1 atm.

M3P.082 **SELF-EXCITED RELAXATION OSCILLATION IN OPTOMECHANICAL RING RESONATOR FOR SENSING APPLICATIONS.....1985**
J.G. Huang[1,2,3], B. Dong[2,3], M. Tang[2], Y.D. Gu[2], J.H. Wu[1], T.N. Chen[1], Z.C. Yang[4], Y.F. Jin[4], Y.L. Hao[4], D.L. Kwong[2], and A.Q. Liu[3]
[1]*Xi'an Jiaotong University, CHINA,* [2]*Agency for Science, Technology and Research (A*STAR), SINGAPORE,* [3]*Nanyang Technological University, SINGAPORE, and* [4]*Peking University, CHINA*

This paper demonstrates the optically induced self-excited relaxation oscillation in a silicon ring resonator for the first time. The observed thermo-optomechanical oscillation has a unique waveform with fast oscillation period close to 16 ns and slow oscillation period approximately 167 ns. Particularly, the oscillation frequency is very sensitive to the wavelength detuning, making it quite suitable for the sensing applications.

TUESDAY - RF MEMS, Resonators, and Oscillators

T4P.078 **TUNABLE FLAT LENS BASED ON MICROFLUIDIC RECONFIGURABLE METASURFACE.....1989**
W.M. Zhu[1], Q.H. Song[1,2], L.B. Yan[1], W. Zhang[1], P.C. Wu[1], L.K. Chin[1], Z.C. Yang[3], Z.X. Shen[1], T.W. Deng[4], S.K. Ting[4], H. Cai[5], Y.D. Gu[5], D.L. Kwong[5], T. Bourouina[2], Y. Leprince[2], and A.Q. Liu[1]
[1]*Nanyang Technological University, SINGAPORE,* [2]*Université Paris-Est, FRANCE,* [3]*Peking University, CHINA,* [4]*National University of Singapore, SINGAPORE, and* [5]*Agency for Science, Technology and Research (A*STAR), SINGAPORE*

A tunable flat lens is demonstrated based on reconfigurable metasurface, which is realized via changing the phase gradient of the metasurface in sub-wavelength level. The sub-wavelength metamolecules are formed by enclosing a liquid metal plug within microfluidic cavities, which can be tuned by changing the geometry of the metamolecules.

T4P.079 **STUDY OF THERMAL NONLINEARITY IN LITHIUM NIOBATE-BASED MEMS RESONATORS** **1993**

R. Lu and S. Gong

University of Illinois, Urbana-Champaign, USA

This paper reports an iteration-driven method to numerically study the thermal nonlinearity in LN based MEMS resonators. This technique adopts an approximation-free algorithm and thus more accurately captures the complex nonlinear. The nonlinearity of LN-based resonators is theoretically investigated and experimentally validated. The admittance response of both S0 and SH0 mode devices was simulated and measured by forward and backward sweeping excitation frequency at different power levels.

T4P.080 **MODELING THE EFFECT OF ANCHOR GEOMETRY ON THE QUALITY FACTOR OF BULK MODE RESONATORS** **1997**

D.D. Gerrard, E.J. Ng, C.H. Ahn, V.A. Hong, Y. Yang, and T.W. Kenny

Stanford University, USA

This work explores several designs of anchor geometries for a width extensional resonator with experimental results confirming that the geometry of the anchor can have a large effect on the mode shape as well as the quality factor, and favorable designs are presented. Temperature dependences of f and Q are also reported.

T4P.081 **ENHANCED SYNCHRONIZATION RANGE FROM NON-LINEAR MICROMECHANICAL OSCILLATORS** **2001**

D.A. Czaplewski[1], D. Antonio[1], J.R. Guest[1], D. Lopez[1], S.I. Arroyo[2], and D.H. Zanette[2]

[1]Argonne National Laboratory, USA and [2]Centro At´omico Bariloche and Instituto Balseiro, ARGENTINA

We demonstrate that the synchronization range for oscillators increases with increasing drive force when operating the oscillators in the non-linear regime. This enhancement is contrary to the same observation for oscillators operating in the linear regime where the synchronization range decreases with increasing drive force.

T4P.082 **DAMPING MECHANISMS IN LIGHT AND HEAVY-DOPED DUAL-RING AND DOUBLE-ENDED TUNING FORK RESONATORS (DETF)** **2005**

J. Rodriguez, Y. Yang, C.H. Ahn, Y. Chen, E.J. Ng, V.A. Hong, S. Ghaffari, and T.W. Kenny

Stanford University, USA

We present models and measurements of lightly-doped and heavily-doped dual ring/dual-bar resonators. These results show that the Quality Factor is not strongly impacted by doping level, despite being dominated by both Thermo Elastic Dissipation and Anchor Damping. We show, through both experiment and simulations that TED has weak temperature dependence, arising from the interplay between ring and bar resonances. These results indicate that it is necessary to carry out complete simulations using anisotropic and temperature dependent materials properties to explain energy dissipation.

T4P.083 **4H-SIC ELECTROSTATIC CANTILEVER ACTUATOR RELEASED BY PHOTOELECTROCHEMICAL ETCHING AND APPLICATION FOR FREQUENCY MIXING** **2009**

F. Zhao[1], A. Lim[1], Q. Tran[1], and C.F. Huang[2]

[1]*Washington State University, Vancouver, USA and* [2]*National Tsing Hua University, CHINA*

We report a single crystal 4H-SiC electrostatically actuated cantilever performing frequency mixing. In order to achieve electrostatic actuation, and solve the challenge of releasing MEMS structures due to the extreme chemical hardness of 4H-SiC, an n-p-n homoepitaxial structure was chosen, with cantilever actuators released by photoelectrochemical (PEC) etching. Frequency mixing was successfully performed by multiplication of the signals to drive the cantilever into resonance.

WEDNESDAY - RF MEMS, Resonators, and Oscillators

W2P.078 **INVESTIGATING THE IMPACT OF STUCTURAL SYMMETRY IN COUPLED RESONATOR ARRAYS ON THE FREQUENCY STABILITY OF A CMOS-MEMS OSCILLATOR** **2013**

A. Erbes, C. Do, P. Thiruvenkatanathan, and A.A. Seshia

University of Cambridge, UK

This paper presents experimental observations of the variations in short-term frequency stability in a low power CMOS-MEMS oscillator embedding two mechanically coupled double-ended tuning fork (DETF) resonators as a function of induced stiffness perturbations on the DETF resonators.

W2P.079 HIGHER DIMENSIONAL FLEXURE MODES FOR ENHANCED EFFECTIVE ELECROMECHANICAL COUPLING IN PZT-ON- SILICON MEMS RESONATORS....2017
J.M. Puder[1], S.S. Bedair[2], J.S. Pulskamp[2], R.Q. Rudy[2], R.G. Polcawich[2], and S.A. Bhave[1]
[1]*Cornell Univeristy, USA and* [2]*US Army Research Laboratory, USA*

This paper reports on a low-loss, flexural-mode resonator with enhanced effective electromechanical coupling. Improvement is achieved by utilizing a higher dimensional vibrational mode that possesses more than one non-zero in-phase stress component. This augments coupling with contributions from both the d31 and d32 piezoelectric coefficients.

