

Thermal Barrier Coatings IV

**Irsee, Germany
22-27 June 2014**

Editors:

**U. Schulz
M. Maloney
R. Darolia**

ISBN: 978-1-5108-0658-0

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2014) by Engineering Conferences International
All rights reserved.

Printed by Curran Associates, Inc. (2015)

For permission requests, please contact Engineering Conferences International
at the address below.

Engineering Conferences International
32 Broadway, Suite 314
New York, NY 10004

Phone: (212) 514-6760

Fax: (212) 514-6030

info@engconfintl.org

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2634
Email: curran@proceedings.com
Web: www.proceedings.com

TABLE OF CONTENTS

SESSION 1: OVERVIEWS

Chair: Odile Lavigne

A Recent History of Thermal Barrier Coatings for Aero-propulsion Applications	1
<i>Brian Hazel, Michael J. Maloney</i>	
High-temperature Ceramic Coatings Used in Aero Engine Environments	3
<i>David Rickerby, Paul Morrell, Matthew Hancock</i>	

SESSION 2: BONDCOAT DEVELOPMENT AND OXIDATION BEHAVIOR

Chairs: Tresa Pollock, Vladimir Tolpygo

The Effect of Exposure Variables on the Development of Alumina Scales	5
<i>Gerry Meier</i>	
Effect of Bondcoat Roughness on Lifetime of APS-TBC Systems in Dry and Wet Gases	7
<i>W.J. Quadackers, D. Naumeko, P. Mor, W. Nowak, L. Singheiser</i>	
Design Constraints and Higher Temperature Intermetallic Bond Coatings	9
<i>T.M. Pollock, D. Jorgensen, R.W. Jackson, M. He, A. Suzuki, D. Lipkin</i>	
Potential Impacts of Alternative Fuels on the Evolution and Stability of Turbine Hot-Section Materials	12
<i>Daniel Mumm, Timothy Montalbano, Matthew Sullivan</i>	
The Role of Reactive Elements in Improving the Cyclic Oxidation Performance of β-NiAl Coatings	14
<i>Hongbo Guo, Hui Peng, Dongqing Li, Tian Zhang, Shengkai Gong</i>	
The Effect of Environment and Superalloy Composition on TBC Lifetime	16
<i>Bruce Pint, Kinga Unocic, Michael Lance, J. Allen Haynes</i>	
Application of EQ bond coat to EB-PVD TBC systems	18
<i>Kazuhide Matsumoto, Kyoko Kawagishi, Yutaka Koizumi, Hiroshi Harada</i>	
On the Behavior of Titanium Within Thermal Barrier Coatings and Its Influence on Residual Stress Within the TGO	20
<i>Robbie J. Bennett, Ian Edmonds, Neil Jones, Catherine Rae</i>	

SESSION 3: TOP COAT DEVELOPMENT - MATERIALS AND PROCESSING

Chairs: Robert Vaßen, Sanjay Sampath

Zirconia-doped Yttrium Tantalates As a Potential Next Generation Thermal Barrier Coating Material	22
<i>David R. Clarke</i>	
New Class of Refractory Ceramics for Thermal Barrier Coatings	24
<i>Wei Pan</i>	
Performance of Columnar 7-8 wt% YSZ Coatings on Platinum Aluminide Bondcoats	57
<i>Christopher Petorak</i>	
Stress and Crack Monitoring During Plasma Spraying of TBC	59
<i>Seiji Kuroda, Xiancheng Zhang, Makoto Watanabe, Kaita Ito, Manabu Enoki</i>	
Engineered Multi-layered Thermal Barrier Coatings for Enhanced Durability	61
<i>Sanjay Sampath, Vaishak Viswanathan, Gopal Dwivedi</i>	
Suspension Plasma Sprayed Thermal Barrier Coatings	63
<i>Per Nysten, Nicholas Curry, Ashish Ganvir, Nicolaie Markocsan</i>	
Columnar Structured Thermal Barrier Coatings by Thermal Spray Methods	65
<i>Robert Vassen, Nadine Schlegel, Stefan Rezanek, Georg Mauer, Emine Bakan, Daniel Mack</i>	
Multilayered Thermal Barrier Coatings	68
<i>Xueqiang Cao</i>	
High Temperature Oxidation and Burner Rig Testing of Different TBCs in the Frame of the European Project TOPPCOAT: A Summary of Results	70
<i>Federico Cernuschi, Robert Vassen</i>	

