Program

Thermal Barrier Coatings III

August 7-12, 2011

Kloster Irsee
Irsee, Germany

Conference Chair:
Dr. Michael J. Maloney
Pratt & Whitney, USA

Conference Co-Chairs:
Dr. Uwe Schulz, German Aerospace Center, Germany
Dr. David Rickerby, Rolls-Royce UK
Dr. Ram Darolia, GE Aviation (Retired), USA
Dr. Odile Lavigne, ONERA DMSM/MAT, France
Dr. Hideyuki Murakami, National Institute for Materials Science, Japan
Prof. Hongbo Guo, School of Materials Science and Engineering, Beihang University, China

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The organizers would like to thank the following for their support of this conference:

The Office of Naval Research

Pratt & Whitney
Sunday, August 7, 2011

16:00 - 18:00 Registration (Hospitality Desk in Kloster Irsee Lobby)

18:15 - 19:30 Organ Concert:
Roland Götz, Organist, will play on the historic organ of the monastery Church

19:30 - 20:30 Reception (Kloster Irsee Restaurant)

20:30 - 22:00 Dinner (Kloster Irsee Restaurant)

22:00 – 23:00 Social Hour (Bierstube/Stiftskeller)

Notes

• Technical sessions will be in “Vortragsaal” (Room 128)
• Lunches and dinners will typically be in the Kloster Irsee Restaurant.
• The conference banquet will be in the Festsaal.
• Audiotaping, videotaping and photography of presentations are prohibited.
• Speakers – Please have your presentation loaded onto the conference computer prior to the session start (preferably the day before).
• Speakers – Please leave at least 3-5 minutes for questions and discussion.
• Please do not smoke at any conference functions.
• Turn your cellular telephones to vibrate or off during technical sessions.
• Be sure to make any corrections to your name/contact information on the Master Participant List or confirm (by your initials) that the listing is correct. A corrected copy will be sent to all participants after the conference.
• Participants staying at the Klosterbräu Hotel Irsee should have breakfast at the hotel. Those staying at Kloster Irsee will have breakfast at Kloster Irsee.
Monday, August 8, 2011

07:00 - 08:00  Breakfast

08:00 - 08:15  Welcome and Conference Overview
               Michael Maloney, Pratt & Whitney
               Ram Darolia, ECI Technical Liaison

SESSION 1: OVERVIEWS
Chair: David Shifler, Office of Naval Research, USA

08:15 - 09:00  H.-P. Bossmann
               Alstom, Switzerland
               RELIABLE THERMAL BARRIER COATINGS FOR HIGH-LOADED
               TURBINE AND COMBUSTOR PARTS

09:00 - 09:45  Huibin Xu
               Beihang University, China
               RESEARCH PROGRESS ON TBCS MATERIALS FOR ULTRA-HIGH
               TEMPERATURE APPLICATIONS

09:45 - 10:15  Coffee Break

10:15 - 11:00  David Rickerby
               Rolls Royce, UK
               LIFING AND DEGRADATION OF EB-PVD THERMAL BARRIER COATINGS

SESSION 2: BONDCOAT DEVELOPMENT AND BEHAVIOR
Chair: Brian Gleeson, University of Pittsburgh, USA

11:00 - 11:40  Teresa Pollock
               University of California, Santa Barbara, USA
               COMBINATORIAL STUDIES OF NIAL-BASED OVERLAY BOND
               COATINGS

11:40 - 12:20  Shengkai Gong,
               Beihang University, China
               NEW BOND COAT MATERIALS IN TBC SYSTEM FOR ADVANCED SINGLE
               CRYSTAL SUPERALLOY

12:20 - 13:30  Lunch

13:30 - 14:10  Akihiro Sato
               Research Laboratory, IHI Corporation, Japan
               DEVELOPMENT OF NEW PT-γ+γ' TYPE BOND COATINGS FOR
               ADVANCED NI-BASE SINGLE CRYSTAL SUPeralloys

14:10 - 14:40  Discussion
**Monday, August 8, 2011 (continued)**

**SESSION 3: FUNDAMENTALS OF OXIDATION**  
Chair: Gerald Meier, University of Pittsburgh, USA

14:40 - 15:20  
Brian Gleeson  
University of Pittsburgh, USA  
COMPOSITIONAL FACTORS AFFECTING THE OXIDATION BEHAVIOR OF CURRENT AND DEVELOPMENTAL BOND COATING SYSTEMS