W2P.080 EMPLOYING PIEZOJUNCTION EFFECT FOR ULTRA-LOW POWER RESONANT MICRODEVICE APPLICATIONS....2021
A. Rasouli, M.J. Syrzycki, and B. Bahreyni
Simon Fraser University, CANADA

This work reports on application of the piezojunction effect as a viable mechanism for detection of resonance frequency in silicon microdevices. In this technique, the sensing *pn*-junction is reverse-biased, making the required power for detection of resonance rather small. A bulk extensional resonator with an embedded *pn*-junction is designed, fabricated and characterized to serve as a proof-of-concept structure. A power consumption as low as 120 nW was needed for detection of extensional-mode of the resonator at a resonant frequency of 8.5 MHz.

W2P.081 HIGH-FREQUENCY AND LOW-RESONANCE-IMPEDANCE LAMB WAVE RESONATORS UTILIZING THE S1 MODE....2025
J. Zou[1], C.-M. Lin[1], Y.-Y. Chen[2], and A.P. Pisano[1,3]
[1]*University of California, Berkeley, USA,* [2]*Tatung University, USA, and* [3]*University of California, San Diego, USA*

We evaluate the multi-resonance performance of a Lamb wave resonator and a high resonance-frequency (fs) and low-resonance-impedance (Zmin) AlN Lamb wave resonator is also demonstrated by utilizing the first symmetric mode(S1 mode). The multi-resonance Modified Butterworth-Van Dyke (MBVD) circuit model is employed to fit the measured performance and characterize the multi-mode performance.

W2P.082 GRAPHENE RF NEMS SHUNT SWITCHES FOR ANALOG AND DIGITAL PHASE SHIFTERS....2029
C.F. Moldovan, W.A. Vitale, M. Tamagnone, and A.M. Ionescu
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We present the wafer-level fabrication and the measurements of RF capacitive NEMS switches based on CVD multilayer graphene for wide band RF phase shifters for analog and digital applications. To assess the performance of the phase shifters, we perform simulations using the specifications of the fabricated NEMS switch and show the performance and future prospects.

W2P.083 REDUCING ANCHOR LOSS IN PIEZOELECTRIC-ON-SILICON LATERALLY VIBRATING RESONATORS BY COMBINATION OF ETCHED-SLOTS AND CONVEX EDGES....2033
X. Di and J.E.-Y. Lee
City University of Hong Kong, HONG KONG

We report improvements in quality factor (Q) of thin film piezoelectric-on-silicon (TPoS) MEMS resonators using a combination of slots and convex edges to reduce anchor loss by almost 9 times. The frequency of these resonators is around 100MHz. This factor of improvement is higher than what has been reported previously for biconvex metal-AlN resonators.

MONDAY - Optical MEMS

M3P.083 A FAST MEMS INFRARED MICROSPECTROMETER FOR THE MEASUREMENT OF HYDROCARBON GASES....2037
M. Ebermann[1], N. Neumann[1], S. Binder[1], M. Meinig[2], M. Seifert[3], S. Kurth[2], and K. Hiller[2]
[1]*InfraTec GmbH, GERMANY,* [2]*Fraunhofer ENAS, GERMANY, and* [3]*Technische Universität Chemnitz, GERMANY*

A new fast infrared microspectrometer based on a MEMS tunable Fabry-Pérot filter (μFPF) is reported. In contrast to previous designs the acquisition time for a complete spectrum is decreased 50 times and the spectral resolution 3 times. This is achieved by the use of higher interference orders and the combination with a room temperature operated PbSe photodetector. Such a system will be especially useful for the measurement of hydrocarbon gases in the spectral range of (3.1…3.8) μm.

M3P.084 TUNABLE BINARY FRESNEL LENS BASED ON STRETCHABLE PDMS/CNT COMPOSITE....2041
X. Li, L. Wei, S. Vollebregt, R. Poelma, Y. Shen, J. Wei, P. Urbach, P.M. Sarro, and G.Q. Zhang
Delft University of Technology, THE NETHERLANDS

This paper presents a tunable micro Fresnel lens made by PDMS/CNTs that can change its focal length by simply stretching the substrate. The Fresnel lens is made by PDMS polymer with embedded vertically aligned CNTs. It utilizes the transparency and flexibility of the PDMS and the perfect absorption properties of CNTs. The lens is fabricated using an unsophisticated and fast process, which requires only one lithography step.

M3P.085 **TUNABLE MULTISEGMENT Si_XN_Y/ALN PIEZO LENSES FOR WAVEFRONT CORRECTION** 2045

V. Zuerbig[1], D. Pätz[3], J. Fries[1], M. Bichra[3], W. Pletschen[1], K. Holc[1], M. Reusch[2], C.E. Nebel[1], S. Sinzinger[3], O. Ambacher[1,2], and V. Lebedev[1]
[1]*Fraunhofer Institute for Applied Solid Staty Physics IAF, GERMANY,* [2]*University of Freiburg - IMTEK, GERMANY, and* [3]*Ilmenau University of Technology, GERMANY*

We develop SixNy/AlN multisegment piezo-actuated micro lenses with fast focusing functionality along with wave front and aberrations correction filter functions. These micro lenses offering free aspheric deformation of the lens surface are highly applicable to operate at high repetition rates along with reproducible and precise tunability. The performance of the lenses were analyzed using white light interferometry, laser Doppler vibrometry and Shack-Hartmann wavefront sensor system.

M3P.086 **MICROFLUIDIC WHITE ORGANIC LIGHT-EMITTING DIODE BASED ON STRIPED FINE MICROCHANNELS FOR GREENISH BLUE AND YELLOW LIQUID EMITTERS** 2049

N. Kobayashi[1], T. Kasahara[1], T. Edura[2], J. Oshima[3], R. Ishimatsu[4], M. Tsuwaki[1], T. Imato[4], S. Shoji[1], and J. Mizuno[1]
[1]*Waseda University, JAPAN,* [2]*Shutech Corporation, JAPAN,* [3]*Nissan Chemical Industries, Ltd., JAPAN, and* [4]*Kyushu University, JAPAN*

We develop microfluidic white organic light-emitting diode with greenish-blue and yellow solvent-free liquid emitters. The device consists of fine microchannels fabricated with microelectromechanical systems and heterogeneous bonding. Greenish-blue and yellow liquid emitters are alternately injected into the microchannels. Electroluminescence emissions are simultaneously generated and then white-light emission is to be observed.

M3P.087 **FABRICATION OF TUNABLE PLASMONIC COLOR FILTER USING AL SUBWAVELENGTH GRATING INTEGRATED WITH ELECTROSTATIC COMB-DRIVE ACTUATOR** 2053

H. Honma[1,2], K. Takahashi[1], M. Ishida[1,3], and K. Sawada[1,3]
[1]*Toyohashi University of Technology, JAPAN,* [2]*Japan Society for the Promotion of Science (JSPS), JAPAN, and* [3]*Electronics Inspired-Interdisciplinary Research Institute (EIIRIS), JAPAN*

We fabricate a surface-plasmon-based tunable color filter using Al subwavelength grating suspended by tiny hinges which are expanded by electrostatic comb-drive actuator. Al subwavelength grating was designed to redshift the peak position of the transmitted light by expanding the period. We obtained a 225 nm displacement of the movable electrode by applied voltage of 45 V. The proposed tunable color filter is expected to have potential of RGB color tuning in a single pixel.

