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# Selected Abstracts of Thermal Spray Literature

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## Applications

### *Biomaterials and Bioactive Materials*

**Bio-inspired water repellent surfaces produced by ultrafast laser structuring of silicon.** We report here an efficient method for preparing stable superhydrophobic and highly water repellent surfaces by irradiating silicon wafers with femtosecond laser pulses and subsequently coating them with chloroalkylsilane monolayers. By varying the laser pulse fluence on the surface one can successfully control its wetting properties via a systematic and reproducible variation of roughness at micro- and nano-scale, which mimics the topology of natural superhydrophobic surfaces. The self-cleaning and water repellent properties of these artificial surfaces are investigated. It is found that the processed surfaces are among the most water repellent surfaces ever reported. These results may pave the way for the implementation of laser surface microstructuring techniques for the fabrication of superhydrophobic and self-cleaning surfaces in different kinds of materials as well. © 2008 Elsevier B.V. All rights reserved.

M. Barberoglou, V. Zorba, E. Stratakis, E. Spanakis, P. Tzanetakis, S.H. Anastasiadis, and C. Fotakis, Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas (IESL-FORTH), Heraklion, 711 10, Greece. Cited: *Appl. Surf. Sci.,* 2009, March 1, **255**(10), p 5425-5429. ISSN 0169-4332.

**Electrochemically deposited $Ca(OH)_2$ coatings as a bactericidal and osteointegrative modification of Ti implants.** A low-temperature method was developed for the electrochemical deposition of calcium hydroxide ($Ca(OH)_2$) coatings as bactericidal and osteointegrative modification of Ti implants. The thickness determination of the $Ca(OH)_2$ films deposited with different coating parameters was carried out with a scanning electron microscope (SEM) DSM 940 after interaction of the Ti disks. The deposition process of CaP in an electrochemical cell is assumed to occur due to a local increase of the pH value near the cathode, which reduces the solubility of CaP. The variation of the coating parameters shows that higher $Ca(NO_3)_2$ concentrations and increased process temperature lead to better results regarding formation and homogeneity of the deposited $Ca(OH)_2$ layers. The number of *S. epidermidis* germs is found to reduce on the $Co(OH)_2$ modification by 50%, while contamination of the coatings with *K. pneumoniae* is lower by about 20%.

C. Moseke, W. Braun, and A. Ewald, Department of Functional Materials in Medicine and Dentistry, University Hospital Wurzburg, 97070 Wurzburg, Germany. Cited: *Adv. Eng. Mater.,* 2009, March, **11**(3), p B1-B6. ISSN 1438-1656.

**Hydroxyapatite coating improves bone integration and interface strength of polymer implants in bone.** A study was conducted to demonstrate that the use of hydroxyapatite coating improves bone integration and interface strength of polymer implants in bone. The study demonstrated that the latest developments in polymer science have led to successful use of polymer for loaded implants in bone. It was found that polyetheretherketone (PEEK) is being successfully used for spinal fusion cages and computer-designed individual implants for defect reconstruction in the skull. Medical grade PEEK was reinforced with short length carbon fibers and extruded in a common procedure to small cylindric specimens. The shear strength of the interface was also quantified by push-out test procedure in native specimens, to evaluate the quality of mechanical interlocking of bone and implant. It was observed that PEEK implants showed inferior mechanical behavior, with low shear strength of the interface, while hydroxyapatite ceramic led to strong and stable interfaces between implants and bone.

J. Brandt, M. Pfennig, C. Bieroegel, W. Grellmann, and A. Bernstein, University of Halle, Department of Orthopaedics, 06097, Halle/Saale, Germany. Cited: *Key Eng. Mater.*, 2009, 396-398, p 331-335. ISSN 1013-9826.

**In vitro characterization of plasma-sprayed apatite/wollastonite glass-ceramic biocoatings on titanium alloys.** Some ceramics have the ability to form direct bonds with surrounding tissues when implanted in the body. Among bioactive ceramics, the apatite/wollastonite (A/W) glass-ceramic, containing apatite and wollastonite crystals in the glassy matrix, has been largely studied because of good bioactivity and used in some fields of medicine, especially in orthopaedics and dentistry. However, medical applications of bioceramics are limited to non-load bearing applications because of their poor mechanical properties. In this study, A/W powders, obtained from industrial and high grade quality raw materials, were thermally sprayed by atmospheric plasma spraying (APS) on Ti-6Al-4V substrates, in order to combine the good bioactivity of the bioceramic and the good mechanical strength of the titanium alloy base material. The microstructure and the resulting properties were evaluated depending on processing parameters and postprocessing thermal treatments. The morphology and the microstructure of the coatings were observed by SEM and the phase composition was examined by x-ray diffraction. The bioactivity of the coatings was evaluated by soaking the samples in a simulated body fluid (SBF) for 1, 2, and 5 weeks. The bioactive behavior was then correlated with the thermal treatments and the presence of impurities (in particular $Al_2O_3$) in the coatings. © 2008 Elsevier Ltd. All rights reserved.

V. Cannillo, J. Colmenares-Angulo, L. Lusvarghi, F. Pierli, and S. Sampath, Dipartimento di Ingegneria dei Materiali e dell'Ambiente, Universita di Modena e Reggio Emilia, 41100, Modena. Italy. Cited: *J. Eur. Ceram. Soc.,* 2009, June, **29**(9), p 1665-1677. ISSN 0955-2219.

**Influence of surface treatments on the bond strength of repaired resin composite restorative materials.** Objectives: The purpose of this study was to investigate the effect of different surface treatments on the bond strength ($\sigma$) of repaired, aged resin composites (ARC). Methods: Forty blocks of Filtek Z250™ (Z2) and Filtek Supreme™ (SU) were made, stored in deionized water for 9 days, and randomly assigned to different surface treatment groups: hydrofluoric acid etching (HA), abrasion using a coarse diamond bur (AB), sandblasting with alumina particles (AO), and silica coating (SC). The average roughness (Ra) of the treated surfaces was measured with a profilometer. An adhesive system (SB-Adper Single Bond Plus™), a silane (SI), or a combination of both (SI + SB) were applied after each surface treatment. The blocks were restored with the same composite (RC) and cut to produce bars that were turned into dumbbell-shaped specimens (0.5 $mm^2$) using a precision grinding machine. The specimens ($n = 30$) were tested in tension to fracture and the microtensile bond strength ($\sigma$) values were calculated (MPa). Data were analyzed using three-way ANOVA/Tukey test $\alpha = 0.05$) and Weibull statistics. Results: AO and SC produced similar Ra values, which were greater than the value produced by HA. The ($\sigma$) values were statistically influenced by the type of RC ($p \leq 0.0001$), by the surface treatment ($p \leq 0.0001$), and by the surface coating ($p \leq 0.0001$). Treating the surface of Z2 with SC + SB produced the greatest $m$ value. Significance: AO and SC produced the greatest $\sigma$ values, irrespective of the primer (SI, SB, or SI + SB) used. Yet, the RC microstructure influenced the mean $\sigma$ values, which were greater for Z2 than for SU. The HA should not be used for repairing ARC. © 2008 Academy of Dental Materials.

S.A.R. Junior, J.L. Ferracane, and A.D. Bona, Department of Operative Dentistry, Federal University of Pelotas, RS, Brazil. Cited: *Dental Mater.,* 2009, April, **25**(4), p 442-451. ISSN 0109-5641.

**Interfaces in graded coatings on titanium-based implants.** Graded bilayered glass-ceramic composite coatings on Ti6A14V substrates were fabricated using an enameling technique. The layers consisted of a mixture of glasses in the $CaO\text{-}MgO\text{-}Na_2O\text{-}K_2O\text{-}P_2O_5$ system with different amounts of calcium phosphates (CPs). Optimum firing conditions have been determined for the fabrication of coatings having good adhesion to the metal, while avoiding deleterious reactions between the glass and the ceramic particles. The final coatings do not crack or delaminate. The use of high-silica layers (<60 wt.% $SiO_2$) in contact with the alloy promotes long-term stability of the coating; glass-metal adhesion is achieved through the formation of a nanostructured $Ti_5Si_3$ layer. A surface layer containing a mixture of a low-silica glass (to ~53 wt.% $SiO_2$) and synthetic hydroxyapatite particles promotes the precipitation of new apatite during tests in vitro. The in vitro behavior of the coatings in simulated body fluid depends both on the composition of the glass matrix and the CP particles, and is strongly affected by the coating design and the firing conditions. © 2008 Wiley Periodicals, Inc.

S. Lopez-Esteban, C.F. Gutierrez-Gonzalez, L. Gremillard, E. Saiz, and A.P. Tomsia, Materials Sciences Division, 62R0203, Lawrence Berkeley National Laboratory, Berkeley, CA 94720. Cited: *J. Biomed. Mater. Res. A,* 2009, March 15, **88**(4), p 1010-1021. ISSN 1549-3296.

**Photodegradation of lauric acid at an anatase single crystal surface studied by atomic force microscopy.** The photodegradation of lauric acid at an anatase single crystal surface was visualized using atomic force microscopy (AFM). Photooxidation was performed for lauric acid thin films with thickness about 80-90 nm to simulate more realistic processing conditions rather than using submonolayer films. It was noticed that lauric acid deposited

by spin coating technique formed domain structure at the $TiO_2$ surface. The phenomenon of domain surface decrease without change in the film thickness was observed. This suggests that only molecules at the crystal-air-lauric acid contact line and extended therefrom were degraded. © 2008.

A. Zaleska, J. Nalaskowski, J. Hupka, and J.D. Miller, Department of Chemical Technology, Gdansk University of Technology, Gdansk, Poland. Cited: *Appl. Catal. B Environ.*, 2009, May 20, **88**(3-4), p 407-412. ISSN 0926-3373.

**The effect of microstructured surfaces and laminin-derived peptide coatings on soft tissue interactions with titanium dental implants.** In the present study, we investigated the dental implant protection from peri-implant inflammation by improving the soft tissue adhesion on the titanium surface. Porous titanium was used to create, at the level of the transmucosal part of the implants (the 'neck'), a microstructured three-dimensional surface that would tightly seal the interface between the implant and soft tissue. Cell-specific adhesion properties were induced via an adhesion peptide derived from laminin-5 coupled to native or cross-linked PLL/PGA multilayered polyelectrolyte films (MPFs), which are used for biomedical device coatings. Porous titanium exhibited good cell-adhesion properties, but the colonization of the material was further improved by a coating with laminin-5 functionalized MPFs and especially with (PLL/$PGA_{6.5}$-PGA-peptide film. Focal contact formation was observed on cross-linked architectures, reflecting cell anchorage on these surfaces. In contrast, when seeded on laminin-5-functionalized native films, epithelial cells formed only very diffuse focal contacts, but adhered via hemidesmosome formation. In vivo experiments confirmed that the porous titanium was colonized by cells of soft tissue. Altogether, the results indicate that the microstructure of the implant neck combined with a specific bioactive coating could constitute efficient routes to improve the integration of soft tissue on titanium dental implants, which could significantly protect implants from peri-implant inflammation and enhance long-term implant stabilisation. © 2009 Elsevier Ltd. All rights reserved.

S. Werner, O. Huck, B. Frisch, D. Vautier, R. Elkaim, J.-C. Voegel, G. Brunel, and H. Tenenbaum, Institut National de la Sante et de la Recherche Medicale, UMR 977, Universite de Strasbourg, 67085 Strasbourg, Cedex, France. Cited: *Biomaterials,* 2009, April, **30**(12), p 2291-2301. ISSN 0142-9612.

## Energy

**Failure behaviors of vacuum plasma sprayed tungsten coatings for plasma facing application.** About 1 mm vacuum plasma sprayed tungsten (VPS-W) coatings were fabricated on the copper chromium zirconium (CuCrZr) alloys substrate. The failure behaviors were studied by means of the steady state and transient heat load using the electron beam facility and the Nd:YAG laser, respectively. The results indicated that the columnar crystals grew up and then microcracks between the lamellar layers were observed. Macrocracks and delamination appeared with the fatigue cycles increase. Finally, the coating failed. The surface cracks were also observed and propagated during the fatigue tests. The failure behaviors of the transient heat load are as follows: the homogeneous melting and microcracks, melting tungsten ejection which enhanced the erosion of tungsten due to the splash and evaporation. In addition, the physical properties of W coatings such as porosity, Vickers hardness were degraded. The roughing phenomenon was not easy to be observed due to the rough surface characteristic of VPS-W coatings. © 2009.

F.L. Chong, J.L. Chen, J.G. Li, and X.B. Zheng, Department of Math and Physics, Xuzhou Institute of Technology, Xuzhou 221008, China. Cited: *J. Nucl. Mater.*, 2009, Apr 30, 386-388 (C), p 780-783. ISSN 0022-3115.

**Functionally graded layers prepared by atmospheric plasma spraying for solid oxide fuel cells**. A method was demonstrated to prepare functionally graded layers of solid oxide fuel cells (SOFCs) using atmospheric plasma spraying. This method successfully fabricated monoblock layer built (MOLB) SOFCs and examined their material composition and microstructure. Commercial YSZ and Ni powders were mixed for making starting anode materials, while carbon powder was added as pore forming agent to improve the anode porosity. The resultant powder mixture was dried at 80 °C after ball-milling in a baking oven and crushed. It was observed that interface resistance of the resultant PEN with the graded layer was less than that without the graded layer. Thermal sprayed FGM PENs were prepared in this method by varying the compositions of powders. The finished PENs with the graded layers showed larger electronic conductivity and lower interface resistance compare to without graded layers.

W.S. Xia, H.O. Zhong, G.L. Wang, and Y.Z. Yang, State Key Laboratory of Materials Processing and Die and Mould Technology, Huazhong University of Science and Technology, Wuhan 430074, China. Cited: *Adv. Eng. Mater.*, 2009, January, **11**(1-2), p 111-116. ISSN 1438-1656.