15:20 - 15:50  
Afternoon Coffee Break

15:50 - 16:30  
Dimitry Naumenko  
Juelich, Germany  
OXIDATION OF MCRALEY-BONDCOATS AND ITS INFLUENCE ON THE THERMAL CYCLIC LIFETIME OF YSZ TBC SYSTEMS

16:30 – 16:50  
Roger Reed (presented by Rudder Wu)  
University of Birmingham, UK  
FACTORS CONTROLLING ADHESION OF TBC SYSTEMS TO NICKEL-BASED SUPERALLOYS

16:50 – 17:10  
Rudder Wu  
ICYS, National Institute for Materials Science, Japan  
TOWARDS A DETAILED UNDERSTANDING OF THE FUNDAMENTAL MECHANISMS UNDERLYING THE BENEFICIAL EFFECTS OF PLATINUM MODIFICATION

17:10 – 17:50  
Vladimir Tolpygo  
Honeywell, USA  
ON THE ORIGIN OF STRESSES IN ALUMINIDE BOND COATS DURING SERVICE AT HIGH TEMPERATURES

17:50 - 18:10  
Discussion

19:00 - 20:30  
Dinner

20:30 - 22:00  
Social Hour
Tuesday, August 9, 2011

07:00 - 08:00 Breakfast

SESSION 4-1: TOP COAT DEVELOPMENT AND CHARACTERISTICS
Chairs: Uwe Schulz, DLR, German Aerospace Center, Germany
       Richard Wellman, Cranfield University, UK

08:00 - 08:40 Konstyantyn Yakovchuk
ICEBT, Ukraine
ELECTRON BEAM TECHNOLOGY AND EQUIPMENT FOR
DEPOSITION OF GRADED TBC

08:40 - 09:20 Frederic Rousseau
LGPPTS Ecole Nationale Supérieure de Chimie de Paris, France
DEVELOPMENT OF A LOW PRESSURE PLASMA DEPOSITION
TECHNIQUE TO IMPROVE THE PROPERTIES AND THE
RESISTANCE OF THERMAL BARRIER COATINGS

09:20 - 10:00 Robert Vassen
Juelich, Germany
SUSPENSION PLASMA SPRAYING FOR THE MANUFACTURE OF
ADVANCED THERMAL BARRIER COATINGS

10:00 - 10:30 Coffee Break

10:30 - 11:10 Derek Hass
DVTI, USA
PROCESSING OF ADVANCED THERMAL BARRIER COATINGS
VIA DIRECTED VAPOR DEPOSITION

11:10 - 11:40 Roman Kubrin
Hamburg University of Technology, Germany
MULTILAYER 3D PHOTONIC CRYSTALS FOR APPLICATION AS
HIGHLY REFLECTIVE THERMAL BARRIER COATINGS

11:40 - 12:10 Lucy Y. Liu
Chromalloy Gas Turbine LLC, USA
A NEW APS MULTILAYER TBC WITH LOW K AND HIGH DURABILITY

12:10 - 12:30 Discussion

12:30 - Boxed Lunch
Optional Excursion

18:00 - 19:00 Dinner
Tuesday, August 9, 2011 (continued)

SESSION 4-2: TOP COAT DEVELOPMENT AND CHARACTERISTICS
Chair: Robert Vassen, Forschungszentrum Jülich GmbH, Germany

19:00 - 19:40     Sanjay Sampath
                  State University of New York, USA
                  CONTROLLED INTRODUCTION ON ANELASTICITY IN PLASMA
                  SPRAYED TBCS: IMPLICATIONS FOR PERFORMANCE AND
                  RELIABILITY

19:40 - 20:20    Konstantin Von Niessen
                  Sulzer, Switzerland
                  VAPOR PHASE DEPOSITION USING A PLASMA SPRAY PROCESS

20:20 - 21:00    Ping Xiao
                  University of Manchester, UK
                  MICROSTRUCTURE, RESIDUAL STRESSES AND MECHANICAL
                  PROPERTIES OF TBCS

21:00 – 21:30    Discussion

21:30 - 23:00    Social Hour
Wednesday, August 10, 2011

07:00 - 08:00 Breakfast

SESSION 4-3: TOP COAT DEVELOPMENT AND CHARACTERISTICS
Chairs: Odile Lavigne, ONERA, DMSM/MAT, France
Kevin Hemker, Johns Hopkins University, USA