TUESDAY - Optical MEMS

T4P.084 **GAN FREESTANDING WAVEGUIDES ON SI SUBSTRATE FOR SI/GAN HYBRID PHOTONIC INTEGRATION** 2057

T. Sekiya, T. Sasaki, and K. Hane
Tohoku University, JAPAN

GaN layer is grown on Si substrate and GaN freestanding waveguides are fabricated by etching the Si substrate with XeF2. The freestanding waveguides are supported by bridge structures. Light wave propagation is simulated using FDTD method. The GaN waveguides are patterned by EB lithography using Cl2 plasma. The waveguiding properties such as waveguide loss are measured at blue and infrared wavelengths. The GaN waveguide on Si substrate is discussed for Si-based platform with GaN light source.

T4P.085 **CHARACTERIZATION OF VIBRATION-TYPE INFRARED THERMAL DETECTOR ON TEMPERATURE, LIGHT, AND THERMAL INFRARED** 2061

J.-H. Jeong[1], S. Kumagai[1], I. Yamashita[2], Y. Uraoka[2], and M. Sasaki[1]
[1]*Toyota Technological Institute, JAPAN and* [2]*Nara Institute of Science and Technology, JAPAN*

To achieve a sensitive detection of M-LWIR, we have developed a micromechanical IR thermal detector using torsional resonators. Since the resonator is a bimaterial structure, it is heated and deformed by IR incidence, thereby shifting its resonant frequency. Through using a tension-enhanced resonating body and an IR absorber, M-LWIR was successfully detected. The frequency shift was observed as 5288 ppm by a thermal source of 450 °C is placed 15 cm away from the detector.

T4P.086 **ALL OPTOMECHANICAL MODULATION IN PHOTONIC CIRCUITS** 2065

J.G. Huang[1,2,3], B. Dong[2,3], M. Tang[2], Y.D. Gu[2], J.H. Wu[1], T.N. Chen[1], Z.C. Yang[4], Y.F. Jin[4], Y.L. Hao[4], D.L. Kwong[2], and A.Q. Liu[3]
[1]*Xi'an Jiaotong University, CHINA,* [2]*Agency for Science, Technology and Research (A*STAR), SINGAPORE,* [3]*Nanyang Technological University, SINGAPORE, and* [4]*Peking University, CHINA*

This paper reports a novel all-optical light tracker by taking advantage of the optomechanical modulation. The optical force generated by a light can be used to control another light without relying on the traditional nonlinear materials. Particularly, the all-optical modulation can transfer the information in a signal light into another tracking light without resorting to electro-optical converting.

T4P.087 **LARGE-AMPLITUDE RESONANT VARIFOCAL MIRROR WITH AN ACOUSTIC CAVITY 2069**
T. Sasaki, L. Rayas, K. Nakazawa, and K. Hane
Tohoku University, JAPAN

This paper reports a large-amplitude resonant varifocal mirror with an acoustic cavity under atmospheric pressure. This is the first time to report the vibration amplification of mirror on the basis of interaction between mechanical vibration and acoustic wave in cavity.

T4P.088 **DESIGN AND FABRICATION OF CURVED SILICON IMAGE PLANES FOR MINIATURE MONOCENTRIC IMAGERS 2073**
T. Wu, S.S. Hamann, A. Ceballos, O. Solgaard, and R.T. Howe
Stanford University, USA

We introduce the design and fabrication of a hemispherical silicon image plane for spherical aberration-free monocentric imaging. This design enables a compact 160o FOV camera with a fill factor over 80% using a single ball lens and CMOS imager technology.

WEDNESDAY - Optical MEMS

W2P.084 **LIQUID LENS BASED ON ELECTROMAGNETIC ACTUATION FOR HIGH-PERFORMANCE MINIATURE CAMERAS 2077**
S.H. Oh, J.H. Seo, J.P. Jeon, K. Rhee, and S.K. Chung
Myongji University, SOUTH KOREA

This paper presents a new design of tunable liquid lens operated by electromagnetic actuation for autofocus (A/F) in miniature cameras. The proposed lens offers a simple design structure to be easily miniaturized but covers a wide range of focal lengths for high optical performance.

W2P.085 **AN UNCOOLED OPTICALLY READABLE INFRARED FOCAL PLANE ARRAY 2081**
F. Feng, Y.S. Zhang, X.H. Ge, X.D. Wei, Y.L. Wang, and X.X. Li
Chinese Academy of Sciences, CHINA

This paper reports a new uncooled optically readable infrared focal plane array (UOR-IRFPA), which is fabricated on a glass substrate. Compared with conventional UOR-IRFPA fabricated on a silicon substrate, infrared light can directly radiate on infrared absorption layer. Therefore, the new UOR-IRFPA has near 100% infrared absorption efficiency without removing silicon substrate underneath UOR-IRFPA pixels by using expensive DRIE (Deep Reactive Ion Etching).

W2P.086 **TERAHERTZ FIELD DETECTOR BASED ON ELECTRON EMISSION 2085**
X. Zhao[1], J. Zhang[2], K. Fan[1], H.R. Seren[1], R.D. Averitt[2], and X. Zhang[1]
[1]*Boston University, USA and* [2]*University of California, San Diego, USA*

We report the electric field induced electron emission across the capacitive gap in a metamaterial structure under intense terahertz (THz) field for the first time. The current of the electron emission is dependent on the strength of the incident field, which can be used as a THz detector.

W2P.087 **AN ELECTROHYDRODYNAMICALLY ACTUATED LIQUID MICROLENS WITH AREAL DENSITY MODULATED ELECTRODES 2089**
A.O. Ashtiani and H. Jiang
University of Wisconsin, Madison, USA

We developed, simulated and fabricated an electrohydrodynamically actuated tunable liquid microlens with a novel electrode layout design, called areal density modulated electrodes. Compared to previously reported electrohydrodynamically actuated liquid microlenses, the proposed concept addresses both continuous tunability and centering of the lens axis with a simple to fabricate, planar electrode structure.

W2P.088 **NEMS SPECTROMETER-ON-A-CHIP 2093**
B. Dong[1,2], H. Cai[2], M. Tang[2], Y.D. Gu[2], Z.C. Yang[3], Y.F. Jin[3], Y.L. Hao[3], D.L. Kwong[2], and A.Q. Liu[1]
[1]*Nanyang Technological University, SINGAPORE,* [2]*Agency for Science, Technology and Research (A*STAR), SINGAPORE, and* [3]*Peking University, CHINA*

We develop a NEMS spectrometer-on-a-chip, which is integrated with fiber-waveguide coupler and photo detector on a single silicon chip. Spectrometer based on Fourier transform has been miniaturized into a waveguide based silicon photonic chip. Our breakthrough research on on-chip spectrometer using nano-silicon-photonic fabrication processes to eliminate moving parts and confine light in nano-waveguides. It has high potential applications in biomedical and physical spectroscopy field.