**High performance metal-supported solid oxide fuel cells fabricated by thermal spray.** Metal-supported solid oxide fuel cells (SOFCs) have been fabricated and characterized in this work. The cells consist of porous NiO-SDC as anode, thin SDC as electrolyte, and SSCo as cathode on porous stainless steel substrate. The anode and electrolyte layers were consecutively deposited onto porous metal substrate by thermal spray, using standard industrial thermal spray equipment, operated in an open-air atmosphere. The cathode materials were applied to the as-sprayed half-cells by screen-printing and heat-treated at 800 °C for 2 h. The cell components and performance were examined by scanning electron microscopy (SEM), x-ray diffraction, leakage test, ac impedance, and electrochemical polarization at temperatures between 500 and 700 °C. The half-inch button cells exhibit a maximum power density in excess of 0.50 W $cm^2$ at 600 °C and 0.92 W $cm^2$ at 700 °C operated with humidified hydrogen fuel, respectively. The half-inch button cell was run at 0.5 A $cm^2$ at 603 °C for 100 h. The cell voltage decreased from 0.701 to 0.698 V, giving a cell degradation rate of 4.3% $kh^1$. Impedance analysis indicated that the cell degradation included 4.5% contribution from ohmic loss and 1.4% contribution from electrode polarization. The 5 cm × 5 cm cells were also fabricated under the same conditions and showed a maximum power density of 0.26 W $cm^{-2}$ at 600 °C and 0.56 W $cm^{-2}$ at 700 °C with dry hydrogen as fuel, respectively. The impedance analysis showed that the ohmic resistance of the cells was the major polarization loss for all the cells, while both ohmic and electrode polarizations were significantly increased when the operating temperature decreased from 700 to 500 °C. This work demonstrated the feasibility for the fabrication of metal-supported SOFCs with relatively high performance using industrially available deposition techniques. Further optimization of the metal support, electrode materials and microstructure, and deposition process is ongoing. Crown Copyright © 2009.

R. Hui, J.O. Berghaus, C. Deces-Petit, W. Qu, S. Yick, J.-G. Legoux, and C. Moreau, National Research Council, Canada—Institute for Fuel Cell Innovation, Vancouver, BC V6T 1W5, Canada. Cited: *J. Power Sour.*, 2009, Jun 15, **191**(2), p 371-376. ISSN 0378-7753.

**Interconnect materials for next-generation solid oxide fuel cells**. Highly efficient solid oxide fuel cell (SOFC) systems are gaining increased attention for future energy conversion applications. Many planar SOFC stack designs utilize ferritic stainless steel (FSS) interconnect components. During operation, surface corrosion of FSS interconnects degrades stack operation by increasing electrical resistance and introducing other deleterious material interactions. To minimize these effects, various surface modifications and coatings are currently under investigation. Two of these methods under development for this application are: metal organic chemical vapor deposition (MO-CVD) and large area filtered arc deposition (LAFAD). SOFC interconnect-relevant corrosion behavior of an MO-CVD coating on Crofer 22 APU, AL453, Fe30Cr and Haynes230, and complex, amorphous LAFAD AlCrCoMnTiYO coatings on FSS 430 were investigated. Both of these surface modifications and coatings exhibit significantly improved corrosion protection as compared with uncoated FSS samples. © 2008 Springer Science+Business Media B.V.

P. Piccardo, R. Amendola, S. Fontana, S. Chevalier, G. Caboches, and P. Gannon, Department of Chemistry and Industrial Chemistry (DCCI), Universita di Genova, Genoa, Italy. Cited: *J. Appl. Electrochem.*, 2009, April, **39**(4), p 545-551. ISSN 0021-891X.

**Ionic conductivity of plasma-sprayed nanocrystalline yttria-stabilized zirconia electrolyte for solid oxide fuel cells**. Nanocrystalline 10 mol.% yttria-stabilized zirconia (YSZ) electrolyte was synthesized via the plasma spray technique. The ionic conductivity was measured using AC impedance spectroscopy within the temperature range 350-600 °C in air. The measured total ionic conductivity of plasma-sprayed YSZ electrolyte is ~2.3 times higher than that of sintered YSZ electrolyte at 600 °C in air. The improvement in ionic conductivity is ascribed to the nanocrystalline grain size and siliceous free grain boundary with grain-to-grain contact. © 2009 Acta Materialia Inc.

Y. Chen, S. Omar, A.K. Keshri, K. Balani, K. Babu, J.C. Nino, S. Seal, and A. Agarwal, Plasma Forming Laboratory, Mechanical and Materials Engineering, Florida International University, Miami, FL 33174. Cited: *Scripta Mater.,* 2009, June **60**(11), p 1023-1026. ISSN 1359-6462.

## Infrastructure

**Coating sheet pile structures: an overview.** Permanent sheet pile structures are either designed with a corrosion allowance or coated to achieve the required design life. Surface preparation and coating are best accomplished in the fabrication shop. Techniques are available to inspect sheet pile structures installed in seawater and freshwater. If maintenance coating is necessary, operations should be performed in the dry, but if dewatering is impractical, underwater applied coatings may be used.

T. Race, Kaked LLC. Cited: *J. Protect. Coat. Lining,* 2009, April, **26**(4), p 36-43. ISSN 8755-1985.

**Introducing a series on analyzing coating failures.** An analytical procedure for identifying the failures of protective and marine coatings is presented, which is based on actual coating and lining failures that affects a wide variety of structures. Special consideration is given to enhance the service life by identifying the prevailing service environments, proper selection of coating and lining system, and above all designing the specifications properly. The emphasis is laid on independently investigating a coating failure so as to identify a responsible party for it and to establish a procedure to repair it. The identification of coating failures and further recommendations should be based

on the site and laboratory investigation where quality assurance (QA) and quality control (QC) coating inspection personnel can help in determining the cause of coating failures. Imaging techniques such as infrared spectroscopy, high-performance liquid chromatography, and gas chromatography-mass spectroscopy can also improve the diagnosis of coatings failures in future.

Anon, Cited: *J. Protect. Coat. Lining,* 2009, March, **26**(3), p 13-18. ISSN 8755-1985.

**Tribological characterization of WC-Co plasma sprayed coatings.** Atmospheric plasma spraying of WC coatings is typically characterized by increased decarburization, with a consequent reduction of their wear resistance. Indeed, high temperature and oxidizing atmosphere promote the appearance of brittle crystalline and amorphous phases. However, by using a high helium flow rate in a process gas mixture, plasma spraying may easily be optimized by increasing the velocity of sprayed particles and by reducing the degree of WC dissolution. To this purpose, a comparative study was performed at different spray conditions. Both WC-Co powder and coating phases were characterized by x-ray diffraction. Their microstructure was investigated by scanning electron microscopy. Mechanical, dry sliding friction, and wear tests were also performed. The wear resistance was highly related to both microstructural and mechanical properties. The experimental data confirmed that high-quality cermet coatings could be manufactured by using optimized Ar–He mixtures. Their enhanced hardness, toughness, and wear resistance resulted in coatings comparable to those sprayed by high velocity oxygen-fuel. © 2009 The American Ceramic Society.

G. Di Girolamo, L. Pilloni, G. Pulci, and F. Marra, ENEA, Department of Advanced Physics Technology and New Materials (FIM), Brindisi Research Center, 72100, Brindisi, Italy. Cited: *J. Am. Ceram. Soc.*, 2009, May, **92**(5), p 1118-1124. ISSN 0002-7820.

**20-Year performance of bridge maintenance systems.** The New Jersey Department of Transportation (DOT), US, conducted an inspection in 2007, to review the performance of different experimental coating systems applied to various spans of the Mathis Bridge. The DOT applied these experimental systems on the spans of the bridge between 1986 and 1987, with each span comprising around 4000 square feet of steel. The experimental coating systems included metallizing, various levels of surface preparation, and several coating strategies. The inspection revealed that some of the coating systems performed significantly and existed in better conditions, while other coating systems had broken down completely. The inspection also focused on reviewing the historical performance of these coating systems and their applied cost. The experimental coating systems applied on the spans of the bridge consisted of inorganic and organic zinc coatings, epoxies, aluminum epoxy urethanes, vinyls, urethanes, oil-alkyds, and aluminum metallizing.

J.P. Ault and C.L. Farschon, Elzly Technology Corporation. Cited: *J. Protect. Coat. Lining,* 2009, January, 26(1), p 16-32. ISSN 8755-1985.

## *Thermal Barrier Coatings*

**A mechanism governing oxidation-assisted low-cycle fatigue of superalloys.** A model capable of characterizing oxidation-assisted low-cycle fatigue is described. It involves the following steps. After a few strain cycles, because of creep, a tensile stress develops during the de-straining phase of the cycle. This stress opens cracks present in the material and exposes the surfaces to the atmosphere, causing thermally grown oxide (TGO) growth. Dilatation takes place upon converting the alloy to oxide, with an associated strain rate that induces a compressive growth stress. Thereafter, during the re-straining phase of the cycle, transverse extension of the substrate induces in-plane tension in the TGO, which 'pushes' the TGO into the substrate along the crack front. Finite element simulations of this process have been presented that predict crack growth per cycle, *da*/*dN*, comparable with experimental measurements. Trends in *da*/*dN* with the TGO dilatation rate and the creep strength of the superalloy have been elucidated. © 2009 Acta Materialia Inc.

A.G. Evans, M.Y. He, A. Suzuki, M. Gigliotti, B. Hazel, and T.M. Pollock, Materials Department, University of California at Santa Barbara, Santa Barbara, CA 93106. Cited: *Acta Mater.,* 2009, June, **57**(10), p 2969-2983. ISSN 1359-6454.

**A sintering model for plasma-sprayed zirconia TBCs. Part I: Free-standing coatings.** A sintering model is presented for prediction of changes in the microstructure and dimensions of free-standing, plasma-sprayed (PS) thermal barrier coatings (TBCs). It is based on the variational principle. It incorporates the main microstructural features of PS TBCs and simulates the effects of surface diffusion, grain boundary diffusion and grain growth. The model is validated by comparison with experimental data for shrinkage, surface area reduction, and porosity reduction. Predicted microstructural changes are also used as input data for a previously developed thermal conductivity model. Good agreement is observed between prediction and measurement for all these characteristics. The model allows separation of the effects of coating microstructure and material properties, and captures the coupling between densifying and non-densifying mechanisms. A sensitivity analysis is presented, which highlights the importance of the initial pore architecture. Predictions indicate that the microstructural changes which give rise to (undesirable) increases in thermal conductivity and stiffness are very sensitive to surface diffusion.[1] A compiled version of the sintering model can be downloaded from www.msm.cam.ac.uk/mmc/publications/software.html1. © 2008 Acta Materialia Inc.

A. Cipitria, I.O. Golosnoy, and T.W. Clyne, Department of Materials Science and Metallurgy, Cambridge University, Cambridge, CB2 3QZ, UK. Cited: *Acta Mater.*, 2009, Feb, **57**(4), p 980-992. ISSN 1359-6454.

**A sintering model for plasma-sprayed zirconia TBCs. Part II: Coatings bonded to a rigid substrate.** The sintering model described in Part I, which relates to free-standing plasma-sprayed thermal barrier coatings, is extended here to the case of a coating attached to a rigid substrate. Through-thickness shrinkage measurements have been carried out for coatings attached to zirconia substrates, and these experimental data are compared with model predictions. The model is then used to explore the influence of the substrate material (zirconia versus a nickel superalloy), and of the in-plane coating stiffness. Both differential thermal expansion stresses and tensile stresses arising from the constraint imposed on in-plane shrinkage can be relaxed via two diffusional mechanisms: Coble creep and microcrack opening. This relaxation allows progression toward densification, although the process is somewhat inhibited, compared with the case of a free-standing coating. Comparison of the stored elastic strain energy with the critical strain energy release rate for interfacial cracking allows estimates to be made of whether debonding is energetically favored.[1] A compiled version of the sintering model can be downloaded from www.msm.cam.ac.uk/mmc/publications/software.html. © 2008 Acta Materialia Inc.

A. Cipitria, I.O. Golosnoy, and T.W. Clyne, Department of Materials Science and Metallurgy, Cambridge University, Cambridge, CB2 3QZ, UK. Cited: *Acta Mater.*, 2009, Feb, **57**(4), p 993-1003. ISSN 1359-6454.

**Damage growth triggered by interface irregularities in thermal barrier coatings.** The efficiency and reliability of modern jet engines strongly depend on the performance of thermal barrier coatings (TBCs), which prevent melting and oxidation of the turbine blades' structural core. The system's lifetime is limited by cracks appearing in and in the vicinity of an oxide layer that grows in the TBC under thermal cycling. High replacement costs have led to an increased demand to identify, quantify, and remedy damage in TBCs. An integrated experimental-numerical approach is presented for studying the main factors that contribute to damage, particularly interfacial irregularities. Damage at several stages of oxidation in TBCs is analyzed in samples with predefined interfacial irregularities. The model predicts the experimentally observed crack patterns, clearly quantifying the influence of imperfections and indicating that damage can be delayed by surface treatment. ©2009 Acta Materialia Inc.

T.S. Hille, T.J. Nijdam, A.S.J. Suiker, S. Turteltaub, and W.G. Sloof, Department of Materials Science and Engineering, Delft University of Technology, 2628 CD Delft, Netherlands. Cited: *Acta Mater.*, 2009, May, **57**(9), p 2624-2630. ISSN 1359-6454.

**Effect of superimposed uniaxial stress on rumpling of platinum-modified nickel aluminide coatings.** Thermal cycling of a platinum modified, nickel aluminide (Ni, Pt)Al-coated single crystal superalloy, between 1000 and 1150 °C with 10 min holds at each temperature, and subject to a compressive uniaxial stress is reported. There are two major effects of the superimposed compressive stress not observed in the absence of the stress. One is that the rumpling pattern exhibits an asymmetry with an increase of the bondcoat surface roughness perpendicular to the applied loading axis. The other is the formation of cracks in the thermally grown oxide aligned parallel to the stress axis. © 2009 Acta Materialia Inc.

S. Dryepondt and D.R. Clarke, Materials Department, College of Engineering, University of California, Santa Barbara, CA 93106-5050. Cited: *Acta Mater.,* 2009, April, **57**(7), p 2321-2327. ISSN 1359-6454.