08:00 - 08:40 Gerry Meier
University of Pittsburgh, USA
THE EFFECT OF PROCESSING VARIABLES ON THE DURABILITY
OF HIGH-PURITY YSZ-TBCS PREPARED BY APS

08:40 - 09:20 Dongming Zhu
NASA, USA
ENVIRONMENTAL BARRIER COATINGS FOR SIC/SIC CERAMIC MATRIX
COMPOSITE TURBINE ENGINE HOT-SECTION COMPONENTS: ADVANCES,
APPLICATIONS AND DIRECTIONS

09:20 - 10:00 Kang Lee
Rolls Royce, USA
RECESSION OF ENVIRONMENTAL BARRIER COATINGS FOR CERAMIC
MATRIX COMPOSITES

10:00 - 10:30 Coffee Break

10:30 - 11:00 Maria Ophelia Jarligo
Julich GmbH, Germany
NEW THERMAL BARRIER COATINGS FROM COMPLEX PEROVSKITES

11:00 - 11:30 Ming Fu
GE Aviation, USA
IMPACT AND EROSIN PERFORMANCE OF THERMAL BARRIER COATINGS

11:30 - 12:00 Federico Cernuschi
RSE, Italy
THERMAL DIFFUSIVITY MEASUREMENT BY THERMOGRAPHIC
TECHNIQUE FOR THE NON DESTRUCTIVE INTEGRITY ASSESSMENT OF
TBCS COUPONS

12:00 - 12:30 Discussion

12:30 - 13:30 Lunch

SESSION 5: CMAS MECHANISMS AND MITIGATION
Chairs: David Litton, Pratt & Whitney, USA
David Clarke, Harvard University, USA

13:30 - 14:10 Carlos Levi
University of California, Santa Barbara, USA
CMAS: LESSONS LEARNED AND PERSPECTIVES
Wednesday, August 10, 2011 (continued)

14:10 - 14:50 Peter Mechnich  
DLR, Germany  
THERMOCHEMICAL ATTACK OF ARTIFICIAL AND NATURAL VOLCANIC ASHES ON 7 YSZ AND PYROCHLORE TBCS

14:50 - 15:20 Wolfgang Braue  
DLR, Germany  
GARNET-TYPE REACTIVE INTERFACES FROM FE-TI-CMAS HOT CORROSION OF YSZ COATED ENGINE HARDWARE

15:20 - 15:50 Coffee Break

15:50 - 16:20 M.H. Vidal-Setif  
ONERA, France  
CMAS DEGRADATION OF EB-PVD THERMAL BARRIER COATINGS: FROM EX SERVICE EXAMINATIONS TO LABORATORY TESTS

16:20 - 17:00 Nitin Padture  
The Ohio State University, USA  
PLASMA-SPRAYED THERMAL BARRIER COATINGS THAT ARE RESISTANT TO DAMAGE BY MOLTEN DEPOSITS: CMAS SAND, VOLCANIC ASH, AND COAL FLY ASH

17:00 - 17:30 M. Shinozaki  
University of Cambridge, UK  
THE EFFECT OF CMAS- ASSISTED SINTERING ON THE THERMOMECHANICAL STABILITY OF PLASMA- SPRAYED TBCS

17:30 - 18:00 Discussion

18:30 - 19:45 Dinner

20:00 - 22:00 **SESSION 6: POSTER SESSION** and Social Hour  
Chair: Sanjay Sampath, SUNY Stonybrook, USA
Thursday, August 11, 2011

07:00 - 08:00 Breakfast

SESSION 7: FAILURE MECHANISMS
Chairs: David Rickerby, Rolls Royce, UK
Ram Darolia, General Electric (retired), USA
Teresa Pollack, University of California Santa Barbara, USA

08:00 - 08:40 Ramesh Subramanian
Siemens, USA
ADVANCED MULTI-FUNCTIONAL COATINGS FOR LAND-BASED INDUSTRIAL GAS TURBINES

08:40 - 09:20 David Clarke
Harvard University, USA
PROPERTY AND DAMAGE EVOLUTION IN THERMAL BARRIER COATINGS

09:20 - 10:00 Wim G. Sloof
Technical University of Delft, Netherlands
DAMAGE GROWTH TRIGGERED BY INTERFACE IRREGULARITIES IN THERMAL BARRIER COATINGS