POSTER/ORAL PRESENTATIONS

MONDAY - Actuators

M3P.088 **A PARAMETRIC ARRAY PMUT LOUDSPEAKER WITH HIGH EFFICIENCY AND WIDE FLAT BANDWIDTH.....2097**

K.H. Been[1], Y.U.B. Je[2], H.S. Lee[2], and W.K. Moon[1]
[1]*Pohang University of Science and Technology (POSTECH), SOUTH KOREA and*
[2]*Agency for Defense Development, SOUTH KOREA*

Previous study, piezoelectric micro-machined ultrasonic transducer (PMUT) is shown that efficient units or PA loudspeaker. This paper investigated to realize a PA loudspeaker with high power efficiency (up to 71%) and wide flat radiation bandwidth (19.5 kHz, difference frequency wave with equalization) that consist of an array of PMUTs with two resonance frequencies (f1 = 100 kHz, f2 = 110 kHz) and use of 'out-of-phase' driving technique.

M3P.089 **DESIGN, FABRICATION AND TESTING OF PIEZO-ELECTRIC DRIVING MECHANISM FOR MICRO-OPTICS 2101**

A. Michael, S.H. Chen, and C.Y. Kwok
University of New South Wales, AUSTRALIA

This paper reports the design, fabrication and characterization of an inter-digitated piezoelectric actuation mechanism for applications in micro-optics. The mechanism allows the improvement of resonance frequency and deflection response without introducing lateral movement. To facilitate the design, a theoretical model has been developed and substantiated by ANSYS simulation. Experimental results show good agreement with both simulation and modelling.

M3P.090 **SILICON-TO-SILICON MICROSWITCH WITH WIDE OPERATION TEMPERATURE RANGE.....2105**

B.W. Soon[1], Y. Qian[1], E.J. Ng[2], T.W. Kenny[2], and C. Lee[1]
[1]*National University of Singapore, SINGAPORE and* [2]*Stanford University, USA*

Using an ultra clean vacuum sealing process, an encapsulated Si-to-Si contact micro switch is fabricated and characterized. Temperature stability of -196 Ω/K from -60°C to 300°C switching temperature is verified. Through continuous on-off cycles in 400 °C high temperature environment, at least 10^6 cycles device lifetime is also successfully demonstrated.

M3P.091 **NEMS ACTUATOR DRIVEN BY ELECTROSTATIC AND OPTICAL FORCE WITH NANO-SCALE RESOLUTION 2109**

J.G. Huang[1,2,3], B. Dong[2,3], M. Tang[2], Y.D. Gu[2], J.H. Wu[1], T.N. Chen[1], Z.C. Yang[4], Y.F. Jin[4], Y.L. Hao[4], D.L. Kwong[2], and A.Q. Liu[3]
[1]*Xi'an Jiaotong University, CHINA,* [2]*Agency for Science, Technology and Research (A*STAR), SINGAPORE,*
[3]*Nanyang Technological University, SINGAPORE, and* [4]*Peking University, CHINA*

We experimentally demonstrate a silicon nano-wire actuator with a nano-scale resolution and tunable actuation range. Taking a control strategy implementing different control regulation, coarse tuning by the electrostatic force and precision tuning by the optical force, the optical force enabled silicon nano-wire actuator can break the classical NEMS 1/3 actuation range limit, extending the actuation range to any arbitrary limit in principle.

M3P.092 **A DISTORTION-FREE SINGLE-CHIP ATOMIC FORCE MICROSCOPE WITH 2DOF ISOTHERMAL SCANNING 2113**

D. Strathearn[1,2], G. Lee[1,2], N. Sarkar[1,2], M. Olfat[1,2], and R. Mansour[1,2]
[1]*University of Waterloo, CANADA and* [2]*ICSPI Corp., CANADA*

We present the first distortion-free imaging results with a single-chip AFM. The inexpensive instrument contains all of the scanning and sensing components required to replace a state-of-the-art AFM and achieves comparable resolution with improved drift and distortion performance. A novel scanner and drive scheme are introduced to mitigate image distortion from thermal coupling and non-ideal flexural suspensions, thereby providing 2 DOF Cartesian coordinate images requiring no post-processing.

TUESDAY - Actuators

T4P.089 **A LINEAR LOW DRIVING VOLTAGE MEMS ACTUATOR WITH LARGE LATERAL STROKE DRIVEN BY LORENTZ FORCE.....2117**

X.D. Lv[1,2], W.W. Wei[1,2], X. Mao[1,2], J.L. Yang[1,2], and F.H. Yang[1]
[1]*Chinese Academy of Sciences, CHINA and* [2]*State Key Laboratory of Transducer Technology, CHINA*

A novel linear MEMS actuator with a large lateral stroke driven by Lorentz force was developed. A lateral displacement of more than 47 μm was achieved with magnetic flux density of 0.3 T and current of 8 mA. The driving voltage is low enough to integrate with IC. Good linear dependence of the displacement on current was achieved. A larger displacement can be obtained by increasing the magnetic field and driving current. The actuator has potential application in optical switches, VOAs, etc.

T4P.090 **PULL-IN VOLTAGE AND FABRICATION YIELD ANALYSIS FOR FIXED-FIXED BEAM NANOELECTROMECHANICAL SWITCHES** **2121**

Y. Qian, B.W. Soon, Z. Xiang, and C. Lee
National University of Singapore, SINGAPORE

A statistical study has been done for all-metal-based laterally actuated nanoelectromechanical switch. 500 devices with 50 different dimensions have been characterised in terms of pull-in voltage and fabrication yield. An analytical solution to predict the pull-in voltage with only 2% deviation compared to finite element modelling is developed. Switches of robust designs show 100% yield and repeatable switching behavior.

T4P.091 **FULLY-MICROFABRICATED ELECTROMAGNETICALLY-ACTUATED MEMBRANE FOR MICROSPEAKER** **2125**

Q. Zhang and E.S. Kim
University of Southern California, USA

This paper presents an electromagnetically actuated membrane that can be microfabricated on silicon wafers in a batch process. The wax-bonded micromagnet suspended by a parylene diaphragm (7x7mm^2) is actuated by the Lorentz force when a current is applied to the dual-layer electroplated coils. Experimental results show that the electromagnetic actuation produces a flat frequency response of 0.35$\mu m_{peak\text{-}to\text{-}peak}$ up to 400Hz for an applied current of 40.8mA_{rms} into the 52Ω coil.

T4P.092 **ELECTRICAL POWERLESS, THERMAL AND OPTICAL RESPONSIVE POLYMER-BASED ACTUATOR** **2129**

Y. Yamamoto, K. Kanao, T. Arie, S. Akita, and K. Takei
Osaka Prefecture University, JAPAN

This study demonstrates thermal and optical responsive actuator operated by skin temperature and sunlight without electrical power supply. we propose to use a mixture of poly(N-isopropylacrylamide) (pNIPAM) as a thermal actuation material and carbon nanotubes as a light absorber to convert into temperature on a polyethylene terephthalate substrate. By considering a packaging technique of pNIPAM, a human body temperature and the sunlight stimuli actuator is successfully demonstrated in air.