**Effect of the starting microstructure on the thermal properties of as-sprayed and thermally exposed plasma-sprayed YSZ coatings**. Thermal barrier coatings (TBCs) experience thermal gradients, excessive temperature, and high heat flux from hot gases in turbines during service. These extended thermal effects induce sintering and significant microstructure changes, which alter the resulting thermal conductivity of the TBCs. To study the effects of different starting microstructures on the sintering behavior, plasma-sprayed yttria-stabilized zirconia (YSZ) TBCs produced from different starting powders and process parameters were subjected to thermal aging at several temperatures and time intervals, after which their thermal conductivity was measured at room temperature. The thermal conductivity results were analyzed by introducing the Larson-Miller parameter that describes the creep-like behavior of thermal conductivity increase with annealing temperature and time. One set of coatings was also annealed under the same conditions and the thermal conductivities were measured at elevated temperatures. The temperature-dependent thermal conductivity data were analyzed and used to predict the long-term thermal property behavior for a general YSZ coating design. © 2009 The American Ceramic Society.

Y. Tan, J.P. Longtin, S. Sampath, and H. Wang, Center for Thermal Spray Research, State University of New York at Stony Brook, Stony Brook, NY 11794-2275. Cited: *J. Am. Ceram. Soc.*, 2009, March **92**(3), p 710-716. ISSN 0002-7820.

**Evolution of thermal properties of EB-PVD 7YSZ thermal barrier coatings with thermal cycling.** During high-temperature exposure, the microstructure of thermal barrier coatings evolves, leading to increased thermal conductivity. We describe the evolution in the thermal properties of a 7 wt.% $Y_2O_3$ stabilized $ZrO_2$ electron beam-physical vapor deposited (EB-PVD) thermal barrier coating with thermal cycling between room temperature and 1150 °C until failure. The thermal diffusivity and conductivity of the coating were evaluated non-destructively based on the analysis of its photothermal infrared emission. Although the coating density does not increase significantly with thermal cycling, the thermal diffusivity and conductivity of the coating increased substantially, particularly during the first 20 1 h cycles. The values then approach a limiting value. Complementary Raman spectroscopy suggests that the increase is accompanied by a reduction in the defect concentration in the coating and that there is also a correlation between the width of the Raman lines and the thermal conductivity. © 2009 Acta Materialia Inc.

T.R. Kakuda, A.M. Limarga, T.D. Bennett, and D.R. Clarke, Materials Department, University of California, Santa Barbara, CA 93106-5050. Cited: *Acta Mater.*, 2009, May **57**(8), p 2583-2591. ISSN 1359-6454.

**Glass-ceramics as oxidation resistant bond coat in thermal barrier coating system.** Thermal barrier coating (TBC) system consisting of yttria-stabilized zirconia (YSZ) topcoat, glass-ceramic bond coat and nickel base superalloy substrate was subjected to static oxidation test at 1200 °C for 500 h in air. Oxidation resistance of this TBC system was compared with the conventional TBC system under identical heat treatment condition. Both the TBC systems were characterized by SEM as well as EDX analysis. No TGO layer was found between the bond coat and the topcoat in the case of glass-ceramic bonded TBC system while the conventional TBC system exhibited a TGO layer of about 16 μm thickness at the bondcoat-topcoat interface region. © 2008 Elsevier Ltd. and Techna Group S.r.l.

S. Das, S. Datta, D. Basu, and G.C. Das, Central Glass and Ceramic Research Institute, Kolkata 700032, India. Cited: *Ceramics International,* 2009, May, **35**(4), p 1403-1406. ISSN 0272-8842.

**On the initiation of cyclic oxidation-induced rumpling of platinum-modified nickel aluminide coatings.** The evolution of the surface roughness of an initially flat platinum-modified nickel aluminide (NiPtAl) coating on a single crystal superalloy with cyclic oxidation has been measured by optical profilometry and correlated with the aluminide microstructure. The roughness evolution is dominated by the relative motion of individual grains on thermal cycling, with the larger-sized grains moving up and the smaller grains moving down with respect to the average surface. Detailed crystallographic analysis indicates that the grains in the coating are randomly distributed and have no crystallographic relationship with the underlying single crystal superalloy. Furthermore, there is a correlation between the number of sides a grain has and the propensity for its center to move relative to the average surface plane: grains with six or more sides bow up, whereas the surfaces of those grains with fewer than six sides bow down. It is proposed that rumpling initiates due to the vertical displacement of the smaller grains having fewer than six sides. Once initiated, rumpling proceeds driven by the strain energy in the thermally grown oxide. © 2009 Acta Materialia Inc.

S. Dryepondt, J.R. Porter, and D.R. Clarke, Materials Department, College of Engineering, University of California, Santa Barbara, CA 93106-5050. Cited: *Acta Mater.*, 2009, April, **57**(6), p 1717-1723. ISSN 1359-6454.

**Sintering and microstructure evolution in columnar thermal barrier coatings.** Sintering of thermal barrier coatings changes their key properties, such as thermal conductivity and thermal shock resistance, thus adversely impacting their reliability. We present a novel modeling approach to study the evolution of coating structure during sintering. We model the sintering of individual columns using a thermodynamic principle, and incorporate the center-to-center approach rates for the columns calculated using this principle in a larger scale discrete dynamics model for the evolution of a large number of columns. Surface energies, grain boundary energies, and strain energies associated with the deformation of the columns are all included in this framework, while sintering is assumed to occur by the concerted action of surface and grain boundary diffusion. Two sets of initial conditions corresponding to different extents of pre-sintering among neighboring columns are considered. When the extent of pre-sintering is small, we observe that small clusters containing 5-20 columns are formed. In contrast, where a larger amount of pre-sintering exists, we observe, especially at large column densities, that clusters containing 50-100 columns separated by large inter-cluster pores/channels that appear to organize themselves into a network are formed. These observations are in good agreement with recently published experimental observations. We also explain how these results can explain the development of a 'mud-crack'-like pattern. ©2008 Acta Materialia Inc.

R. Krishnamurthy and D.J. Srolovitz, Department of Mechanical Engineering, Princeton Institute for the Science and Technology of Materials, Princeton University, NJ 08542. Cited: *Acta Mater.*, 2009, Feb, **57**(4), p 1035-1048. ISSN 1359-6454.

**The influence of bondcoat and topcoat mechanical properties on stress development in thermal barrier coating systems.** A finite-element study has been undertaken to investigate the stress development within a TBC system consisting of an EB-PVD YSZ topcoat and a Pt-aluminized diffusion bondcoat. Particular attention has been paid to the role of variables such as the elastic anisotropy within the topcoat, interface roughness, variation in creep strength of the bondcoat, and the volumetric strains associated with the formation of the thermally grown oxide (TGO). Bondcoat oxidation and thermal loading during cooling give rise to significant tensile stresses within the topcoat and tensile tractions at the TGO interfaces. Bondcoat creep, as distinct from yield and plastic behavior, was the dominant stress relaxation process, and strong bondcoats (in creep) tended to show higher tensile stress levels. Another important factor determining thermal barrier coating stress levels was the level of elastic anisotropy of the topcoat: an elastic isotropic yttria-stabilized zirconia gave rise to considerably higher stresses than a transversely isotropic topcoat. © 2009 Acta Materialia Inc.

E.P. Busso, Z.Q. Qian, M.P. Taylor, and H.E. Evans, Centre des Materiaux, Mines ParisTech, CNRS-UMR 7633, 91003 Evry, France. Cited: *Acta Mater.*, 2009, May, **57**(8), p 2349-2361. ISSN 1359-6454.

**Thermophysical properties of complex rare-earth zirconate ceramic for thermal barrier coatings.** Two complex rare-earth zirconates ($La_{0.4}Sm_{0.5}/Yb_{0.12}$ $(Zr_{0.7}Ce_{0.4})_2O_{7.4}$ and $(Sr_{0.1}La_{0.3}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.3}$ for thermal barrier coatings (TBCs) were synthesized by the coprecipitation method. Their phase composition, microstructure, and thermophysical properties were investigated. X-ray diffractometry results revealed that single-phase $(La_{0.4}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.4}$ and $(Sr_{0.1}La_{0.3}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.3}$ with pyrochlore structure were prepared, and the scanning electron microscopy results showed that the microstructures of the products were dense and no other phases existed among the grains. With the temperature increasing, the thermal expansion coefficient (CTE) of the ceramics increased, while the thermal conductivity decreased. The results indicated that the CTE of $(Sr_{0.1}La_{0.3}Sm_{0.5}Yb_{0.1})_2Zr_{0.7}Ce_{0.4})_2O_{7.3}$ was slightly higher than that of $(La_{0.4}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.4}$ and the thermal conductivity of $(Sr_{0.1}La_{0.3}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.3}$ was lower than that of $(La_{0.4}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.4}$. These results imply that the thermophysical properties of $(Sr_{0.1}La_{0.3}Sm_{0.5}Yb_{0.1})_2Zr_{0.7}Ce_{0.4})_2O_{7.3}$ are better than that of $(La_{0.4}Sm_{0.5}Yb_{0.1})_2(Zr_{0.7}Ce_{0.4})_2O_{7.4}$ as the material for the ceramic layer in the TBC system. © 2008 The American Ceramic Society.

L. Liu, Q. Xu, F. Wang, and H. Zhang, School of Materials Science and Engineering, Beijing Institute of Technology, Beijing 100081, China. Cited: *J. Am. Ceram. Soc.*, 2008, July, **91**(7), p 2398-2401. ISSN 0002-7820.

## Diagnostics and Control

**A novel integrated temperature investigation approach of sprayed coatings during APS process.** Coating temperature is important for the coating reliability and reproducibility during the process of atmospheric plasma spray. A novel measurement and control approach for substrate and coating temperatures is presented. It is based on infrared (IR) pyrometry combined to specific robot spray trajectories in order to avoid harsh environment of spray workshops. The temperature evolution is continuously detected and recorded during preheating, spraying, and cooling stages. The two specific factors, periodic average temperature and standard deviation were adopted to evaluate the temperature variation and the fluctuation of the thermal cycle relevant to one robot spray cycle based on the statistical method. These two factors are successful in describing the temperature variation during experimental processing sets. Finally, based on the monitoring system, the influence of Z-type robot spray trajectory parameters, including spray distance, scanning velocity, and scanning step on coating temperature characterized by the two factors, is systemically investigated. Experimental results show that average temperature has no evident difference as a function of scanning velocity and no fixed relationship with scanning step, but just is dominated by the heating time of plasma jet and particle flux. Therefore, the selection of optimal scanning velocity just needs to take the temperature fluctuation into consideration. The temperature fluctuation decreases when scanning step increases, but both average temperature and fluctuation decrease with the increasing of spray distance and vice versa. Finally, on the basis of experimental results, a control experiment of sprayed coating temperature is presented to obtain constant temperature cycles by means of adjusting robot trajectories, cooling, among other considered operating parameters. Excellent control performance is observed. © 2008 Elsevier B.V. All rights reserved.

W. Xia, H. Zhang, G. Wang, and Y. Yang, State Key Laboratory of Materials Processing and Die and Mould Technology, Huazhong University of Science and Technology, Wuhan, 430074, China. Cited: *J. Mater. Process. Technol.*, 2009, March 19, **209**(6), p 2897-2906. ISSN 0924-0136.

**Role of process type and process conditions on phase content and physical properties of thermal sprayed $TiO_2$ coatings.** Thermal spray represents an advantageous technique for depositing large-area titanium

dioxide coatings that are of interest for both traditional wear-resistant coatings as well as functional applications such as photo-induced decontamination surfaces. Numerous past studies have examined the phase evolution and properties of $TiO_2$ coatings using different thermal spray processes or parameters. In this paper, an integrated study of thermal-sprayed $TiO_2$ was conducted with different thermal spray devices and process parameters for a single feedstock powder comprising the metastable anatase phase. The aforementioned variables are correlated with in-flight particle state (particle temperature and velocity), phase evolution, and coating physical properties. The results are represented through the framework of process maps which connect process parameters with material properties. Based on the phase characterization, an initial exploration of the metastable phase evolution during thermal spray deposition of $TiO_2$ is proposed. Furthermore, the sprayed $TiO_2$ coatings show varying degrees of electrical conductivity associated with process-induced stoichiometric changes (vacancy generation) in the $TiO_2$. The effects of these stoichiometric changes as well as extrinsic microstructural attributes (pores, cracks, interfaces), contribute to the complex electrical response of the coatings. This integrated study provides insights into the process-microstructure-property relationship with the ultimate goal of tailoring the functionality of spray deposited oxide thick films. 

J.R. Colmenares-Angulo, V. Cannillo, L. Lusvarghi, A. Sola, and S. Sampath, Center for Thermal Spray Research, Department of Materials Science and Engineering, Stony Brook University, Stony Brook, NY 11794-2275. Cited: *J. Mater. Sci.*, 2009, May, **44**(9), p 2276-2287. ISSN 0022-2461.

## Measurement Methods

**Front surface thermal property measurements of air plasma spray coatings.** A front-surface measurement for determining the thermal properties of thermal barrier coatings has been applied to air plasma spray coatings. The measurement is used to determine all independent thermal properties of the coating simultaneously. Furthermore, with minimal requirements placed on the sample and zero sample preparation, measurements can be made under previously impossible conditions, such as on serviceable engine parts. Previous application of this technique was limited to relatively thin coatings, where a one-dimensional heat transfer model is applied. In this paper, the influence of heat spreading on the measurement of thicker coatings is investigated with the development of a two-dimensional heat transfer model. 

T. Bennett, T. Kakuda, and A. Kulkarni, University of California, Santa Barbara, CA 93106-5070. Cited: *J. Appl. Phys.*, 2009, **105**(8). ISSN 0021-8979.