SESSION 4: FAILURE MECHANISMS – CMAS AND MITIGATION STRATEGIES

Chairs: David Shiffler, Carlos Levi

CMAS Degradation and Implications for Coating Design	89
<i>Arlos Levi</i>	
TBC Lifetime Under Thermal Gradient Cyclic Testing with Simultaneous CMAS Attack: Towards Prediction of Advanced Tbc Performance	91
<i>Daniel Mack, Doris Sebold, Michael Müller, Robert Vassen, Maria Ophelia Jarligo, Tanja Wobst</i>	
Solubility of Oxides from ZrO₂-Y₂O₃ and ZrO₂-Nd₂O₃ Systems in a Molten CAS. Selection of a Thermal Barrier Composition Resistant to CAS Infiltration	94
<i>Marie-Helene Vidal-Setif, Catherine Rio, Odile Lavigne, Nezha Chellah, M. Vilasi, C. Rapin, C. Petitjean, P. Panteix</i>	
A Thermodynamic Database for Simulation of CMAS and TBC Interactions	97
<i>Lina Kjellqvist, Johan Brattberg, Ake Jansson, Huahai Mao</i>	
Attack of Thermal Barrier Coatings by Molten Silicate Deposits (Sand, Ash) and Its Mitigation	111
<i>Nitin P. Padture</i>	
CMAS Deposition Within the Turbine of a Small Jet Engine and Effects on TBC Spallation	113
<i>T.W. Clyne</i>	
Examination of CMAS-induced EB-PVD TBC Failure	115
<i>Vladimir Tolpygo</i>	
Development of a Naturalistic Test Media for Dust Ingestion CMAS Testing of Gas Turbine Engines	117
<i>Andrew W. Phelps, Lynne Pfluederer</i>	
Yttrium Oxide a Candidate Material for Environmental and Thermal Barrier Coatings	119
<i>Peter Mechnich, Wolfgang Braue, Nadine K. Eils, Stefan Hackemann, Ravisankar Naraparaju</i>	

SESSION 5: FAILURE MECHANISMS – LIFE MODELING AND DEGRADATION

Chairs: Matt Begley, Stefan Lampenscherf

APS TBC Life Prediction - Impact of Manufacturing Variations	121
<i>Stefan Lampenscherf, Ramesh Subramanian</i>	
Probabilistic Lifetime Prediction of TBC Coated Parts Considering Design, Operation and Manufacturing + Thermal Barrier Coatings Ageing Mechanisms in Land-based Gas Turbines	123
<i>Hans Peter Bossmann, Gregoire Witz</i>	
Specific Failure Modes of Ni-base Superalloys and TBCs Under a Simulated Combustion Gas Atmosphere	125
<i>Mazaku Okazaki, Satoshi Yamagishi, Y. Hayashi</i>	
Lifetime Assessment Tools for Thermal Barrier Systems	127
<i>Jean Louis Chaboche, Frederic Feyel, Martine Poulain, Noemie Rakotamalala, Arjen Roos, Jean Roch Vaunois, Arnaud Longuet, Pascale Kanaoute</i>	
Reliable Measurement of Mechanical TBC Properties for Quality Control and Life Prediction	130
<i>Peter Wittig, Stefan Lampenscherf, Uwe Rettig, Matthias Oechsner</i>	
Mechanical Stability Limits of Bi-layer Thermal Barrier Coatings	132
<i>Mario Rudolphi, Mathias Galetz, Michael Schutze, Martin Frommherz, Alfred Scholz, Mathias Oechsner, Emine Bakan, Robert Vassen, Werner Stamm</i>	
Simulations of Fracture in Coatings with Complex Microstructures	148
<i>Mathew R. Begley, William Pro, Rone Kwei Lim, Linda Petzold</i>	

SESSION 6: ENVIRONMENTAL BARRIER COATINGS FOR BEYOND NI-BASED MATERIALS

Chairs: Brian Hazel, Gerry Meier

High Temperature Environmental Resistance of Mo-Si-B Alloys and Coatings	150
<i>John H. Perepezko</i>	
Manufacture of Silicide Coatings for the Protection of Niobium Alloys Against High Temperature Oxidation	152
<i>M. Vilasi, S. Matheieu, S. Knittel, L. Portebois, T. Katrina, C. Rapin, C. Petitjean, P. Panteix, S. Drawin</i>	
Lifetime of Environmental/thermal Barrier Coatings Deposited on an Nb/Nb₅Si₃- Based Alloy with Fe₂-modified M₇Si₆-based Bond Coat	155
<i>Reinhold Braun, Annika Lange, Uwe Schulz, L. Portebois, Stephane Mathieu, M. Vilasi, S. Drawin</i>	
Ceramic Matrix Composite Environmental Protection Strategies	158
<i>Bradley Richards, Hengbei Zhao, Haydn Wadley</i>	

Nasa's Advanced Environmental Barrier Coatings Development for SiC/SiC Ceramic Matrix Composites: Understanding Cmas Degradations and Resistance	160
<i>Dongming Zhu</i>	

SESSION 7: PROPERTIES AND CHARARTERIZATION TECHNIQUES

Chairs: Mike Maloney, Hongbo Guo

Evaluating Deformation Behavior of a TBC-System During Thermal Gradient Mechanical Fatigue by Means of High Energy X-ray Diffraction	162
<i>M. Bartsch, J. Wischek, C. Meid, K. Knipe, A. Manero, S. Raghavan, A. M. Karlsson, J. Okasinski, J. Almer</i>	
Nondestructive Thickness Measurements on EBPVD Thermal Barrier Coatings by Using Terahertz Technique	N/A
<i>Thomas Cosack</i>	
Prediction of the Cyclic Durability As a Function of Cycle Duration and Temperature of an Air Plasma Sprayed Coating Using Inelastic Strain	182
<i>Eric H. Jordan, Shayan Ahmadian, Maurice Gell</i>	
High Temperature Thermodynamic, Mechanical and Kinetic Properties from First Principles	184
<i>Anton Van der Ven</i>	
Demonstration of Two Novel Methods for Residual Stress Management on NiAl Bond Coats	186
<i>Markus Krottenthaler, Karsten Durst, Mathias Goken</i>	
Author Index	