T4P.093 ***IN-SITU* GENERATED BIOCOMPATIBLE ALGINATE ACTUATORS FOR FLOW CONTROL IN MICROFLUIDICS** **2132**

J. Saez[1], M. Antoñana[1,2], J. Etxebarria[1,2], and F. Benito-Lopez[1,3]
[1]*CIC microGUNE, SPAIN,* [2]*IKERLAN, SPAIN, and* [3]*Dublin City University, IRELAND*

We describe for the first time the use of alginate gels as miniaturised valves in microfluidic devices. These biocompatible and biodegradable microvalves are in-situ generated, on demand, allowing for microfluidic flow control.

T4P.094 **INVESTIGATION OF SCAFFOLD MATERIALS FOR A BIO-MICROPUMP USING IPS CELL DERIVED CARDIOMYOCYTES** **2136**

H. Fujita[2] and Y. Tanaka[1,2]
[1]*Osaka University, JAPAN and* [2]*Institute of Physical and Chemical Research (RIKEN), JAPAN*

We have investigated the effects of scaffold material difference, especially regarding glass and polydimethylsiloxane (PDMS) for the development of a bio-micropump using iPS cell derived cardiomyocytes.

T4P.095 **DESIGN AND CHARACTERIZATION OF CONTRACTION MOTION ACTUATOR CONVERTED FROM SWELLING PNEUMATIC BALLOON ACTUATOR FOR LARGE DEFORMATION AND FORCE** **2140**

S. Honda, Y. Tsujimura, and S. Konishi
Ritsumeikan University, JAPAN

We report on design and characterization of contraction motion actuator converted from swelling pneumatic balloon actuator for large deformation and force. Recent results will be presented on site.

WEDNESDAY - Actuators

W2P.089 **FABRICATION AND CHARACTERISATION OF SCALN-BASED PIEZOELECTRIC MEMS CANTILEVER** **2144**

P.M. Mayrhofer, E. Wistrela, M. Kucera, A. Bittner, and U. Schmid
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Our work demonstrates the fabrication of MEMS cantilevers based on sputter deposited ScxAl1-xN thin films (x = 27 %) sandwiched between gold electrodes. Structuring of ScAlN films is performed by a reactive ion etching process using SiCl4. The actuation potential of the fabricated devices is characterised electrically by electrical impedance spectroscopy. Furthermore, application of the Butterworth Van-Dyke equivalent circuit demonstrates an increase of the effective piezoelectric constant d31.

W2P.090 **RING-SHAPE SMA MICRO ACTUATOR WITH PARYLENE RETENSION SPRING FOR LOW POWER CONSUMPTION, LARGE DISPLACEMENT LINEAR ACTUATION 2148**
T.D. O. Moura[1,2], T. Tsukamoto[3], D.W. de Lima Monteiro[1], and S. Tanaka[3]
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This paper reports a novel ring-shape micro actuator for a latching mechanism used in a low power consumption and large displacement micro linear actuation. The proposed linear actuator consists of two shape memory alloy (SMA) actuators and high aspect-ratio parylene retention springs. The pushing force as high as 40 mN could be generated by the spring, and the maximum displacement as high as 100 um was obtained by the ring-shape SMA actuator.

W2P.091 **A FLEXIBLE, METALLIC ELECTROSPRAY EMITTER WITH EMBEDDED FLOW HOMOGENIZER 2152**
X. Wang, C. Li, W. Yang, W. Deng, and H.J. Cho
University of Central Florida, USA

This work reports a novel design and batch fabrication method for an metallic electrospray emitter that only involves two-step photolithography and electroplating processes to realize an integrated thruster/actuator for a space propulsion subsystem. A long effective nozzle could be fabricated consistently with high aspect ratio post arrays embedded within the nozzle as a flow homogenizer. With its compact and flexible structure, the uniform jet formation and thrust vectoring was demonstrated.

W2P.092 **HIGH-POWER MEMS RELAY ARRAY WITH IMPROVED RELIABILITY AND CONSISTENCY 2156**
B. Ma, Z. You, Y. Ruan, S.K. Chang, and G.F. Zhang
Tsinghua University, CHINA

We develop a power MEMS relay array with numerous improvements in current carrying capacity, which is designed as a matrix of microcantilevers connected in parallel to allocate high current to individual relays. The cantilevers are hollowed through ICP etching to obtain a small driving voltage while enhancing their stability. To ensure the reliability and consistency of the relay matrix, the silicon-on-insulator anodic bonding technology is used to improve the uniformity of the device structure.

W2P.093 **A LATCHABLE THERMALLY ACTIVATED PHASE CHANGE ACTUATOR AND OPTIMIZATION OF ITS RESPONSE BEHAVIOUR 2160**
C. Richter, E. Wilhelm, A. Voigt, and B.E. Rapp
Karlsruhe Institute of Technology (KIT), GERMANY

We present a latchable and thermally activated phase change actuator that can be driven using a highly integrated platform which allows the individual control of up to several hundred actuators using only two external pressure sources. To optimize the response time of the actuator we analyzed the influence of the heating power of the used resistors, the volume of the phase change material as well as the chosen phase change material itself.

MONDAY - Theory, Design and Test Methodology

M3P.093 **A WAFER-LEVEL PRESSURE CALIBRATION METHOD FOR INTEGRATED ACCELEROMETER AND PRESSURE SENSOR IN TPMS APPLICATION 2164**
Y. Zhang[1], F. Meng[1], G. Liu[1], C. Gao[1], and Y. Hao[1,2]
[1]*Peking University, CHINA and* [2]*Innovation Center for MicroNanoelectronics and Integrated System, CHINA*

This paper reports a new wafer-lever calibration method which can reduce cost and workload in TPMS sensor testing by measuring accelerometer's full-range response in a static pressure test step, integrated pressure sensor can also be tested in this step without extra equipments. This method uses a beam-block-membrane structure accelerometer. Simulation shows the feasibility to calculate the accelerometer's response from pressure test results. A integrated sensor was fabricated and calibrated.

M3P.094 **FLUIDIC DAMPING IN MICRO- AND NANO-SCALE MECHANICAL RESONATORS IN THE MOLECULAR FLOW REGIME: A MOMENTUM TRANSFER BASED ANALYTICAL APPROACH 2168**
J. Manz, G. Wachutka, and G. Schrag
Munich University of Technology, GERMANY

We derived an easy-to-use analytical model to predict the fluidic damping forces acting on mechanical resonators in the free molecular flow regime. The model is based on fundamental physical relations, which take the momentum transfer between the air molecules and the oscillating structure into account. The obtained analytical relation is compared to data extracted from pressure-dependent Laser-Doppler vibrometric measurements.