10:00 - 10:30 Coffee Break

10:30 - 11:10 Yutaka Kagawa
University of Tokyo, Japan
EFFECT OF EXTRINSIC FACTORS FOR DEFORMATION OF EB-PVD THERMAL BARRIER COATINGS: SOME RESULTS OF THERMO-MECHANICAL FATIGUE TESTS

11:10 - 11:50 Kevin Hemker
John Hopkins University, USA
EXPERIMENTAL INVESTIGATIONS OF DELAMINATION TOUGHNESS IN LAYERED PROTECTION SYSTEMS

11:50 - 12:20 Mario Schweda
Forschungszentrum Jülich, Germany
INFLUENCE OF BONDCOAT CREEP AND ROUGHNESS ON TBC-DAMAGE

12:20 - 13:30 Lunch

13:30 - 14:10 Eric Jordan
University of Connecticut, USA
UNDERSTANDING APS TBC FAILURE BY SUFFICIENTLY REALISTIC MODELING AND SUPPORTING EXPERIMENTS

14:10 - 14:50 Richard Wellman, University of Cranfield, UK
ARE EB PVD TBCS MORE EROSION RESISTANT THAN PS TBCS?

14:50 - 15:20 M. Rudolphi
Karl-Winnacker-Institut der DEHEMA, Germany
FAILURE PREDICTION OF THERMAL BARRIER COATINGS USING A FRACTURE MECHANICS APPROACH

15:20 - 15:50 Afternoon Coffee
Thursday, August 11, 2011 (continued)

15:50 - 16:30  Matthias Oechsner
               University of Darmstadt, Germany
PROPERTY VARIATIONS IN TBC SYSTEMS AND THEIR IMPACT ON
TURBINE DESIGN

16:30 - 17:30  Discussion

18:30 -        Conference dinner and social hour
Friday, August 12, 2011

07:00 - 08:00 Breakfast

SESSION 8: LIFE MODELING AND CHARACTERIZATION TECHNIQUES
Chairs: Matthias Oechsner, Technische Universitaet Darmstadt, Germany
Yukata Kagawa, The University of Tokyo, Japan

08:00 - 08:40 Tilmann Beck
FZ Juelich, Germany
TBC’S FOR GAS TURBINES UNDER THERMO-MECHANICAL LOADINGS: FAILURE BEHAVIOUR AND LIFE PREDICTION

08:40 - 09:20 Kyoko Kawagishi (presented by Hiroshi Harada)
National Institute for Materials Science, Japan
THERMAL CYCLIC LIFE OF EB-PVD TBC SYSTEM

09:20 - 10:00 Jeffery Eldridge
NASA, USA
OBSERVING DAMAGE EVOLUTION IN THERMAL BARRIER COATINGS BY LUMINESCENCE IMAGING

10:00 - 10:30 Coffee Break

10:30 - 11:00 Pascale Kanoute,
ONERA, France
LIFE TIME ANALYSIS FOR TBC SPALLATION

11:00 - 11:30 Bauke Heeg
Lumium, The Netherlands
OPTICAL DIAGNOSTICS ON THERMAL BARRIER COATING STRUCTURES

11:30 - 12:00 Hua Wei
Institute of Metals, Academy of Science, China
A NUMERICAL MODEL FOR FAILURE MECHANISMS OF THERMAL BARRIER COATINGS

12:00 – 12:30 Wrap-up discussions

12:30 Lunch and Departures
Poster Presentations

1. Ashutosh S. Gandhi
   Indian Institute of Technology Madras, India
   FRACTURE TOUGHNESS OF RARE-EARTH STABILISED ZIRCONIA THERMAL BARRIER MATERIALS: EFFECT OF PHASE TRANSFORMATIONS

2. Gopal Dwivedi
   Stony Brook University, USA
   EFFECT OF MOISTURE ON THE COMPLIANCE OF THERMAL BARRIER COATINGS

3. Hui Peng
   Beihang University, China
   IMPROVED OXIDATION RESISTANCE OF A NOVEL NICOCRALY COATING FABRICATED BY PLASMA-ACTIVATED EB-PVD

4. Fanny Riallant
   Institut Prime CNRS-ENSMA, Snecma - SAFRAN Group, France
   STRESS INFLUENCE ON HIGH TEMPERATURE OXIDE SCALE GROWTH: EXPERIMENTAL INVESTIGATION ON THE AM1/NIALPT/EBPVD YSZ SYSTEM