**Nondestructive evaluation of thermal barrier coatings using impedance spectroscopy.** This article reviews previous studies on nondestructive evaluation of thermal barrier coatings (TBCs) using impedance spectroscopy (IS). IS or electrochemical impedance spectroscopy has been widely used to measure the electrical properties of materials and electrochemical behavior at electrode/electrolyte interfaces. TBCs, which comprise metallic and ceramic multilayers, have been widely used in the hot section of aeroturbine engines to increase turbine efficiency and to extend the life of metallic components. Since 1999, IS has been developed to examine degradation of the TBCs as a nondestructive evaluation tool, which is critical for prediction of TBCs lifetime during service. IS has been used both at high temperature in dry environments and in aqueous solutions. Impedance spectra of TBCs reflect change in TBC thickness, porosity, cracks, sintering, and yttria-stabilized zirconia phase transformation. Meanwhile, impedance measurements indicate the thermally grown oxide growth and the failure in TBCs. In addition, the thermal conductivity of TBCs can be correlated to impedance measurement results. 

F. Yang and P. Xiao, School of Materials, University of Manchester, Manchester M1 7HS, UK. Cited: *Int. J. Appl. Ceram. Technol.*, **6**(3), p 381-399. ISSN 1546-542X.

**Process-controlled plasma-sprayed Yttria-stabilized zirconia coatings: new insights from ultrasmall-angle x-ray scattering.** A multicomponent microstructure model is applied in ultrasmall-angle x-ray scattering studies of two groups of plasma-sprayed yttria-stabilized zirconia thermal barrier coatings (TBCs). One group was sprayed from a single powder feedstock using controlled processing conditions. The other group included three different feedstock morphologies (obtained from different manufacturing methods), each with a similar particle size distribution and sprayed under the same average controlled processing conditions. The microstructure is quantitatively related to the feedstock morphology and processing conditions. Relationships are explored among these microstructures and the coating properties (e.g., thermal conductivity, elastic modulus). The degree of microstructural anisotropy is demonstrated to be pore-size dependent, being more pronounced for larger pores, and more sensitive to feedstock morphology (powder processing) than to spray processing. The microstructure analysis indicates two broad distributions of interlamellar pores, which combined, account for 70-80% of the pore volume. The total porosity is found to increase with decreasing particle temperature or velocity. For all coatings, a negative linear relationship exists between thermal conductivity and total porosity. Comparison of the new analysis is made with earlier small-angle neutron scattering results, and implications are considered for a more general application of this metrology in TBC microstructure design. 

Y. Li, W. Chi, S. Sampath, A. Goland, H. Herman, A.J. Allen, and J. Ilavsky, Department of Materials Science and Engineering, State University of New York at Stony Brook, Stony Brook, NY 11794-2275. Cited: *J. Am. Ceram. Soc.*, 2009, **Feb** 92(2), p 491-500. ISSN 0002-7820.

## Microstructure

**Microstructure and wear resistance of WC-Co by three consolidation processing techniques.** Tungsten carbide-cobalt (WC-Co) has been extensively employed as an abrasion/wear protective material. However, carbon loss (decarburization) of WC-Co powders during processing reduces the efficiency of the material against abrasive wear. This paper examines the efficiency of three consolidation processing techniques to obtain coatings and bulk samples from WC-Co powder. In this work, high velocity oxy-fuel (HVOF) spray forming and laser engineered net shaping (LENS$^{TM}$ were applied to make WC-Co coatings; spark plasma sintering (SPS) was used to produce bulk WC-Co samples for comparison. The microstructures of two types of coatings and one bulk sample were analyzed by scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDX) to recognize material modification. In addition, porosity and tribological properties of the WC-Co samples were tested. The ultra-microindentation technique was applied to measure the universal hardness and the elasto-plastic properties of the samples. Experiments using a tribometer (ball on disc configuration) under dry conditions have been performed in order to evaluate the friction and wear properties of the different systems. 

J.A. Picas, Y. Xiong, M. Punset, L. Ajdelsztajn, A. Forn, and J.M. Schoenung, Light Alloys and Surface Treatments Design Centre (CDAL), Technical University of Catalonia, 08800 Vilanova i la Geltru, Spain. Cited: *Int. J. Refract. Metal Hard Mater.*, 2009, March, **27**(2), p 344-349. ISSN 0263-4368.

**Microstructural characterization and hardness evaluation of HVOF sprayed Ni-5Al coatings on Ni- and Fe-based superalloys.** HVOF sprayed Ni-5Al coatings on Ni- and Fe-based superalloy substrates were characterized to assess the microstructural features and strength in the as deposition condition for their applications in high-temperature corrosive environment of gas turbine. X-ray diffraction (XRD), optical microscopy, scanning electron microscopy (SEM), energy-dispersive x-ray analysis (EDAX), and x-ray mapping analysis are used to characterize the Ni-5Al coatings. The dense coatings with less porosity and inclusions were produced using HVOF process. The deposited Ni-5Al coatings exhibited splat like layered morphologies due to deposition and resolidification of successive molten and semi-molten powder particles. The hardness of coatings on three different superalloy substrates was measured and it was in the range of 210-272 Hv. The average bond strength and surface roughness of the as-sprayed coatings were 42.62 MPa and 9.22-9.45 μm, respectively. Diffusion of alloying elements from the substrate into the coating has occurred in all the three superalloy substrates as observed from the x-ray mapping analysis. 

R.A. Mahesh, R. Jayaganthan, and S. Prakash, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Roorkee, Roorkee, 247667, India. Cited: *J. Mater. Proces. Technol.*, 2009, Apr 1, **209**(7), p 3501-3510. ISSN 0924-0136.

## Modeling

### *Mechanical and Thermal Modeling*

**Analysis of fracture and delamination in laminates using 3D numerical modeling.** The static failure behavior of the fiber-metal laminate GLARE is examined using 3D finite element simulations. The configuration analysed is a center-cracked tensile specimen composed of two aluminum layers sandwiching a cross-plied, fiber-epoxy layer. The crack and delamination growths are simulated by means of interface elements equipped with a mixed-mode damage model. The mode-mixity is derived from an energy criterion typically used in linear elastic fracture mechanics studies. The damage kinetic law is rate-dependent, in order to simulate rate effects during interfacial delamination and to avoid numerical convergence problems due to crack bifurcations. The numerical implementation of the interface damage model is based on a backward Euler approach. In the boundary value problem studied, the failure responses of GLARE specimens containing elastic aluminum layers and elasto-plastic aluminum layers are compared. The development of plastic deformations in the aluminum layers stabilizes the effective failure response, and increases the residual strength of the laminate. For a 'quasi-brittle' GLARE

specimen with elastic aluminum layers, the residual strength is governed by the toughness for interfacial delamination, and is in close correspondence with the residual strength obtained from a closed-form expression derived from energy considerations. Conversely, for a 'ductile' GLARE specimen with elasto-plastic aluminum layers, the residual strength is also determined by the relation between the fracture strength and the yield strength of the aluminum. The amount of constraint by the horizontal displacements at the vertical specimen edges has a moderate to small influence on the residual strength. Furthermore, the ultimate laminate strength is lower for a larger initial crack length, and shows to be in good correspondence with experimental values. 

M.V. Cid Alfaro, A.S.J. Suiker, R.D. Borst, and J.J.C. Remmers, Faculty of Aerospace Engineering, Delft University of Technology, 2629 HS Delft, Netherlands. Cited: *Eng. Fract. Mech.*, 2009, April, **76**(6), p 761-780. ISSN 0013-7944.

**Dependence of splat remelt and stress evolution on surface roughness length scales in plasma sprayed thermal barrier coatings**. Analysis of real surfaces in plasma sprayed thermal barrier coatings showed roughness features at different length scales. It was found that the basic physics of the underlying splat remelt process can be characterized using a single non-dimensional temperature. Significantly different levels of remelt were calculated for the different surface roughness wavelengths, highlighting the importance of multiple length scales. A fully coupled thermo-mechanical finite element model was used to study the buildup of stresses during splat solidification. It was found that only roughness features on the scale of splat thickness are important in providing locations of maximum stress concentrations. It was found that the surface roughness features in real coatings are not sinusoidal. Instead, a more realistic 'ideal' surface roughness geometry is proposed, with periodic regions of stress concentration defined as small concave arcs with large curvatures surrounded by large convex arcs of smaller curvature on either side. 

S.N. Basu, G. Ye, R. Khare, B. Mccandless, M. Gevelber, and D. Wroblewski, Department of Manufacturing Engineering, Boston University, Brookline, MA 02446. Cited: *Int. J. Refract. Metal Hard Mater.*, 2009, March, **27**(2), p 479-484. ISSN 0263-4368.

**Estimation of heat flux and thermal stresses in multilayer gun barrel with thermal contact resistance.** In this study, a conjugate gradient method based on an inverse algorithm is applied to estimate the unknown time-dependent heat flux at the inner surface of gun barrel, in which the interlayer thermal contact resistance between the steel cylinder and the chrome coating is taken into account in the boundary conditions. While knowing the temperature history at the measuring position, no prior information is needed on the functional form of the unknown heat flux. The temperature data calculated from the direct problem are used to simulate the temperature measurement. The influence of measurement errors and initial guess values upon the precision of the estimated results is also investigated. Results show that an excellent estimation on the time-dependent heat flux, temperature distributions, and thermal stresses can be obtained for the case considered in this study. 

H.-L. Lee, Y.-C. Yang, W.-J. Chang, and T.-S. Wu, Clean Energy Center, Department of Mechanical Engineering, Kun Shan University, Yung-Kang City, Tainan 710-03, Taiwan. Cited: *Appl. Math. Comput.*, 2009, March 15, **209**(2), p 211-221. ISSN 0096-3003.

**Microcrack nucleation in thermal barrier coating systems.** Crack nucleation in thermal-barrier coating (TBC) systems subjected to a monotonic cooling process is studied. The TBC system is modeled using the finite element method, where cracks are represented as discrete discontinuities across continuum elements using the partition-of-unity method. The numerical implementation used for crack nucleation is based on an algorithm where, at insertion of a discontinuity, the traction response is derived from a cohesive zone model that has been modified to (i) behave like an initially rigid cohesive model, and to (ii) ensure smoothness of the traction-separation law at zero crack opening. Accordingly, an adequate convergence behavior of the numerical formulation can be warranted in boundary value problems of systems with relatively complex geometries. In the present numerical study, a comparison is made between TBC systems composed of different constitutive models. The fracture patterns and evolutions of the overall crack growth resulting from the simulations clearly illustrate the importance of accounting for the effects of plasticity in the bond coating and anisotropy in the topcoating. The computed fracture profile is in good correspondence with experimental observations reported in the literature. 

T.S. Hille, A.S.J. Suiker, and S. Turteltaub, Faculty of Aerospace Engineering, Delft University of Technology, 2600 GB, Delft, Netherlands. Cited: *Eng. Fract. Mech.*, 2009, April, **76**(6). p 813-825. ISSN 0013-7944.

**Quantitative analysis of a new model for the sintering of columnar thermal barrier coatings.** Sintering of thermal barrier coatings adversely affects their long-term reliability by changing their key attributes. In recent work, we developed a novel modeling approach to study coating structure evolution due to the sintering of topcoat columns and predicted the formation of large clusters, and a network of elongated pore channels separating these [R. Krishnamurthy, D.J. Srolovitz, *Acta Mater.*, in press]. Here we extract statistical measures, such as the pair correlation function, the in-plane porosity and pore size distribution from the predicted sintered microstructures, and systematically analyze their variation as a function of coating system parameters. The variables that have the greatest effect on these measures are the column density and the extent of the 'feathery' structure of the coating. At early times, low column densities, and where the 'feathery' protrusions extend only to a small distance, small clusters containing mainly neighboring columns are formed. On the contrary, when these variables assume large values, clusters many columns wide are formed. We also predict the formation of in-plane pores of sizes comparable to the width of the 'mud-cracks' seen in experiment [V. Lughi, V.K. Tolpygo, D.R. Clarke, *Mater. Sci. Eng. A* 368 (2004) 212-221]. Estimates for cluster size based on this pore size also agree with experiment. 

R. Krishnamurthy and D.J. Srolovitz, Department of Mechanical Engineering, Princeton Institute for the Science and Technology of Materials, Princeton University, NJ 08542. Cited: *Mater. Sci. Eng. A*, 509(1-2), May 25 2009, p 46-56. ISSN 0921-5093.

**Substrate-affected indentation contact parameters of elastoplastic coating/substrate composites.** In coating/substrate bilayer systems, the indentation contact behavior transitionally varies from coatinglike to substratelike behaviors. Spatial confinement effects of the substrate induce very complicated plastic flows in the coating beneath the indenter, leading to a crucial difficulty that is not accounted for by any of the present quantitative analytical/theoretical predictions for the substrate-affected contact hardness. In this work, the author presents finite-element-based studies on the elastoplastic indentation contact mechanics of coating/substrate systems. The effect of the substrate is taken into account by introducing the spatially variable elastic modulus and the yield stress; this approach quantitatively describes the substrate-affected stress/strain field in the spatially localized area beneath the indenter. The elastoplastic constitutive relationship of the contact hardness for semi-infinite homogeneous bulks combined with these spatially variable material characteristics are successfully applied to analytically as well as quantitatively predict the substrate-affected contact hardness of bilayer composite systems having wide ranges of elastoplastic coating/substrate characteristics. The experimental procedures for determining the elastic/plastic parameters both of the coating and the substrate are also discussed, in which the importance of the experimental determination of substrate-affected indentation contact radius/area is emphasized. 

M. Sakai, Department of Materials Science, Toyohashi University of Technology, Toyohashi 441-8580, Japan. Cited: *J. Mater. Res.*, 2009, March, **24**(3), p 831-843. ISSN 0884-2914

**Thermal-mechanical modeling of nodular defect embedded within multilayer coatings.** The initiation of laser damage within optical coatings can be better understood by thermal-mechanical modeling of coating defects. The result of this modeling shows that a high-temperature rise and thermal stress can be seen just inside the nodular defect compared to surrounding coating layers. The temperature rise and thermal stress tend to increase with seed diameter. Shallower seed tends to cause higher temperature rise and greater thermal stress. There is a critical seed depth at which thermal stress is largest. The composition of the seed resulting from different coating-material emission during evaporation can affect the temperature rise and thermal stress distribution. 