M3P.095 **SUSPENDED PIEZORESISTIVE SILICON NANOGAUGES BRIDGE FOR MEMS TRANSDUCTION: SPURIOUS SIGNAL REJECTION CAPABILITY** 2172

G. Jourdan[1,2], F. Terry[1,2], F. Blard[1,2], A. Berthelot[1,2], P. Rey[1,2], C. Coutier[1,2], and P. Robert[1,2]
[1]*University of Grenoble Alpes, FRANCE and* [2]*CEA, FRANCE*

We propose to evaluate the spurious signal rejection capability of two suspended piezoresistive silicon nanogauges used for sensing mechanical motion in MEMS sensors. Thanks to their small cross section, silicon nanogauges are extremely sensitive to stress caused by MEMS motion. However a nanogauge alone depends also on temperature. Here, we show that the use of a nanogauges pair makes it possible to reject temperature signal change by a factor 1000, over a large temperature range [-40°C:150°C].

M3P.096 **CHARACTERIZING MEMS NONLINEARITIES DIRECTLY: THE RING-DOWN MEASUREMENTS** 2176

P. Polunin[1], Y. Yang[2], J. Atalaya[1], E. Ng[2], S. Strachan[1], O. Shoshani[1], M. Dykman[1], S. Shaw[1], and T. Kenny[2]
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We show that analysis of the amplitude and phase of the ring-down response of a MEMS resonator allows one to estimate conservative and dissipative nonlinearities, in addition to the linear natural frequency and quality factor, associated with a vibrational mode. The nonlinearities result in an amplitude-dependent frequency and non-exponential decay during ring-down. The coefficients obtained from the test allow one to predict the nonlinear open and closed loop response of the resonator.

TUESDAY - Theory, Design and Test Methodology

T4P.096 **LARGE DYNAMIC RANGE TIME DOMIAN MEASUREMENT OF Q-FACTOR IN MEMS** 2180

S. Voigt, M. Freitag, A. Sorger, and J. Mehner
Technische Universität Chemnitz, GERMANY

This paper reports on a time and frequency domain measurement technique where logarithmic amplifiers are used in order to compress the dynamic range of a time domain decay response in a ring down test or to compress the frequency response of a MEMS resonator. The goal is to observe small signal behavior and large deflection amplitudes in one and the same sampling window because this allows evaluating nonlinear behavior and different damping effects.

T4P.097 **EFFICIENT NONLINEAR SIMULINK MODELS OF MEMS GYROSCOPES GENERATED WITH A NOVEL MODEL ORDER REDUCTION METHOD** 2184

A. Parent[1], A. Krust[1], G. Lorenz[1], I. Favorskiy[1], and T. Piirainen[2]
[1]*Coventor, FRANCE and* [2]*Murata Electronics Oy, FINLAND*

We describe a model-order reduction (MOR) approach for creating fast-running, nonlinear, multiphysics models of MEMS sensors for Simulink. The accuracy of this MOR is verified for a commercial three-axis capacitive gyroscope from Murata Electronics by comparing simulations with experimental data. This solution has been implemented in the MEMS/IC co-design tool MEMS+. It allows to easily create a MOR and use it into a Simulink schematic.

T4P.098 **CHARACTERIZATION AND MODELLING OF DIFFERENTIAL SENSITIVITY OF NANORIBBON-BASED PH-SENSORS** 2188

P. Scarbolo[1], E. Accastelli[2], F. Pittino[1], T. Ernst[3], C. Guiducci[2], and L. Selmi[1]
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We report accurate characterization and modeling of SOI nanoribbon-based pH sensors comparing operations in air and liquid environments. We find remarkably different current distributions and geometry scaling rules, but similar series resistances and active trap state densities in the two configurations. TCAD based simulations in good agreement with experiments provide the necessary insights to interpret the non trivial dependence of the threshold voltage and drain current sensitivities on pH.

WEDNESDAY - Theory, Design and Test Methodology

W2P.094 **PERFORMANCE AND NOISE ANALYSIS OF CAPACITIVE SILICON MICROPHONES USING TAILORED SYSTEM-LEVEL SIMULATION** 2192

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[1]*Munich University of Technology, GERMANY and* [2]*Infineon Technologies AG, GERMANY*

A fully coupled fluidic-electro-mechanical system-level model has been assembled and applied to existing and novel silicon microphone designs. Distributed and non-linear effects like fluidic damping and electrostatic forces and their impact on the overall system performance can be investigated. Employing the fluctuation-dissipation theorem we predict and discriminate the noise contribution of single microphone regions to suggest design measures for the enhancement of the signal-to-noise ratio.

W2P.095 COMPARATIVE STUDY OF DIFFERENT OUTPUT METRICS FOR A THREE WEAKLY COUPLED RESONATOR SENSOR 2196
C. Zhao[1], G.S. Wood[1], J.B. Xie[2], H. Chang[2], S.H. Pu[1,3], and M. Kraft[4]
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[3]*University of Southhampton, MALAYSIA, and* [4]*University of Liege, BELGIUM*

This work, for the first time, investigates the characteristics of different output metrics for a three degree-of-freedom (DoF) coupled resonator sensor. The main aspects examined are sensitivity and linear range. It is shown from electrical measurements that using the vibration amplitude ratio as an output signal provides improved sensitivity and linearity range, compared to other methods such as shift in eigenstate, mode frequency or amplitude difference.

W2P.096 DETERMINATION OF THE EFFECTIVE MASS AND STIFFNESS OF A MICRO RESONATOR FROM A SINGLE OPTICAL CHARACTERIZATION 2200
A. Bhaswara[1,2], D. Dezest[1,2], T. Leichle[1,2], L. Nicu[1,2], and B. Legrand[1,2]
[1]*CNRS LAAS, FRANCE and* [2]*Université de Toulouse, FRANCE*

We propose a method for the experimental determination of the effective mass and stiffness of a micro mechanical resonator using optical interferometry in a Fabry-Perot configuration. The method relies on the spectral analysis of the photodiode signal, which is ruled by the Jacobi-Anger expansion, allowing the absolute calibration of the vibration amplitude. Effective parameters are then calculated from the thermomechanical noise spectrum of the resonator.

W2P.097 SIMPLE MODEL FOR THE PERFORMANCE OF REALISTIC AMR MAGNETIC FIELD SENSORS.....2204
A.S. Spinelli[1], P. Minotti[1], G. Laghi[1], G. Langfelder[1], A.L. Lacaita[1], and D. Paci[2]
[1]*Politecnico di Milano, ITALY and* [2]*STMicroelectronics, ITALY*

We report on a numerical model for the performance of realistic AMR sensors in a multi-strip geometry matching the experimental characteristics without any fitting parameters. A simplified model is also developed employing effective demagnetization coefficients and matching the exact solution, that can be useful as a design optimization tool.

MONDAY - Late News

M3P.097 RF WIRELESS LC TANK SENSORS FABRICATED BY 3D ADDITIVE MANUFACTURING 2208
S.-Y. Wu[1,2], C. Yang[1], W. Hsu[2], and L. Lin[1]
[1]*University of California at Berkeley, USA and* [2]*National Chiao Tung University, TAIWAN*

Wireless LC tank sensors constructed by a 3D additive manufacturing technique are presented. Fabricated 3D structures with hollow channels are filled with liquid metal to form basic electrical components including inductors and capacitors. This LC tank sensor is utilized in rapid detection of liquid food (e.g., milk and juice). This work presents a new class of manufacturing concepts to construct arbitrary 3D electrical systems for wireless sensing applications.