5. Olena Trunova
   Research Centre Jülich, Germany
   MICROSTRUCTURAL AND ACOUSTIC DAMAGE ANALYSIS OF AIR PLASMA-SPRAYED THERMAL BARRIER COATINGS UNDER THERMAL CYCLING

6. Qing He
   Chinese Academy of Agricultural Mechanization Science, China
   SEGMENTED TBCS PRODUCED BY ATMOSPHERIC PLASMA SPRAYING 7YSZ POWDER WITH LOW IMPURITY CONTENT

7. Fan Yang
   University of Manchester, UK
   THERMAL CONDUCTIVITIES OF ZIRCONIA-CERIA-YTTRIA SOLID SOLUTIONS

8. Julie M. Drexler
   The Ohio State University, USA
   THERMAL GRADIENT CYCLING WITH SIMULTANEOUS SILICATE PARTICLE DEPOSITION ONTO ADVANCED AIR PLASMA SPRAYED THERMAL BARRIER COATINGS

9. Andrzej Nowotnik
   Rzeszow University of Technology, Poland
   TECHNOLOGY AND THE DEVELOPMENT OF ADVANCED THERMAL BARRIER COATINGS

10. Andrew D Gledhill
    The Ohio State University, USA
    LIFETIME MODELING OF COAL FLY ASH INFILTRATED THERMAL BARRIER COATINGS IN CYCLIC THERMAL GRADIENT TESTING

11. Ying Zhu
    School of Fundamental Research, China
    PREPARATION AND PROPERTIES OF HOLLOW YSZ NANO-POWDERS
12. J.-R. Vaunois
ONERA, France
EXPERIMENTAL TESTS FOR MEASURING INTERFACE FRACTURE TOUGHNESS OF THERMAL BARRIER COATINGS

13. Jessica A. Krogstad
University of California Santa Barbara, USA
REVISITING PHASE STABILITY IN T'-ZIRCONIA BASED TBCS: A COMPARISON OF APS AND EBPVD TBCS

14. Erin M. Donohue
University of California Santa Barbara, USA
MODE I DELAMINATION TOUGHNESS OF AIR PLASMA SPRAY ZIRCONIA COATINGS: EXPERIMENTAL MEASUREMENTS AND FINITE ELEMENT ANALYSIS

15. Peter Wittig
Technische Universität Darmstadt, Germany
FRACTURE MECHANICAL CHARACTERIZATION OF PLASMA-SPRAYED THERMAL BARRIER COATINGS

16. Gregoire Witz
Alstom Switzerland AG, Switzerland
ANALYTICAL TOOLS FOR INVESTIGATION OF EX-SERVICE THERMAL BARRIER COATINGS

17. Daniel E. Mack
IEK-1, Forschungszentrum Jülich GmbH, Germany
MICROSTRUCTURE EVOLUTION AND THERMAL CYCLING PERFORMANCE OF PLASMA SPRAYED ALUMINATES FOR USE AS THERMAL BARRIER COATINGS

18. Daniel E. Mack
IEK-1, Forschungszentrum Jülich GmbH, Germany
THERMOGRAPHIC ONLINE MONITORING OF FAILURE EVOLUTION OF THERMAL BARRIER COATINGS IN GAS BURNER THERMAL CYCLING RIG ENVIRONMENT

19. Ralf Webler
Institute I: General Materials Properties, University of Erlangen-Nürnberg, Germany
NANOINDENTATION AND MICROSTRUCTURAL CHARACTERIZATION OF THERMALLY CYCLED NI-AL-CR BOND COATS ON NI-BASE SUPERALLOYS

20. Markus Krottenthaler
Institute I: General Materials Properties, University of Erlangen-Nürnberg, Germany
IN-SITU TENSILE TESTING AND RESIDUAL STRESS CHARACTERIZATION OF NIAL BOND COATS USED ON NICKEL BASED SUPERALLOYS

21. Christoph Metzner
Fraunhofer Institute for Electron Beam and Plasma Technology, Germany
(FEP) PLASMA-ACTIVATED ELECTRON BEAM VAPOR DEPOSITION - TECHNOLOGIES AND TECHNIQUES

22. Wesley Jackson
University of California, Santa Barbara, USA
OXIDATION AND RUMPLING BEHAVIOR OF β-PHASE BOND COATS

23. Wesley Jackson
University of California, Santa Barbara, USA
DELAMINATION OF CMAS INFILTRATED TBCS UNDER A THERMAL GRADIENT