X. Ling, J. Shao, and Z. Fan, R and D Center of Optical Thin Film Coatings, Shanghai Institute of Optics and Fine Mechanics, Shanghai 201800, China. Cited: *J. Vac. Sci. Technol. A Vac Surf Film*, 2009, **27**(2), p 183-186. ISSN 0734-2101.

## *Process Modeling*

**Numerical study of melted particles crush metallic substrates and the interaction between particles and a plasma beam in the thermal projection process.** Plasma spray processes have been widely used to produce high performance coatings of a wide range of materials (metallic, non-metallic, and ceramics), offering protection from, e.g., wear, extreme temperature, chemical attack, and environmental corrosion. To obtain good quality coatings, spray parameters must be carefully selected. Due to the large variety in process parameters, it is difficult to optimize the process for each specific coating and substrate combinations. Furthermore modeling the spray process allows a better understanding of the process sequences during thermal spraying. The simulation of coating formation to estimate the process parameters is an important tool to develop new coating structures with defined properties. In this work, the process of plasma sprayed coating has been analyzed by numerical simulation. Commercial code is used to predict the plasma jet characteristics, plasma-particle interaction, and coating formation. Using this model we can obtain coating microstructure and characteristics which form a foundation for

further improvement of an advanced ceramic coating build up model. 

I. Kriba and A. Djebaili, Plasma Laboratory, Faculty of Sciences, Department of Physics, Ouargla, Algeria. Cited: *Appl. Surf. Sci.*, 2009, March 1, **255**(10), p 5637-5640. ISSN 0169-4332.

## Postprocessing

**Degradation of plasma-sprayed yttria-stabilized zirconia coatings via ingress of vanadium oxide.** $V_2O_5$ reaction and melt infiltration in plasma-sprayed 7 wt.% $Y_2O_3$-$ZrO_2$ (YSZ) coatings were investigated at temperatures ranging from 750 to 1200 °C using SEM and TEM combined with EDS. The interlamellar pores and intralamellar cracks, common in plasma-sprayed materials, provide pathway for the molten species. The microstructure of the contaminated coatings is therefore the result of the interplay between the dissolution/reaction rates of the $V_2O_5$ with YSZ coating and the infiltration rates of the molten species. Near the coating surface, the reaction front proceeds in a planar fashion, via dissolution of the lamella and precipitation of fine-grained reaction products composed of $ZrV_2O_7$ (for reactions at 750 °C and below), *m*-$ZrO_2$ and $YVO_4$. The thickness of this planar reaction zone or PRZ was found to increase as reaction time and temperature increased. The melted $V_2O_5$ was observed to infiltrate along the characteristic microstructure of plasma-sprayed coatings, i.e., the interconnected pores and cracks, and react with the YSZ. The thickness of this melt infiltrated reaction zone or MIRZ ranged from 5 μm for reactions at 750 °C for 30 min to 130 μm for reactions at 1000 °C for 90 min. At 1200 °C, only a PRZ was observed (i.e., the thickness of the MIRZ was nominally zero), suggesting that the dissolution reaction within the pores/cracks and subsequent formation of reaction products may limit infiltration. Fifty-hour heat-treatments at 1000 and 1200 °C prior to reaction with the $V_2O_5$ at 800 °C for 90 min were used to change the microstructural features of the coating, such as crack connectivity and pore size. The heat-treatment at 1000 °C was found most deleterious to the coating due to large cracks created via a desintering process that afforded deep penetration of the molten $V_2O_5$. 

Z. Chen, J. Mabon, J.-G. Wen, and R. Trice, School of Materials Engineering, Purdue University, West Lafayette, IN 47907. Cited: *J. Euro. Ceram. Soc.*, 2009, June, **29**(9), p 1647-1656. ISSN 0955-2219.

**Effect of laser melting on plasma-sprayed aluminum oxide coatings reinforced with carbon nanotubes.** The effect of laser melting on the microstructure and mechanical properties of plasma-sprayed aluminum oxide composite coating reinforced with 4 wt.% multi-walled carbon nanotubes (CNTs) is reported. Laser-melted layer consists of dense, coarse columnar microstructure which is significantly different from plasma-sprayed coating that consists of splats and porosity. CNTs retained their original cylindrical graphitic structure after undergoing laser irradiation. Three-dimensional heat flow model has been developed to estimate temperature variation in the laser-melted composite layer. Laser-melted layers show an increase in the microhardness at the expanse of degradation of fracture toughness. Nanoindentation study indicates an increase in the elastic modulus and yield strength of the laser-melted layer which is attributed to dense microstructure with absence of weak-bonding splats and porosity. 

Y. Chen, A. Samant, K. Balani, N.B. Dahotre, and A. Agarwal, Mechanical and Materials Engineering, Florida International University, Miami, FL 33174. Cited: *Appl. Phys. A Mater. Sci. Process.*, **94**(4), p 861-870. ISSN 0947-8396.

**Effect of remelting process on characterization of air-plasma sprayed $Fe_{67.5}Ni_{23.5}B_9$ alloy coatings onto $_1Cr_{18}Ni_9Ti$ stainless steel.** To develop a composite material with good mechanical and radiation shielding properties, the Fe-Ni-B ($Fe_{67.5}Ni_{23.5}B_9$, wt.%) coatings onto $_1Cr_{18}Ni_9Ti$ stainless steel substrate (SS, same as below) were prepared using air-plasma spraying (APS) technique in this work. A remelting process (1050 °C/2 h) was performed on the Fe-Ni-B coatings laminated composite under vacuum condition. The microstructure, phase composing, adhesion strength, Vickers hardness distribution, and residual stress of Fe-Ni-B coatings before and after the remelting process were contrastively characterized. The results show that the remelting process decreases the coating defects and makes the coating more cohesive and stable. The element diffusion and new compounds formation within the coating and interface area improve the adhesion and thermal fatigue of Fe-Ni-B coatings. In addition, the drop of variability of Vickers hardness data and residual stress level qualitatively identify that the Fe-Ni-B coatings possess more consistent microstructure and mechanical integrity after the remelting process. 

W. Yang and M. Li, Aviation Engineering Institute, Civil Aviation Flight University of China, 618307, Sichuan, China. Cited: *J. Mater. Process. Technol.*, 2009, Apr 1, **209**(7), p 3256-3263. ISSN 0924-0136.

**Investigation of reactions between vanadium oxide and plasma-sprayed yttria-stabilized zirconia coatings.** The phase evolution occurring during the reaction between corrosive $V_2O_5$ ($T_m = 690$ °C) and a plasma-sprayed 7 wt.% $Y_2O_3$-$ZrO_2$ (YSZ) coating from 700 to 900 °C has been investigated in situ by x-ray diffraction. The temperature and time of interaction between the $V_2O_5$ and YSZ coating determines the phases observed. Between 700 and 750 °C, reaction products of $ZrV_2O_7$ and $YVO_4$ were observed within minutes of reaching the test temperature. *m*-$ZrO_2$ was observed after 220 and 60 min at 700 and 750 °C, respectively. The simultaneous formation of both $ZrV_2O_7$ and $YVO_4$ at the beginning of the reaction along with the delay of the *m*-$ZrO_2$ formation suggests similar reactivity between both Zr and Y with $V_2O_5$. The weight percent of the $ZrV_2O_7$ phase began to diminish after 150 and 60 min at 700 and 750 °C, respectively. For reaction temperatures of 800 and 900 °C, there is a rapid decrease in the amount of t′-$ZrO_2$ and a rapid increase in the amount of *m*-$ZrO_2$ with reaction time. $YVO_4$ was also observed at these reaction temperatures. SEM and TEM microstructural observations confirmed the phases detected from the in situ XRD experiments. Reactions between YSZ and $V_2O_5$ suggest that the formation of a liquid phase due to the high solubility of both zirconia and yttria in vanadia is the dominate mechanism that damages the coating. The thermal conductivity of a plasma-sprayed YSZ coating reacted with up to 1 wt.% $V_2O_5$ did not significantly change due to the small volume affected. 

Z. Chen, S. Speakman, J. Howe, H. Wang, W. Porter, and R. Trice, Purdue University, West Lafayette, IN 47907-2044. Cited: *J. Euro. Ceram. Soc.*, 29(8), May 2009, p 1403-1411 ISSN 0955-2219.

## Powder

**Flame-synthesized ceria-supported copper dimers for preferential oxidation of CO.** Rapid synthesis of Cu-$CeO_2$ catalysts by flame spray pyrolysis produces highly active Cu dimer morphologies without the need for additional catalyst pretreatment. The active Cu component is enriched onto the $CeO_2$ surface at concentrations higher than the nominal loading with no evidence of amorphous or crystalline CuO phase. Increasing the Cu content results in a morphological transition from isolated Cu monomers to oxygen-bridged dimers and an associated increase in oxygen vacancy concentration. Dimer-containing Cu-$CeO_2$ catalysts display high levels of activity and selectivity in the low-temperature preferential oxidation of CO. Experimental measurements and simulations suggest that the geometry of the dimer presents a comparatively ionic Cu-O bond at the catalyst surface. Further studies indicate that these ionic dimer species promote preferential CO oxidation at lower temperatures than observed for monomeric Cu species. This is the first report to explicitly propose and demonstrate that the structural distortion associated with the formation of Cu dimers directly induces increased bond ionicity at the catalyst surface and that these changes are responsible for improved catalytic activity. 

R. Kydd, W.Y. Teoh, K. Wong, Y. Wang, J. Scott, Q.-H. Zeng, A.-B. Yu, J. Zou, and R. Amal, ARC Centre of Excellence for Functional Nanomaterials, School of Chemical Sciences and Engineering, University of New South Wales, Sydney, NSW 2052, Australia. Cited: *Adv. Funct. Mater.*, 2009, Feb. 10, **19**(3), p 369-377. ISSN 1616-301X.

**Characteristics of Sn-Ni alloy powders directly prepared by spray pyrolysis.** Fine size Sn-Ni alloy powders with spherical shape were directly prepared by spray pyrolysis. The alloy powders prepared at temperatures below 1200 °C had bimodal size distributions of nano- and submicron-sized powders. Nano-sized powders were formed by chemical vapor deposition process from the evaporated Sn component. The powders had main peaks of Sn-Ni alloys irrespective of the preparation temperatures. Ni and Sn components are well dispersed inside the submicron-sized powders. The initial discharge capacity of the Sn-Ni alloy powders prepared at a temperature of 1100 °C was 477 mAh/g. However, the initial discharge capacity of the Sn-Ni alloy powders prepared at temperature of 1000 and 1200 °C temperature were 255 and 411 mAh/g, respectively. The Sn-Ni alloy powders prepared at a temperature of 1100 °C had more good cycle performance than those prepared at temperatures of 1000 and 1200 °C. 

S.H. Ju, H.C. Jang, Y.C. Kang, and D.-W. Kim, Department of Chemical Engineering, Konkuk University, Seoul, 143-701, South Korea. Cited: *J. Alloy Compd.*, 2009, Jun 10, **478**(1-2), p 177-180. ISSN 0925-8388.

**Modified solution combustion route for the preparation of plasma sprayable ceria powder.** Plasma sprayable grade ceria powder was prepared by the solution combustion method. This is the first report on the application of solution combustion for the synthesis of plasma sprayable grade oxide powders. The fuels and fuel ratios used in the solution combustion were modified to achieve adequate flowability. It was found that when a mixture of fuels like glycine and ammonium acetate was used, the combustion process yielded larger agglomerates. Phase purity of the powders was confirmed by powder XRD. The morphology of the particles was determined by scanning electron microscopy. 

S.T. Aruna and K.S. Rajam, Surface Engineering Division, National Aerospace Laboratories, Bangalore, 560 017, India. Cited: *Ceram. Int.*, 2009, May **35**(4), p 1353-1355. ISSN 0272-8842.

**Suspension plasma sprayed composite coating using amorphous powder feedstock.** $Al_2O_3$-$ZrO_2$ composite coatings were deposited by the suspension plasma spray process using molecularly mixed amorphous powders. X-ray diffraction (XRD) analysis shows that the as-sprayed coating is composed of $\alpha$-$Al_2O_3$ and tetragonal $ZrO_2$ phases with grain sizes of 26 and 18 nm, respectively. The as-sprayed coating has 93% density with a hardness of 9.9 GPa. Heat treatment of the as-sprayed coating reveals that the $Al_2O_3$ and $ZrO_2$ phases are homogeneously distributed in the composite coating. 

D. Chen, E.H. Jordan, and M. Gell, Department of Chemical, Materials and Biomolecular Engineering, Institute of Materials Science, University of Connecticut, Storrs, CT 06269. Cited: *Appl. Surf. Sci.*, 2009, March 15, **255**(11), p 5935-5938. ISSN 0169-4332.

**Synthesis, characterization, and electronic structure of nitrogen-doped $TiO_2$ nanopowder.** Nanopowders of $TiO_2N$ were synthesized in a two step process. At first, $TiO_2$ was prepared from titanium tetraisopropoxide (TTIP) in form of crystalline powder by flame spray synthesis (FSS). In a second step, $TiO_2$-FSS with a specific surface area (SSA) of 54 $m^2/g$ and $TiO_2$-P25 as a reference material were ammonolysed in a rotating tube furnace. X-ray diffraction (XRD) and transmission electron microscopy (TEM) were used to investigate crystallinity before and after ammonolysis. Based on the x-ray photoelectron spectroscopy (XPS) studies, it has been established that the N 1s peak at 395.9 eV can be assigned to substitutional nitrogen. New electron transitions and resulting band gap changes in respect to undoped sample have been observed in $TiO_{2-x}N_x$. Diffusive reflectance and the resulted band gap energy were determined by diffuse reflection spectroscopy (DRS), where the correlation between differential reflectance and Tauc plot, known as a second method of the band gap determination, is discussed for pure and N-doped $TiO_2$ nanopowders. The photocatalytic performance of the nanopowders under visible light irradiation (400-500 nm) was studied by the degradation of methylene blue (MB) in aqueous suspensions. 