M3P.098 A SUB-MICRON-GAP SOI CAPACITIVE ACCELEROMETER ARRAY UTILIZING SIZE EFFECT 2212
Y. Matsui, Y. Hirai, T. Tsuchiya, and O. Tabata
Kyoto University, JAPAN

We have developed a 10x10 single-axis accelerometer array, whose dimensions are 1/10 of typical accelerometers. Here, the size effect of the capacitive sensitivity is investigated. To solve the pull-in problem, which is more apparent on miniaturizing, nonlinear programming to optimize dimensions is used. The accelerometer is fabricated using electron beam lithography. The fabricated accelerometer was successfully operated without pull-in, which showed our design method was useful to avoid it.

M3P.099 A BACTERIAL BIOFILM COMBINATION TREATMENT USING A REAL-TIME MICROFLUIDIC PLATFORM.....2216
S. Subramanian, K. Gerasopoulos, H.O. Sintim, W.E. Bentley, and R. Ghodssi
University of Maryland, USA

We report the results of a biofilm treatment using a small molecule inhibitor in combination with electric fields, completely eliminating the need for antibiotics. We utilize a real-time high-throughput biofilm analysis platform to quantify the treatment efficacy. We demonstrate the high-throughput capability of the platform and the spatiotemporal monitoring capacity of the system by tracking the growth and treatment of biofilms when subjected to the combination treatment in real-time.

M3P.100 **A WIRELESS CHEMICAL SENSING SCHEME USING ULTRASONIC IMAGING OF MICROBUBBLES EMBEDED HYDROGEL** 2220

J.H. Park[1], A. Kim[1], S.H. Song[2], P. Bhandari[1], J. Irudayaraj[1], and B. Ziaie[1]
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In this paper, we demonstrate a wireless chemical sensing scheme using ultrasonic imaging of a microbubble-functionalized hydrogel, named bubblegel. By incorporating oxygen microbubbles into hydrogel, its volume transition, which is responsive to its chemical microenvironment, can be wirelessly monitored by ultrasonic imaging; measuring volume directly or measuring the reflected acoustic intensity from the surface of the bubblegel. The bubblegel fabricated with pH-sensitive poly (methacrylic aci

M3P.101 **SURFACE TENSION-DRIVEN ASSEMBLY OF METALLIC NANOSHEETS AT THE LIQUID-AIR INTERFACE: APPLICATION TO HIGHLY LAMINATED MAGNETIC CORES** 2224

J. Kim[1], M. Kim[1], and M.G. Allen[2]
[1]*Georgia Institute of Technology, USA and* [2]*University of Pennsylvania, USA*

This paper presents a fabrication technique to develop highly laminated structures comprising stacked thin films, in which the structures are based on surface tension-driven assembly at the liquid-air interface. When multiple metallic films are removed from a liquid solution, there is a surface tension-driven coalescence and self-alignment of the wetted films, resulting in thick metallic microstuctures comprised of many layers of metallic nanosheets after evaporation of the liquid.

M3P.102 **SELF-CALIBRATED FLUORESCENT THERMOMETER NANOPARTICLES ENABLE IN VIVO MICRO THERMOGRAPHY IN MILIMETER SCALE LIVING ANIMALS** 2228

Ferdinandus[1], S. Arai[2], S. Ishiwata[2,3], M. Suzuki[2,3], and H. Sato[1]
[1]*Nanyang Technological University, SINGAPORE,*
[2]*WASEDA Bioscience Research Institute in Singapore (WABIOS), SINGAPORE, and* [3]*Waseda University, JAPAN*

We develop fluorescent nanoparticle thermometer capable of mapping out temperature distributions in small animals with higher spatial resolution than conventional infrared thermography. To acquire fluorescence intensity change solely owing to the temperature shift, we encapsulated both the thermo-sensitive dye and the thermo-insensitive (reference) dye into the particle. It showed a notably high thermo-sensitivity of 3.6%/°C, and could measure the temperature distributions in fruit fly larvae.

M3P.103 **WIRE-BONDING-BASED VERTICAL MICROPROBE ELECTRODE ARRAYS INTEGRATED ONTO HIGH-DENSITY MICROELECTRODE ARRAYS WITH ACTIVE CIRCUITRY FOR EXTRACELLULAR RECORDING** 2232

S. Hidaka[1], M.E.J. Obien[2], U. Frey[2], and S. Konishi[1]
[1]*Ritsumeikan University, JAPAN and* [2]*RIKEN Quantitative Biology Center, JAPAN*

This paper presents wire-bonding-based vertical microprobe electrode arrays integrated onto high-density microelectrode arrays (HDMEAs) with active circuitry for extracellular recording. We developed a novel wire-bonding technology to manufacture vertical microprobe electrode arrays with uniform tip heights. This paper also reports successful detection of neuronal activity in an acute cerebellar slices using the vertical microprobe electrodes on HDMEAs.

TUESDAY - Late News

T4P.099 **HIGH-THROUGHPUT PRINT-TO-SCREEN (P2S) PLATFORM FOR COMBINATORIAL CHEMOTHERAPY** 2236

J. Li, Y. Ding, W. Xiao, K. Xiao, J. Lee, U. Bhardwaj, Z. Zhu, P. Digiglio, K.S. Lam, and T. Pan
University of California, Davis, USA

We report a microfluidic enabled print-to-screen platform, which achieves low-cost, high-throughput printing and parallel screening for large-scale combinatorial libraries, and shows potent applicability in speeding up the entire cycle of drug discovery. Using this platform, the cell-killing performance of 3-drug combination towards ovarian cancer cell is, for the first time, studied and as a result, 15 out of 175 drug combinations are newly identified to exert potent cancer cell toxicity.

T4P.100 **TESTING A CAPPED MEMS GYROSCOPE BY AN INFRARED TECHNIQUE** 2240

M. Wolfer[1], C. Hepp[1], M. Reimann[2], U. Kunz[2], and C. Rembe[1,3]
[1]*Polytec GmbH, GERMANY,* [2]*Bosch GmbH, GERMANY, and* [3]*Technische Universität Clausthal, GERMANY*

Sealing MEMS devices by wafer capping is an important step during MEMS fabrication. MEMS gyroscopes in general are sensitive to stress introduced by the capping process because the mechanical resonances have an influence to the sensor properties. We present a rapid analysis of a MEMS gyroscope performed with an infrared confocal laser-vibrometer microscope. We demonstrate that accurate geometric parameters and vibration spectra can be obtained from structures inside the capped device.

