# **2016 International Symposium** on 3D Power Electronics **Integration and Manufacturing** (3D-PEIM 2016)

Raleigh, North Carolina, USA 13-15 June 2016



**IEEE Catalog Number: CFP16G64-POD ISBN:** 

978-1-5090-0939-8

## Copyright © 2016 by the Institute of Electrical and Electronics Engineers, Inc All Rights Reserved

Copyright and Reprint Permissions: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923.

For other copying, reprint or republication permission, write to IEEE Copyrights Manager, IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854. All rights reserved.

\*\*\*This publication is a representation of what appears in the IEEE Digital Libraries. Some format issues inherent in the e-media version may also appear in this print version.

 IEEE Catalog Number:
 CFP16G64-POD

 ISBN (Print-On-Demand):
 978-1-5090-0939-8

 ISBN (Online):
 978-1-5090-2940-2

#### **Additional Copies of This Publication Are Available From:**

Curran Associates, Inc 57 Morehouse Lane Red Hook, NY 12571 USA Phone: (845) 758-0400 Fax: (845) 758-2633

E-mail: curran@proceedings.com Web: www.proceedings.com



# 3D - PEIM 2016 Table of Contents

## Session Mon - PM1

## **Additive Manufacturing**

Chairs:

Ola Harryson, *NC State University* Govindarajan Muralidharan, *Oak Ridge National Laboratory* 

**3D Printing Technology for Automotive Applications 3** Madhu Chinthavali, *Oak Ridge National Laboratory* 

Additive Manufacturing of Planar Inductor for Power Electronics Applications 16 Guo-Quan Lu, *Virginia Tech* 

Thermal Response of Additive Manufacturing Aluminum 20 Tong Wu, Oak Ridge National Laboratory

**3D Printed Microchannel Heat Sink Design Considerations 25** Frank Wang, *Crane EG* 

## Session Mon - PM2

## **Thermal Management & Systems Integration**

Chair.

Sreekant Narumanchi, National Renewable Energy Laboratory

Design for Additive Manufacturing of Wide Band-Gap Power Electronics Components 41

Eric Dede, Toyota Research Institute of North America

Thermal Management and Reliability of Power Electronics and Electric Machines 45 Sreekant Narumanchi, *National Renewable Energy Laboratory* 

A High Power-Density Three-Phase Inverter Adopting Double-End Sourced Power Module Structure 58

Dr. Fang Luo, Ohio State University

Novel Packaging and Thermal Measurement for 3D Heterogeneous Stacks 63 Theodore Harris, *NC State University* 

## Session Tue - AMI

## **Plenary Road Mapping**

Chair:

Brian Narveson. PSMA

2017 iNEMI Roadmap Process and a Preview of Selected IoT/Wearables, Packaging & Board Assembly Chapter Highlights 77
Chuck Richardson, iNEMI

International Technology Roadmap for Wide Band-gap Power Semiconductors 112

Bram Ferreira, *Technical University of Delft* 

Heterogeneous Integration for IoT, Cloud, and Smart Things 125 Bill Chen, ASE-US and IEEE CPMT

## Session Tue - AM2

## **Multiphysics Modeling & Simulation**

Chair:

Zhenxian Liang, Oak Ridge National Laboratory

**Automatic Thermal Calibration of Detailed IC Package Models** 143 John Wilson, *Mentor Graphics* 

Parasitic Induction Extraction and Verification for 3D Planar Bond All Module 152 Fei Yang, *University of Tennessee, Knoxville* 

**FEA-Based Thermal-Mechanical Design Optimization for DBC Based Power Modules 157** 

Yang Xu, NC State University

Decomposition and Electro-Physical Model Creation of the CREE 1200V, 50A 3-Ph SiC Module 163

Adam Morgan, NC State University

## Session Tue - PM1

#### **Materials**

Chair:

Thomas Lei, Ford

**Ag Sinter Joining and Stress Migration Bonding for WBG Die Attach** 171 Katsuaki Suganuma, *Osaka University* 

#### Materials for 3D Integration 175

Patrick McCluskey, University of Maryland

## Session Tue - PM2

## **Manufacturability**

Chair:

Jared Hornberger, Wolfspeed

**Towards Better Power Electronics Building Blocks** 203 Bram Ferreira, Technical University of Delft

Design and Manufacturability of a High Power Density M2C Inverter 220 Joseph Kozak, *University of Pittsburgh* 

3D System in a Package (3D SiP) with Embedded Chip, Providing Integration **Solutions for Power Applications 225** Lee Smith. UTAC

Parametric Power Electronic Module Design Techniques for Rapid Analysis, Prototyping, and Transition to Manufacturing 231 Brice McPherson, Wolfspeed

## Session Tue - PM3

## **Networking Reception, Interactive Presentations & Vendor Exhibits**

Advanced Multi-physics Simulation for High Performance Power Electronic Design 247

Xin Zhao, Yang Xu, NC State University

Application of 3D Printing for Rapid Prototyping of Adv. Power Electronic Modules N/A

Yang Xu, NC State University

A Folded GaN VRM with High Electrical and Thermal Performance 248 Bo Gao, NC State University

**Developments for Copper-Graphite CTE-Matched Thermal Cores for High** Reliability GaN Systems 253

David Saums, DS&A LLC

Metallic TIM Testing and Selection for IC, Power, and RF Semiconductors 255 David Saums. DS&A LLC

Enabling High Reliability Power Modules: A Multidisciplinary Task 266 Li Ran, *University of Warwick* 

## Session Wed - AMI

## **Embedding Technologies**

Chair:

Paul McCluskey, Tyndall National Institute, University of Cork

#### Power System-in-Package 273

Cian O'Mathuna, Tyndall National Institute, University of Cork

Significant developments and trends in embedded substrate and component technologies for power applications 294

Brian Narveson, *PSMA* 

On Size and Magnetics: Why Small Efficient Power Inductors Are Rare 312 Charlie Sullivan. *Dartmouth* 

## Session Wed - AM2

## **Embedded Components**

Chair:

Khai Ngo, Virginia Tech

Batch Fabrication of Radial Anisotropy Toroidal Inductors 319
Charlie Sullivan, *Dartmouth* 

Small, Fast Voltage Regulators using Heterogeneous Integration 323 Greg Miller, Sarda Tech

**High Efficiency Power Solutions by Chip Embedding 327** Kay Essig, *ASE-EU* 

**High performing vertical Silicon Capacitors for RF power modules** 331 Catherine Bunel, *Ipdia* 

Increase Power Density and Simplify Designs with 3D SiP Modules 346 Jim Moss, *Texas Instruments* 

## Session Wed - PMI

## **Quality & Reliability**

Chair:

Patrick McCluskey, University of Maryland

An Overview of Die Attach and Wire Bond Fatigue Models and Test Results 351 Craig Hillmann, *DFR Solutions* 

An Evaluation of BME C0G Multilayer Ceramic Capacitors as Building Blocks for DC-Link Capacitors in 3D Power Electronics 377
John Bultitude, *Kemet* 

**Heavy Cu Wedge Bonding Ready for Mass Production 383**Bill Maldonado, *Hesse-Mechatronik* 

**Development of a Particle Erosion Model for Silicon Microchannel Coolers** 399 David Squiller, *University of Maryland*