K.A. Michalow, D. Logvinovich, A. Weidenkaff, M. Amberg, G. Fortunato, A. Heel, T. Graule, and M. Rekas, Faculty of Material Science and Ceramics, AGH University of Science and Technology, 30-059 Krakow, Poland. Cited: *Catal. Today,* 2009, June 15, **144**(1-2), p 7-12. ISSN 0920-5861.

## Processing

**Direct synthesis of maghemite, magnetite, and wustite nanoparticles by flame spray pyrolysis.** Magnetic iron-oxide nanoparticles have been prepared by flame spray pyrolysis (FSP) under controlled atmosphere. This way controlled and direct flame synthesis of $Fe_2O_3$ (maghemite), $Fe_3O_4$ (magnetite), and FeO (wustite) particles is possible by a scalable process. The Fe oxidation state was controlled by varying the fuel to air ratio during combustion as well as by varying the valence state of the applied Fe precursor. The as-prepared materials were characterized by electron microscopy, nitrogen adsorption, x-ray diffraction, and Raman spectroscopy. Magnetic properties were investigated with SQUID, which unravelled superparamagnetic behavior for all materials and typical features for the corresponding crystal structures and particle sizes. Maximum magnetization was achieved for a mixture of maghemite and magnetite. 

R. Strobel and S.E. Pratsinis, Particle Technology Laboratory, Department of Mechanical and Process Engineering, Institute of Process Engineering, CH-8092, Zurich, Switzerland. Cited: *Adv. Powder Technol.*, 2009, March, **20**(2), p 190-194. ISSN 0921-8831.

**Flame spray synthesis and characterisation of stabilized $ZrO_2$ and $CeO_2$ electrolyte nanopowders for SOFC applications at intermediate temperatures.** Zirconia ($Y_{0.16}Zr_{0.84}O_2$, $Sc_{0.2}Zr_{0.8}O_2$, and $Sc_{0.2}Ce_{0.01}Zr_{0.79}O_2$) and ceria ($Gd_{0.2}Ce_{0.8}O_2$) based electrolyte materials are synthesized at production rates up to 260 g $h^{-1}$ by a liquid-fed one-step flame spray synthesis from water-based solutions, or cost-effective rare earth nitrates with a high water content. It was found that this one-step synthesis, based on an acetylene-supported flame is able to produce phase pure and highly crystalline, nanoscale electrolyte materials. The as-synthesized powders show a cubic lattice structure independent of production rates. Specific surface areas of the powders were adjusted between 20 and 60 $m^2$ $g^{-2}$, where the latter is an upper limit for the further processing of the powders in terms of screen printing. The influence of process parameters on morphology, particle size, composition, crystallinity, lattice parameter, shrinkage behavior, and coefficient of thermal expansion of the as-synthesized powders were systematically investigated by transmission electron microscopy (TEM), nitrogen adsorption (BET), x-ray diffraction (XRD), and dilatometry. Electrochemical impedance spectroscopy (EIS) was applied at temperatures between 300 and 900 °C and confirmed the high quality and the competitive electrochemical behavior of the produced powders. 

A. Heel, A. Vital, P. Holtappels, and T. Graule, Laboratory for High Performance Ceramics, EMPA Swiss Federal Laboratories for Materials Testing and Research, Duebendorf, 8600, Switzerland. Cited: *J. Electroceram.*, 2009, Feb, **22**(1-3), p 40-46. ISSN 1385-3449.

**Foamy coating obtained by laser ablation of glass ceramic substrates at high temperature.** This paper presents a study of the effect of temperature in the machining of glass ceramic cooking plates by laser ablation. A Q-switched Nd:YAG laser at its fundamental wavelength of 1064 nm with pulsewidths in the nanosecond range was used. The beam was focalized and scanned over the surface covering an area of several squared millimeters. With the same irradiance and process parameters, the rise of the surface temperature some hundreds of degrees changes drastically the ablation conditions. As temperature is risen the amount of particles ejected from the interaction zone diminishes, recasting over the processed area generating a white and foamy self-layer. The size of the ejected particles and the morphology, composition, and microstructure of the new layer are described. This layer could be used to change the thermal conductivity of the glass ceramic plate as well as for aesthetic purposes. 

D. Sola and J.I. Pena, Departamento de Ciencia y Tecnologia de Materiales y Fluidos, Instituto de Ciencia de Materiales de Aragon, Universidad de Zaragoza-CSIC, 50.018, Zaragoza, Spain. Cited: *Appl. Surf. Sci.*, 2009, March 1, **255**(10), p 5322-5328. ISSN 0169-4332.

**Low pressure cold spraying of tungsten carbide composite coatings.** Tungsten carbide cobalt (WC-Co) coatings are mainly used for wear resistance applications as the cobalt binder increases the toughness. Today, WC-Co hard coatings have replaced the electrolytic hard chrome (EHC) coatings as per the recent implementation of regulation that eliminates the environmental impact of hexavalent chromium. Meanwhile, the cold spray processes can help out the imperfections done by WC-Co coating like cracks, blisters, and delaminations. In addition, low pressure cold spray has the advantage of being portability while having a low operating cost.

J. Wang and J. Villafuerte, CenterLine Windsor Ltd., Windsor, ON, Canada. Cited: *Adv. Mater. Process.*, 2009, Feb **167**(2), p 54-56. ISSN 0882-7958.

**Manipulation of air plasma spraying parameters for the production of ceramic coatings.** Thermal barrier coatings (TBCs) were sprayed on stainless steel coupons by an air plasma thermal spray (APS) technique. The porosity of the topcoat was varied by controlling the different spraying parameters. Three types of thermal shock tests were designed to determine the TBCs life. Effect of different spraying parameters on the thermal shock life was observed. The spraying distance was found to be an important parameter that controls the thermal shock life. It was observed that the thermal shock properties could be related with an empirical parameter called the critical thermal shock parameter (CTSP). Fracture toughness ($K_{IC}$) was determined by Vicker's indentation technique and it was observed that for a certain range of the porosity the toughness increased with increase of porosity. The possible increase in thermal shock life for a certain range of CTSP may be attributed to residual stresses and increase in fracture toughness of the topcoat. 

A.N. Khan and J. Lu, Metallurgy Division, Rawalpindi, Pakistan. Cited: *J. Mater. Process. Technol.*, 2009, March 1, **209**(5), p 2508-2514. ISSN 0924-0136.

**$Mg_{65}Cu_{25}Gd_{10}$ BMG rod and ribbon and composite synthesized via spray forming.** Mg bulk metallic glass rod, ribbon, and composite plate were synthesized via injection casting, melt spinning, and spray forming, respectively. The BMG composite plate has various microstructure combinations, from fully amorphous phase to mixture of nanocrystals, crystals, and amorphous phase. XRD analyses were done on the rod and ribbon and throughout the vertical locations of the plates at the maximum thickness. Glass transition temperature ($T_g$) and onset crystallization temperature ($T_x$) were measured with DSC, and GFA (Glass Forming Ability) was estimated with various GFA models. The microhardness of the spray-formed Mg-Cu-Gd layered composite plate at various positions and Mg-Cu-Gd rod and ribbon were measured.

K.F. Chang, F.H. Chen, S.K. Fan, and C.Y.A. Tsao, Cited: *Advanced Materials Research* (Conf. Proc.) Nov 16-17 2007 (Hsinchu), 2008, Vol. 51, Trans Tech Publications. ISSN 1022-6680.

**Palladium and tantalum aluminide coatings for high-temperature oxidation resistance of titanium alloy IMI 834.** The present article explains the efforts made in developing new protective coatings based on palladium, tantalum, and aluminum with considerably improved oxidation resistance for effective protection of titanium alloy IMI 834. Systematic characterization was carried out on as-prepared as well as oxidized coatings and these results are presented. The performance of new coatings was evaluated by generating weight-gain data as a function of time followed by detailed characterization in order to confirm the ability of the coatings to prevent oxidation and alpha-case formation. The results showed that tantalum aluminide and simple aluminide coatings exhibit improved oxidation resistance when compared to palladium aluminide. Finally, the advantages of developed new coatings and the

necessity of their use in modern gas turbine engines that allow the alloy to be used safely at high temperatures, which in turn would enhance the efficiency of gas-turbine engine-compressor sections, will be stressed. © 2008 FSCT and OCCA.

I. Gurrappa, A. Wilson, and P.K. Datta, Advanced Materials Research Institute, School of Computing, Engineering and Information Sciences, Northumbria University, Newcastle Upon Tyne, NE1 8ST, UK. Cited: *J. Coat. Technol. Res.*, 2009, June, **6**(2), p 257-268. ISSN 1547-0091.

**Polymeric coatings deposited from an aerosol-assisted non-thermal plasma jet.** By combining a non-equilibrium, atmospheric pressure, plasma jet with an aerosol delivery system, it is possible to deposit polymeric coatings onto three-dimensional substrates. In this study, the effects of varying process parameters on the deposition of a fluorocarbon precursor, using this system, are investigated. A statistically designed experiment is undertaken to probe the factors altering the deposition properties. It is shown that highly functional coatings can be deposited with minimal fragmentation of the precursor monomer. Both the plasma power and distance from the plasma to the substrate are factors which significantly affect the deposition rate and chemistry of the coatings. © 2009 WILEY-VCH Verlag GmbH and Co. KGaA.

L. O'neill and C. O'Sullivan, Dow Corning Plasma Solutions, Midleton, Cork, Ireland. Cited: *Chem. Vapor Deposit.*, 2009, March, **15**(1-3), p 21-26. ISSN 0948-1907.

**Properties of TiN-matrix coating deposited by reactive HVOF spraying.** TiN-matrix coating was prepared by reactive high velocity oxygen fuel (HVOF) spraying on carbon steel based on the self-propagating high temperature synthesis (SHS) technique in air. The phase composition, structures, and properties of TiN-matrix coating were analyzed using XRD, EDS, SEM, and Vickers microhardness equipment. The anti-corrosion property in nearly neutral 3.5 wt.% NaCl electrolytic solution was measured. The Weibull distribution of Vickers microhardness at different loads and their linear fitting were analyzed. The apparent fracture toughness of the coating was also calculated. The coating is composed of main phases (TiN, $TiN_3$), minor phases ($Ti_2O_3$, $TiO_2$), and porosity. The anti-corrosion property of an HVOF-sprayed TiN-matrix coating in electrolytic solution is superior to that of AISI 316L stainless steel. The microhardness values from $1137HV_{0.05}$ to $825HV_1$ are relatively high and have indentation size effect (ISE). With the increment of *m*, which increases with the increment of applied load, the microhardness values are more concentrated. The average value of apparent fracture toughness $K_{IC}$ is 4.62 MPa $m^{1/2}$. It is higher than that of reactive plasma sprayed (RPS) TiN coating, which reflects the good toughness of a TiN-matrix coating deposited by reactive HVOF spraying. © 2008 FSCT and OCCA.

Z. Mao, J. Ma, J. Wang, and B. Sun, State Key Laboratory of Metal Matrix Composites, Shanghai Jiaotong University, Shanghai 200240, China. Cited: *J. Coat. Technol. Res.*, 2009, June, **6**(2), p 243-250. ISSN 1547-0091.

**Shockwave Induced Spraying.** A new solid-state spray process, the shockwave induced spraying (SISP) is used for deposition of metals, alloys, cermets, polymers, and substrates. Since SISP can be used to induce thick coatings on different surfaces, SISP is highly recommended for depositing a range of temperature-sensitive and advanced materials. SISP enhances surfaces for corrosion protection, thermal insulation, thermal dissipation, wear resistance, electrical conductivity, restoration, and other applications without the detrimental effects of high temperature processes.

J. Villafuerte, D. Vanderzwet, M. Yandouzi, and B. Jodoin, Centerline Windsor Ltd., Windsor, ON N9J 3T8, Canada. Cited: *Adv. Mater. Process.*, 2009, March, **167**(3), p 32-34. ISSN 0882-7958.

**The preparation of barium hexaferrite coatings using HVOF.** Thick coatings of barium hexaferrite with the compositions $BaFe_{12}O_{19}$ and $BaCoTiFe_{10}O_{19}$ were prepared using high-velocity oxygen-fuel (HVOF) spraying technology. Nanocrystalline precursors embedded in an amorphous matrix were obtained on both Fe and glass-ceramic substrates. To promote the crystallization of the hexaferrites, the coatings were annealed at 800-1000 °C, and single-phase coatings were obtained at 1000 °C. The crystallization process was studied with x-ray powder diffraction and with electron microscopy. The magnetic measurements of the coatings were carried out in a static field and at high frequencies. The magnetization of the coatings increased with the annealing temperature to above 50 emu/g for both compositions. The coercivity of $BaFe_{12}O_{19}$ increased with the annealing temperature to above 2400 Oe, whereas the coercivity of $BaCoTiFe_{10}O_{19}$ decreased from over 800 Oe, for the as-deposited sample, to 400 Oe for the sample annealed at 1000 °C. A minimum 90% absorption was calculated for the $BaFe_{12}O_{19}$ coatings with thicknesses of 0.15-0.25 mm at around 47 GHz and for the 1- to 4-mm-thick coatings of $BaCoTiFe_{10}O_{19}$ at 3-9 GHz. © 2009 The American Ceramic Society.

D. Lisjak, D. Makovec, S. Gyrgyek, A. Hujanen, P. Lintunen, T. Varis, G. Bolelli, L. Lusvarghi, and M. Drofenik, Department for Materials Synthesis, Jozef Stefan Institute, Ljubljana 1000, Slovenia. Cited: *J. Am. Ceram. Soc.*, 2009, April, **92**(4), p 818-824. ISSN 0002-7820.