POSTER/ORAL PRESENTATIONS

T4P.101 **STACKED BIOFUEL CELLS SEPARATED BY ARTIFICIAL LIPID BILAYERS** **2244**

K. Shoji and K. Morishima
Osaka University, JAPAN

We report the first demonstration of stacked biofuel cells (SBFC) separated by artificial lipid bilayers which block the flow of ions in electrolysis solution. The output voltage of 2.04 V was obtained from the quad SBFC and we succeeded in driving a digital clock (driving voltage, 1.3 V) powered by the quad SBFC without external circuits. These results indicate the potentially for developing the high voltage BFC implanted in living organisms.

T4P.102 **VERSATILE CMOS-MEMS INTEGRATED PIEZOELECTRIC PLATFORM** **2248**

J.M. Tsai[1], M. Daneman[1], B. Boser[2], D. Horsley[2], M. Rais-Zadeh[3], H.Y. Tang[2],
Y. Lu[2], O. Rozen[2], F. Liu[1], M. Lim[1], and F. Assaderaghi[1]
[1]*InvenSense Inc., USA,* [2]*University of California, Berkeley, USA, and*
[3]*University of Michigan, USA*

InvenSense presents an extension of an InvenSense Platform by introducing AlN as piezoelectric material. The proposed fabrication platform incorporates piezoelectric transducing mechanism and enables new opportunity to versatile applications. Several demonstration vehicles are presented as proof of its flexibility.

T4P.103 **SAIL-SHAPED PIEZOELECTRIC MICRO-RESONATORS FOR HIGH RESOLUTION GAS FLOWMETRY** **2252**

A. Ramezany[1], M. Mahdavi[1], A. Moses[2], and S. Pourkamali[1]
[1]*University of Texas, Dallas, USA and* [2]*femtoScale Inc., USA*

This work presents sail-shaped thin film aluminum nitride resonators operating as high resolution gas flow meters. Sensitivity of frequency to flow velocity was measured to be 0.5Hz/mm/s leading to minimum detectable velocity of 0.2mm/s. Such sensors with frequency modulated output are much less susceptible to noise compared to the conventional sensors with amplitude modulated output, and can be directly fed into a digital readout/control system without the need for A/D conversion.

T4P.104 **A HIGH-*Q* AlGaN/GaN PHONON TRAP WITH INTEGRATED HEMT READ-OUT** **2256**

A. Ansari, R. Tabrizian, and M. Rais-Zadeh
University of Michigan, USA

In this work, we present novel phonon traps implemented on an AlGaN/GaN electro-acoustic platform. The geometry of acoustic cavities has been engineered to efficiently trap the energy in the central region of devices, where the interdigitated excitation/read-out electrodes and HEMT read-outs are located. An unloaded quality factor (Q) of ~13,000 has been measured at ~740 MHz, resulting in frequency × Q value of 0.96 ×1013, which is the highest reported for GaN resonators to date.

WEDNESDAY - Late News

W2P.098 **SOFT POLYMER-BASED CANTILEVER PROBE FOR AFM NANOINDENTATION OF LIVE MAMMALIAN CELLS IN LIQUID** **2260**

F. Yu, J. Liu, S. Yu, Z. Yang, Y. Pan, N. Gao, Q. Zou, and J. Jeon
Rutgers, The State University of New Jersey, USA

A soft polymer-based V-shaped cantilever probe is proposed for atomic force microscopy (AFM), and the first well-functioning, visually-flat prototype fabricated using a simple, but novel low-cost process and bio-compatible materials is demonstrated. With the prototype, for the first time, AFM nanoindentation was performed on live mammalian cells—human cervical adenocarcinoma cells in liquid.

W2P.099 **SOFT MICROFLUIDIC NEURAL PROBES FOR WIRELESS DRUG DELIVERY IN FREELY BEHAVING MICE** **2264**

J.-W. Jeong[1], J.G. McCall[2], Y. Zhang[3], Y. Huang[3], M.R. Bruchas[2], and J.A. Rogers[4]
[1]*University of Colorado, Boulder, USA,* [2]*Washington University School of Medicine, St. Louis, USA,*
[3]*Northwestern University, USA, and* [4]*University of Illinois at Urbana-Champaign, USA*

We present ultrathin, soft microfluidic neural probes with wireless drug delivery capability that can be injected precisely in the deep brain tissue. These probes permit targeted, wireless, spatiotemporal control of pharmacologic manipulation in freely behaving mice. Because of the flexible, wireless nature of this probe, it is minimally invasive and has potential for broad applications in neuroscience as well as clinical medicine.

W2P.100 AN ULTRA-LOW COST DEEP REACTIVE ION ETCHING (DRIE) TOOL FOR FLEXIBLE SMALL VOLUME MANUFACTURING....2268
P.A. Gould, M.D. Hsing, H.Q. Li, K.K. Gleason, and M.A. Schmidt
Massachusetts Institute of Technology, USA

In order to demonstrate that radical reductions in the capital cost of advanced micro/nano fabrication equipment can be achieved without significant performance sacrifices, we present a fully functional DRIE system for processing small substrates (~1-2'') for a capital cost of under $32K. We have designed, built and tested this system, which currently can achieve silicon etch rates up to 2.8 µm/min with vertical sidewall profiles and etch depth uniformity to within 2% across the substrate.

W2P.101 ETCH "SANDBOX": CONTROLLED RELEASE DIMENSIONS THROUGH ATOMIC LAYER DEPOSITION ETCH STOP WITH TRENCH REFILL AND POLISH....2272
M.M. Winterkorn, A.L. Dadlani, Y. Kim, J. Provine, and F.B. Prinz
Stanford University, USA

We report on the demonstration of a microfabrication process which allows the release of suspended films or structures of varying sizes in which the release volume is predefined by lithographic patterning, etch stop deposition by atomic layer deposition (ALD), refilling sacrificial layer into the empty volume, and subsequent chemical mechanical planarization (CMP). Within a single substrate and single release, defined etch volumes differing by up to a factor of 10 000 can be realized.

W2P.102 ETCH-A-SKETCH FILTER....2276
R. Wangand S.A. Bhave
Cornell University, USA

We demonstrates an ''Etch-A-Sketch'' filter on a Z-cut LiNbO3 thin-film. The filter consists of two resonators coupled by a reconfigurable phononic crystal that can be programmed by AFM-based post-release piezoelectric domain engineering. We demonstrated a band-pass filter at 553MHz with 8.6MHz 3dB BW. Then, we ''Etch-A-Sketch'' domain inverted patterns on the coupling element thus changing the coupling impedance, and reduces the filter BW by 4.6%. This method requires no DC bias during RF operation.

W2P.103 CONVERSION MECHANISM FOR BIOHYBRID MICROSYSTEMS: LINEAR MOTION OF MAGNETICALLY PATTERNED MICROORGANISMS TO ROTARY MOTION OF ARTIFICIAL COMPONENT....2280
M. Nagai, K. Tanizaki, and T. Shibata
Toyohashi University of Technology, JAPAN

We established a conversion mechanism of the linear motion of magnetically patterned microorganisms through a movable component. We developed a fabrication process of a movable component in a microchannel decorated with magnetic blocks. Cells of Vorticella were patterned around magnetic blocks in a microchannel using a magnetic force. A movable component was integrated with a cell for conversion of the motion of Vorticella to a rotational motion.