# Properties

## *Adhesion*

**An evaluation of plasma-sprayed coatings based on $Al_2O_3$ and $Al_2O_3$ 13 wt.% $TiO_2$ with bond coat on pure titanium substrate.** In this study, the effects of bond coat on the properties of $Al_2O_3$ and $Al_2O_3$-13 wt.% $TiO_2$ coatings, which is plasma sprayed onto a commercial pure titanium substrate with and without Ni-5 wt.% Al (METCO 450 NS) as bond coating layer were investigated in terms of microhardness, bonding strength, and surface roughness. Optical and scanning electron microscopy (SEM) examinations revealed that there is a uniform coating layer with no spalling and delamination. However, there is a little amount of porosity. The results indicated that the application of bond coat layer in the plasma spraying of $Al_2O_3$ and $Al_2O_3$-13 wt.% $TiO_2$ on pure titanium substrate has increased the hardness and bonding strength of coatings. While the adhesive bonding is dominant without bond coat, the cohesive bonding is dominant with the application of the bond coating layer. It has been observed that percentage of cohesion strength was about three times higher than that of adhesion strength. © 2008 Elsevier Ltd. and Techna Group S.r.l.

S. Yilmaz, Department of Metallurgical and Material Engineering, Engineering Faculty, Sakarya University, Sakarya, Turkey. Cited: *Ceram. Int.*, 2009, July, **35**(5), p 2017-2022. ISSN 0272-8842.

## *Corrosion*

**Self-healing polymer coatings.** The generalized approach of self-healing polymer-coating systems, and demonstrations of its effectiveness for model and industrially important coating systems were reported. The two self-healing approaches ranging from siloxane-based materials systems was explored, where in one approach the catalyst is microencapsulated and siloxanes were presented as phase separated droplets. The siloxanes were also encapsulated and dispersed in the coating matrix in the other approach. The experiment was carried out using polyurethane (PU) microcapsules containing 5% dimethyldineodecanoate tin (DMDNT) in chlorobenzene, with PDMS healing agent filled urea formaldehyde microcapsule's formation. The evaluation of self-heating function of the coating was carried out through corrosion testing of damaged and healed coated steel samples. The experiment concluded that the autonomic corrosion protection can be obtained by self-healing under ambient environmental conditions.

S.H. Cho, S.R. White, and P.V. Braun, Department of Materials Science and Engineering, Beckman Institute, University of Illinois at Urbana-Champaign, Urbana, IL 61801. Cited: *Adv. Mater.*, 2009, Feb 9, **21**(6), p 645-649. ISSN 0935-9648.

## *Mechanical*

**Damage behavior of the NiCrAlY coating systems with or without barrier layer during three-point bending.** With the aid of three-point bending test, the mechanical behavior of the NiCrAlY coating systems with or without barrier layer was analyzed. Together with the results from tensile adhesion test, the damage mechanism of the investigated systems was discussed. It is found that the damage behavior was mainly dependent on the interfacial adhesion and the overlayer property. With a strong or weak interfacial adhesion and the brittle or ductile overlayer different damage mechanism was developed during test. The presence of residual stress and brittle precipitates or flaws at the coating/substrate interface influenced the interfacial adhesion property. The thermal exposure treatment improved the interfacial strength and the overlayer ductility. © 2009 Elsevier B.V. All rights reserved.

W.Z. Li, Y. Yao, Y.Q. Li, J.B. Li, J. Gong, C. Sun, and X. Jiang, State Key Lab for Corrosion and Protection, Institute of Metal Research, Chinese Academy of Sciences, Shenyang, 110016, China. Cited: *Mater. Sci. Eng. A*, 2009, Jun 25, **512**(1-2), p 117-125. ISSN 0921-5093.

**Effect of WC on the residual stress in the laser-treated HVOF coating.** HVOF coating of diamalloy 1005 containing WC particles onto steel (304) is considered and laser melting of the coating is carried out. The effect of WC content on the residual stress formed in the coating is examined. Temperature rise and the temperature gradient developed in the coating are modeled and predicted. XRD technique is used to measure the residual stress in the coating while the analytical formulation is used to predict the residual stress at the coating base material interface. The indentation tests are carried out to measure the Young's modulus and fracture toughness of the coating with and without WC content. It is found that existing of WC modifies temperature rise and the temperature gradient in the coating; in which case, increasing WC content reduces the temperature gradient. The Young's modulus, the magnitude of the residual stress, and the fracture toughness of the coating increase with increasing WC content in the coating. © 2008 Elsevier B.V. All rights reserved.

Z.Y. Taha-Al, M.S. Hashmi, and B.S. Yilbas, ME Department, KFUPM, Dhahran, Saudi Arabia. Cited: *J. Mater. Process. Technol.*, 2009, Apr 1, **209**(7), p 3172-3181. ISSN 0924-0136.

**Fatigue resistance and failure mechanisms of plasma-sprayed CrC-NiCr cermet coatings in rolling contact.** The rolling contact fatigue (RCF) resistance and failure mechanisms of plasma-sprayed CrC-NiCr cermet coatings were experimentally investigated. Fatigue tests were conducted at two different contact stresses. At a given contact stress, 13 rolling contact tests were performed to obtain the statistical result. The Weibull distribution plots of fatigue life data of the coatings were obtained. At higher contact stress, the bimodal distribution of the fatigue life data of the coatings was observed in the Weibull plot. The fatigue life of the coating decreased with increasing the contact stress. The failure modes of coatings could be classified into two main categories, i.e., spalling and delamination. © 2008 Elsevier Ltd. All rights reserved.

X.C. Zhang, B.S. Xu, S.T. Tu, F.Z. Xuan, H.D. Wang, and Y.X. Wu, National Key Lab. of Metal Matrix Composites, Shanghai Jiaotong University, Shanghai, 200030, China. Cited: *Int. J. Fatigue,* 2009, May, **31**(5), p 906-915. ISSN 0142-1123.

**Hard coatings based on thermal spray and laser cladding.** Thermal spray and laser cladding have been used to develop hard coatings. HVOF and laser glazing techniques were used to form hard and corrosion resistant coatings, using WC/Co, impregnated in Ni-Cr powder, to protect the heat exchanger tubes from fireside erosion and corrosion, while PM 20 alloy (chromium carbide in Ni-Cr powder), WC/Co in Wi-Cr powder were used to develop a very hard and friction resistant coatings for engine groves, using plasma spray and laser cladding techniques. Results indicate that an optimized composition (15-30% of WC/Co in NiCr matrix) was best to control the erosion and corrosion of heat exchanger tubes and PM 20 alloy, applied using laser cladding, gave excellent hardness and adequate wear and friction resistance. © 2008 Elsevier Ltd. All rights reserved.

A.S. Khanna, S. Kumari, S. Kanungo, and A. Gasser, Corrosion Science and Engineering, Indian Institute of Technology, Bombay, India. Cited: *Int. J. Refract. Metal Hard Mater.*, 2009, March **27**(2), p 485-491. ISSN 0263-4368.

**Helicopter rotor blade coatings development offers superior erosion resistance and deicing capability.** Naval aircraft regularly operates in hostile environments that include sandy or dusty landing zones and severe sand, rain, or ice storms. Helicopters and other vertical/short take-off and landing (VTOL/STOL) aircraft such as the V-22 Osprey are expected to endure these severe environments without rapid erosion to the leading edge of their rotor blade. To avoid rapid deterioration of the rotor blade and potentially irreparable damage, the leading edge is typically protected with erosion resistant materials. The aim of this article is to find an optimum class of polymers with superior erosion resistance and deicing capability.

Y. Golfman, Neo-Advent Technologies, LLC, Sudbury, MA. Cited: *J. Adv. Mater.*, 2009, April, **41**(2), p 53-63. ISSN 1070-9789.

**Microstructure, corrosion behavior, and microhardness of plasma-sprayed W-Ni composite coatings.** Commercial tungsten powder of average particle size 12 μm was mixed with 10 wt.% Ni powder and plasma sprayed on a SUS304 stainless steel substrate. W-Ni composite coatings have been sprayed at different Ar plasma gas flow rates of 120,150, and 1701/min and different Ar carrier gas flow rates of 5, 8, and 10 L/min. The microstructure and phase structure of the sprayed coatings were investigated using a scanning electron microscope (SEM), x-ray diffraction (XRD), and an energy dispersive spectrometer (EDS). Corrosion tests were performed for the sprayed W-Ni coatings in a 3.5% NaCl solution using an electrochemical polarization method. It was found that the W-Ni coatings sprayed at a higher Ar gas flow rate showed higher corrosion resistance compared with coatings sprayed at a lower gas flow rate. A more positive value of the corrosion potential and a lower value of the corrosion current are observed for coatings sprayed at a higher Ar gas flow rate. © 2009 The Society of Manufacturing Engineers. Published by Elsevier Ltd. All rights reserved.

M.F. Morks, N.F. Fahim, and A. Kobayashi, Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan. Cited: *J. Manuf. Process.*, **10**(1), p 6-11. ISSN 1526-6125.

**Performance of abrasive wear of WC-12Co coatings sprayed by HVOF.** The performance of multimodal and conventional materials in the form of coatings deposited by high velocity oxy-fuel (HVOF) thermal spraying has been studied. WC-12Co coatings were deposited under same conditions using multimodal and conventional WC-12Co powder feedstocks. The phase composition of the feedstock powders and the coatings were analyzed by XRD. Abrasive wear resistances of coatings were carried out on wet sand rubber wheel abrasion tester. The characterizations of spraying feedstock powders, microstructure and surface micrographs of the prophase, and anaphase attrition surfaces were performed by SEM. The results indicated the multimodal coating shows slight higher microhardness and better abrasive wear resistance than the conventional counterpart. Also, the thermally sprayed carbide-based coatings have excellent wear resistance with respect to the hard chrome coatings. © 2009 Elsevier Ltd. All rights reserved.

Q. Wang, Z.H. Chen, and Z.X. Ding, College of Materials Science and Engineering, Hunan University, Changsha, Hunan 410082, China. Cited: *Tribol. Int.*, 42(7), July 2009, p 1046-1051. ISSN 0301-679X.

**Performance of $Al_2O_3$-3%$TiO_2$ detonation gun coated ferritic steels in coal fired boiler.** Alumina-titania coatings were obtained by detonation gun thermal spray process on ferritic steels namely T11 (1Cr 0.5Mo steel ASTM-SA213-T-11) and T22 (2.25Cr 1Mo steel ASTM-SA 213-T-22) and were evaluated for their performance inside the running boiler of a thermal power plant. In D-gun process, particle velocity is extremely high which may be effective in increased interlocking between particles and thus highest possible density. Homogeneous and dense coatings performed well and were found to provide adequate protection to the substrate steels. © 2009, Inderscience Publishers.

P.K. Sapra, S. Singh, S. Prakash, and N. Arivazhagan, Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Roorkee, Uttranchal, 247667, India. Cited: *Int. J. Surf. Sci. Eng.*, **3**(1-2), p 145-156. ISSN 1749-785X.

**Rolling contact fatigue mechanism of a plasma-sprayed and laser-remelted Ni alloy coating.** The rolling contact fatigue behavior of the plasma-sprayed and laser-remelted Ni-Cr-B-Si alloy coatings under two different tribological conditions of contact pressure was investigated. Two sets of fatigue-life data of coatings were characterized by Weibull distributions. The failure mode of the coatings was identified on the basis of worn morphologies as observed at the surfaces of the failed coatings. The tribological mechanism leading to the formation of the fatigue spall was discussed on the basis of the subsurface morphologies observed in the failed coating. Experimental results showed that the mean life and characteristic life of the coating decreased with increasing the contact pressure. The failure of the coatings can be termed as spalling-type failure. A refined 'ring-crack model' was proposed to explain the formation of the fatigue spall. In the refined model, it was postulated that the joining of the ring-type cracks and subsurface branched cracks was directly responsible for the spall formation. © 2009 Blackwell Publishing.

X.C. Zhang, B.S. Xu, S.T. Tu, F.Z. Xuan, Y.K. Zhang, H.D. Wang, and Y.X. Wu, Laboratory of Laser Materials Processing and Modification, Shanghai Jiao Tong University, Shanghai 200030, China. Cited: *Fatigue Fract. Eng. Mater. Struct.*, **32**(2), p 84-96. ISSN 8756-758X.

**Stress rupture behavior of a thermal barrier coated AE 437A Ni-based superalloy used for aero turbine blades.** The stress rupture characteristics of bare and thermal barrier coated (TBC) superalloy AE 437A were determined in air at temperatures between 600 and 850 °C with both short- and long-term testing undertaken at 800 °C. Because the bond coat contributed an addition [similar to] 10% cross-sectional area and was able to support load, the higher stress, shorter term rupture lives of the TBC-coated alloy exceed those for the bare material. However under lower stress, longer life conditions the ability of the bond coat to support loading was reduced, and the rupture lives of both bare and TBC-coated alloy were similar. © 2009 Elsevier B.V. All rights reserved.

A.K. Ray and J.D. Whittenberger, Materials Science and Technology Division, National Metallurgical Laboratory (Council of Scientific and Industrial Research), Jamshedpur, 831007, India. Cited: *Mater. Sci. Eng. A*, 2009, May 25, **509**(1-2), p 111-114. ISSN 0921-5093.

**Study on the tribological properties of low-power plasma-sprayed Al-Cu-Cr quasicrystalline coating.** Al-Cu-Cr quasicrystalline coatings were prepared by low power plasma spraying with axially fed powder system. The $Al_{65}Cu_{20}Cr_{15}$ powders were deposited on AISI 1045 steel substrate at the power ranged from 4.0 to 5.5 kW. The effects of $H_2$/Ar flow ratio on the phase composition, microstructure and tribological properties of the as-sprayed coatings were investigated. The XRD results showed that the feedstock powders and as-sprayed coatings contained a predominant icosahedral quasicrystalline phase I-$Al_{65}Cu_{24}Cr_{11}$ and three minor crystalline phases, including a body-centered cubic α-$Al_{69}Cu_{18}Cr_{13}$, a monoclinic θ-$Al_{13}Cr_2$ (i.e., $Al_{83}Cu_4Cr_{13}$) and a hexagonal ε-$Al_2Cu_3$. A qualitative analysis on the XRD patterns indicated that the volume fraction of any crystalline phase (α, ε, or θ) in the coatings increased, while the quasicrystalline I-phase decreased with the rise of hydrogen ($H_2$) content in the working gas. However, as increasing the plasma power, the friction and wear resistance of the coating were improved under the same dry sliding wear test conditions. The improvement of the wear resistance may be attributed to the high hardness of quasicrystal. © (2009) Trans Tech Publications, Switzerland.

Y. Fu, F. Zhou, D. Yang, N. Li, and Y. Gao, Department of Materials Science and Engineering, Dalian Maritime University, Dalian, 116026, China. Cited: *Materials Science Forum* (Conf. Proc.) Jun 9-12 2008 (Chongqing), Vol. 610-613, Trans Tech Publications Ltd., 2009, ISSN 0255-5476.

**The role of nozzle diameter on the microstructure and abrasion wear resistance of plasma sprayed $Al_2O_3/TiO_2$ composite coatings.** $Al_2O_3$-50 wt.% $TiO_2$ composite coatings were sprayed on a mild steel substrate by using Bay State Plasma spraying and SC-series plasma systems. Oxygen was used as a carrier gas for the feedstock powder during spraying with a Bay State Plasma gun to reduce the extent of reduction of alumina and titania (extraction of oxygen) in the high plasma jet temperature and provide higher heating energy to the particles in the plasma jet. The powder was injected internally into the plasma jet. The influence of nozzle diameter on

the coating properties was studied. The interior diameter of the Bay State plasma gun (PG-series) nozzle (anode) was ~7.5 mm and it was increased to 8 mm by a mechanical drilling process. $Al_2O_3/TiO_2$ composite coatings were deposited with the two different nozzle diameters. The microstructure and mechanical properties Of $Al_2O_3/TiO_2$ composite coatings were evaluated. The results showed that the nozzle diameter greatly affected the microstructure and mechanical properties of the composite coatings. Sprayed coatings with a smaller nozzle showed high hardness, low porosity, and high abrasion resistance. Moreover, the $Al_2O_3/TiO_2$ composite coatings sprayed with the Day State Plasma system showed better mechanical properties than $Al_2O_3/TiO_2$ coatings sprayed by a SG-series gun. © 2008 The Society of Manufacturing Engineers. Published by Elsevier Ltd. All rights reserved.

M.F. Morks and K. Akimoto, Central Metallurgical Research and Development Institute, Helwan El-Tibben, Cairo, Egypt. Cited: *J. Manuf. Process.*, **10**(1), p 1-5. ISSN 1526-6125.

**Young`s moduli of cold and vacuum plasma sprayed metallic coatings.** Monolithic metallic copper alloy and NiCrAlY coatings were fabricated by either the cold spray (CS) or the vacuum plasma spray (VPS) deposition processes. Dynamic elastic modulus property measurements were conducted on these monolithic coating specimens between 300 and 1273 K using the impulse excitation technique. The Young's moduli decreased almost linearly with increasing temperature at all temperatures except in the case of the CS Cu-23%Cr-5%Al and VPS NiCrAlY, where deviations from linearity were observed above a critical temperature. It was observed that the Young's moduli for VPS Cu-8%Cr were larger than the literature data compiled for Cu. The addition of 1%Al to Cu-8%Cr significantly increased its Young's modulus by 12-17% presumably due to a solid solution effect. Comparisons of the Young's moduli data between two different measurements on the same CS Cu-23%Cr-5%Al specimen revealed that the values measured in the first run were about 10% higher than those in the second run. It is suggested that this observation is due to annealing of the initial cold work microstructure resulting form the cold spray deposition process.

S.V. Raj, R. Pawlik, and W. Loewenthal, NASA Glenn Research Center, Cleveland, OH 44135. Cited: *Mater. Sci. Eng. A*, 2009, Jul 15, **513-514**(C), p 59-63. ISSN 0921-5093.

### *Oxidation*

**Cyclic oxidation of Pt/Pd-modified aluminide coating on a nickel-based superalloy at 1150 °C.** Pt-, Pd-, and Pt/Pd-modified aluminide coatings were prepared on Inconel 738LC by pack aluminizing at 1034 °C. During pack aluminizing, Pt-modified aluminide coating formed a two-phase β-NiAl + $PtAl_2$ layer and a β-NiAl layer on an interdiffusion zone, whereas Pd- and Pt/Pd-modified aluminide coatings formed only the thicker β-NiAl layer. However, Pd-modified aluminide coating had many pores. During cyclic oxidation, Pt/Pd-modified aluminide coating had a surface that was less rumpled than that of Pt-modified aluminide coating due to its thicker thickness. Pt/Pd-modified aluminide coating had a 22% greater Al-uptake than Pt-modified aluminide coating. Cyclic oxidation tests at 1150 °C showed that Pt/Pd-modified aluminide coating had the best cyclic oxidation resistance. After the cyclic oxidation, an additional γ-Ni phase was seen beneath the outermost alumina scale on the γ′-$Ni_3Al$ phase in Pt/Pd-modified aluminide coating. The γ′-Ni phase, which had a higher Cr content, increased the adhesion and stability of the alumina. © 2008 Elsevier Ltd. All rights reserved.

S.J. Hong, G.H. Hwang, W.K. Han, and S.G. Kang, Division of materials science and engineering, Hanyang University, Seoul, 133-791, South Korea. Cited: *Intermetallics,* **17**(6), June 2009, p 381-386. ISSN 0966-9795.

**High temperature oxidation behavior of nanostructured Ni-Al coatings on superalloy.** The high temperature oxidation behavior of magnetron sputtered Ni-Al coatings on the superalloy substrate has been studied in the present work. The microstructural and morphological features of Ni-Al coatings were characterized by FE-SEM, AFM, and XRD. Thermo gravimetric technique was used to investigate the oxidation behavior of the coatings, in air at 900 °C. The growth kinetics of oxide layers was predicted from the weight changes of the coating samples measured during oxidation. It was found that the corrosion rate of nanostructured Ni-Al coated superalloy was lower than that of the uncoated superalloy due to the formation of continuous, dense, adherent, and protective oxide scale over the surface of the coatings. The morphological features and phases of the corroded coatings were used to elucidate the mechanism of high temperature oxidation. A continuous thin layer of protective oxide films such as NiO and $Al_2O_3$ has formed over the Ni-Al coatings exposed to air at high temperature, 900 °C. © 2008 Elsevier B.V. All rights reserved.

A. Rahman, R. Jayaganthan, S. Prakash, V. Chawla, and R. Chandra, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Roorkee, Roorkee, 247667, India. Cited: *J. Alloy Compd.*, **472**(1-2), March 20, 2009, p 478-483. ISSN 0925-8388.

**High-temperature oxidation studies of cold-sprayed Ni-20Cr and Ni-50Cr coatings on SAE 213-T22 boiler steel.** The high-temperature oxidation behavior of cold-sprayed Ni-20Cr and Ni-50Cr coatings on SAE 213-T22 boiler steel has been investigated at 900 °C in air under cyclic heating and cooling conditions for 50 cycles. The kinetics of oxidation of coated and bare boiler steel has been established with the help of weight change measurements. It was observed that all the coated and bare steels obeyed parabolic rate law of oxidation. X-ray diffraction, FE-SEM/EDAX, and x-ray mapping techniques were used to analyse the oxidation products of the coated and uncoated boiler steel. The uncoated steel suffered corrosion in the form of intense spalling and peeling of its oxide scale, which was perhaps due to the formation of unprotective $Fe_2O_3$ oxide scale. Both the coatings showed better resistance to the air oxidation as compared to the uncoated steel. The Ni-50Cr coating was found to be more protective than the Ni-20Cr-coated steel. The formation of oxides and spinels of nickel and chromium may be contributing to the development of air oxidation resistance in the coatings. © 2009 Elsevier B.V. All rights reserved.

N. Bala, H. Singh, and S. Prakash, Baba Banda Singh Bahadur Engineering College, Fatehgarh Sahib, Punjab 140407, India. Cited: *Appl. Surf. Sci.*, **255**(15), May 15 2009, p 6862-6869. ISSN 0169-4332.

### *Thermal*

**Thermal conductivity of AlSi/polyester abradable coatings.** Abradable seals are used in aerospace applications to control the overtip leakages between the blades of an engine rotor and its static parts. To achieve the combination of properties required, these seals have been developed with thermally sprayed coatings and are generally elaborated from a range of two or three phase powder mixtures. In the present study, the thermal conductivity of thermally sprayed AlSi/Polyester abradable coatings produced with Metco 601 NS and Durabrade 1605 powders was measured and investigated using finite element and finite difference methods based on two-dimensional structures obtained from micrographs. The computed values were compared to the experimental results.

R. Bolot, J.-L. Seichepine, F. Vucko, C. Coddet, S. Dieter, F. Petr, and B. Brent, University of Technology, Belfort-Montbeliard, France. Cited: *Weld. Cut.*, **8**(2), p 104-109. ISSN 1612-3433.

## Review

**Anticorrosive coatings: a review.** The main objective of this review is to describe some of the important topics related to the use of marine and protective coatings for anticorrosive purposes. In this context, 'protective' refers to coatings for containers, offshore constructions, wind turbines, storage tanks, bridges, rail cars, and petrochemical plants while 'marine' refers to coatings for ballast tanks, cargo holds and cargo tanks, decks, and engine rooms on ships. The review aims at providing a thorough picture of state-of-the-art in anticorrosive coatings systems. International and national legislation aiming at reducing the emission of volatile organic compounds (VOCs) have caused significant changes in the anticorrosive coating industry. The requirement for new VOC-compliant coating technologies means that coating manufacturers can no longer rely on the extensive track record of their time-served products to convince consumers of their suitability for use. An important aspect in the development of new VOC-compliant, high-performance anticorrosive coating systems is a thorough knowledge of the components in anticorrosive coatings, their interactions, their advantages and limitations, as well as a detailed knowledge on the failure modes of anticorrosive coatings. This review, which mainly deals with European experience and practice, includes a description of the different environments an anticorrosive coating system may encounter during service. In addition, examples of test methods and standards for determination of the performance and durability of anticorrosive coatings have been included. The different types of anticorrosive coatings are presented, and the most widely applied generic types of binders and pigments in anticorrosive coatings are listed and described. Furthermore, the protective mechanisms of barrier, sacrificial, and inhibitive coatings are outlined. In the past decades, several alternatives to organic solvent-borne coatings have reached the commercial market. This review also presents some of these technologies and discusses some of their advantages and limitations. Finally, some of the mechanisms leading to degradation and failure of organic coating systems are described, and the reported types of adhesion loss are discussed. © 2008 FSCT and OCCA.

P.A. Sorensen, S. Kiil, K. Dam-Johansen, and C.E. Weinell, Department of Chemical and Biochemical Engineering, Technical University of Denmark, Building 229, Lyngby DK-2800 Kgs, Denmark. Cited: *J. Coat. Technol. Res.*, 2009, June, **6**(2), p 135-176. ISSN 1547-0091.

**Overview of structure and properties of high-pressure and low-pressure cold-sprayed coatings.** Cold spraying is a new thermal spray process enabling the production of metallic and composite coatings with low porosity and low oxygen content. Such coatings are attractive for use in applications requiring, e.g., corrosion resistance and electrical conductivity. The aim of this study is to characterize the structural and mechanical properties of HPCS and LPCS coatings. HPCS Ta, Ni, and Cu coatings showed a uniformly dense

structure; however, HPCS Ni20Cr and LPCS $Cu + Al_2O_3$ coatings contained through-porosity according to corrosion tests. Furthermore, LALPCS (laser assistance) showed a significant denseness improvement of the $Cu + Al_2O_3$ coating.

H. Koivuluoto, M. Kotilainen, and P. Vuoristo, Tampere University of Technology, Department of Materials Science, Tampere, FIN. Cited: *Weld. Cut.*, **8**(2), p 98-103. ISSN 1612-3433.

**Thermal spray research activities at Xi'an Jiaotong University.** The Xi'an Jiaotong University (XJTU) have thermal spray researches that focuses on the understanding of thermal spray coating formation mechanisms. These mechanisms include splat formation with the use of spray particles in different states, the quantitative characterization of lamellar structure of plasma spray coatings, and the establishment of the relationships between coating microstructure and properties. In addition, several developments were done with regards to the high performance of thermal barrier coatings, the wear-resistant super-hard cermet coatings and the functional coatings that are both applicable to solid oxide fuel cells and dye-sensitized solar cells.

C.-J. Li, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, China. Cited: *Adv. Mater. Process.*, 2009, Feb, **167**(2), p 58-61. ISSN 0882-7958.

**What makes a good $TiO_2$ photocatalyst?** Titanium dioxide photocatalysis is an area which has witnessed an enormous progress during the past three decades. Applications of $TiO_2$ photocatalysis include environmental remediation, self-cleaning coatings, and is also at the heart of $TiO_2$ based energy production ($H_2$ and electricity). Despite an enormous literature a comprehensive understanding of the surface reaction steps on $TiO_2$ is still lacking. This reflects both the complex nature of photocatalytic processes and the difficulties of studying nanoparticles. In this paper, we present examples from combined in situ molecular spectroscopy studies that highlight the dependence of surface reactions on the structure of $TiO_2$ nanoparticles. We show that for a broad class of organic molecules the reactivity is governed mainly by the bonding and reactivity of a few common intermediate species. The photocatalytic efficiency is correlated with the particle structure and elementary surface reactions steps. We show that $\mu$-formate is a common intermediate that control the overall photo-degradation rate of propane, ketones, and carboxylic acid on rutile $TiO_2$. In contrast, on anatase $TiO_2$ photo-oxidation of acetone is rate determining. This shows that the reactivity of $TiO_2$ is sensitive to both surface modification and reactant molecule. Furthermore, the photo-oxidation rate of formic acid depends on the detailed anatase surface properties. This is attributed to a balance of formate bonded to coordinately unsaturated surface (c.u.s.) Ti atoms and hydrogen bonded molecules due the different bonding strength of formate on c.u.s. sites present on different crystal facets and defects. Ways to improve the surface reactivity of $TiO_2$ nanoparticles are discussed.

L. Osterlund, A. Mattsson, and P.O. Andersson, FOI SE-901 82, Umea, Sweden. Cited: *Ceramic Engineering and Science Proceedings* (Conf. Proc.) Jan 27-Feb 1 2008 (Daytona Beach, FL), 2009, Vol. 29, American Ceramic Society. ISSN 0196-6219.