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Selected Abstracts of Thermal Spray Literature

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Applications

Art and Architecture

Novel thermal spray technique plants the seed of artistic creativity. Thermal spraying, a widely used industrial process, has evolved as a viable tool for the architectural fabrication and for all artistic creations ranging from murals to sculptures. Thermal spraying as an enhanced finishing technique efficiently eliminates the unsightly corrosion and rusting that unavoidably attacks carbon steel during industrial finishes, and also saves cost of maintenance painting. An improved feature of proposed process as a subordinate to architectural fabrication is coating a less expensive material, such as carbon steel, with copper and bronze to achieve corrosion protection and a large improvement in appearance. A newly patented technique from Bauer Fabrication is Bauer Art Metal (BAM) that involves thermal spraying any metal into the wire mesh to build free standing objects. The techniques is effective for fabricating materials ranging from bronze fountain bowls, art murals, tiles, and signage to large outdoor sculptures and memorials. (Edited abstract)

E.C. Bauer, Bauer Fabrication. Cited: *Welding J. (Miami, FL),* 2008, November, **87**(11), p 80-81. ISSN 0043-2296.

Automotive

Impact of thermal barrier coating application on the performance and emissions of a turbocharged diesel engine. In this study, the effect of thermal-barrier-coated piston top and combustion chamber surfaces on turbocharged diesel engine performance was experimentally investigated. Satisfactory performance was obtained with TBC_1 (with coated cylinder head and valves) and TBC_2 (with coated cylinder head, piston top, and valves). Compared with a standard diesel engine, engine power was increased by 2%, the engine torque was increased by 1.5-2.5%, and brake specific fuel consumption (b.s.f.c.) was decreased by 4.5-9%. The NO_x emissions were increased by 10% in diesel engines with TBC coatings compared with a standard diesel engine. Experimental studies have shown that there is a reduction in smoke emissions of up to 18% as a result of TBC application. Copyright: IMechE 2008.

M. Ciniviz, C. Hasimoglu, F. Sahin, and M.S. Salman, Faculty of Technical Education, Institute of the Natural and Applied Sciences, Alaeddin Keykubat Campus, Konya,Turkey. Cited: *Proc. Instit. Mech. Eng. D: J. Automobile Eng.*, **222**(12), p 2447-2455. ISSN 0954-4070.

Biomaterials and Bioactive Materials

A new era in porous metals: applications in orthopaedics. The development of porous metals and coatings has revolutionized the field of orthopaedics. However, most implants are fabricated utilizing traditional materials (i.e. sintered beads, metal, plasma spray), which have several inherent limitations. Several new porous metals have been recently introduced to improve upon the biomaterial properties of these traditional metals. Tritanium (Stryker, Mahwah, NJ), Regenerex (Biomet, Warsaw, IN), Stiktite (Smith and Nephew, Memphis, TN), and Trabecular Metal (Zimmer, Warsaw, IN) are currently available for use in orthopaedic surgery, all with a characteristic appearance similar to cancellous bone. The open-cell structure of these materials affords several intriguing properties, including; high volumetric porosity (60-80%), low modulus of elasticity, and high frictional characteristics. The following represents a review of the biomaterial properties and applications in orthopaedic surgery for this new class of highly porous metals. Copyright: 2008 WILEY-VCH Verlag GmbH and Co. KGaA.

B. Levine, Midwest Orthopaedics at Rush, Chicago, IL 60612. Cited: *Adv. Eng. Mater.*, 2008, September, **10**(9), p 788-792. ISSN 1438-1656.

Coating of TiO_2 thin films on the surface of SiO_2 microspheres: toward industrial photocatalysis. A core/shell SiO_2/TiO_2 photocatalyst was prepared using a liquid-phase deposition (LPD) method. Zeta-potential measurement showed that deposition of a layer of polyelectrolyte on the surface of SiO microspheres was a prerequisite for subsequent deposition of the TiO_2 shell with a controllable and uniform thickness. The photocatalytic activity of the core/shell SiO_2/TiO_2 catalyst for decomposition of Orange II in liquid phase was observed to be comparable with that of P25 (a commercial TiO_2 product of Degussa). Experimental data also showed that the SiO_2/TiO_2 core/shell nanostructured photocatalyst can be easily separated from the reaction medium by sedimentation, and the solid can be recycled and reused. Thus, the photocatalyst described in this work represents a new catalyst system with a high potential for practical applications in treating wastewater. Copyright: 2008 American Chemical Society.

G. Li, R. Bai, and X.S. Zhao, Department of Chemical and Biomolecular Engineering, National University of Singapore, Singapore 117576, Singapore. Cited: *Ind. Eng. Chem. Res.*, 2008, Nov 5, **47**(21), p 8228-8232. ISSN 0888-5885.

Formation of double-walled TiO_2 nanotubes and robust anatase membranes. The formation of double-walled TiO_2 nanotubes, tube wall separation was reported, that demonstrated that the tube layers can be converted to an ordered TiO_2 nanoporous membrane by a simple, but optimized rapid thermal annealing process. Titanium sheets were sonicated in acetone and methanol, followed by rinsing with deionized (DI) water and drying the samples in a nitrogen stream. The electrolytes were prepared from ethylene glycol containing less than 0.2 wt.%, with addition of 0.2 M HF, and 0.12 M H_2O_2. The voltage was ramped from open circuit potential of 120 V for 2 h. Thermal treatments of the nanotube layers were carried out in air using a Rapid Thermal Annealer at different temperatures. Highly ordered porous oxide layers sow excellent mechanical stability, particularly compared to any sort of previously produced layers. (Edited abstract)

S.P. Albu, A. Ghicov, S. Aldabergenova, P. Drechsel, D. Leclere, G.E. Thompson, J.M. Macak, and P. Schmuki, Department of Materials Science, WW4-LKO, University of Erlangen-Nuremberg,91058 Erlangen, Germany. Cited: *Adv. Mater.*, 2008, Nov 3, **20**(21), p 4135-4139. ISSN 0935-9648.

In vitro behavior of titania-hydroxyapatite functionally graded coatings. The in vitro behaviour of titania-hydroxyapatite graded coatings obtained by plasma spraying was investigated by a microstructural and mechanical point of view. To verify the bioactivity of the graded coatings, as sprayed and after thermal treatment, in vitro tests were performed in simulated body fluid. Furthermore, since the mechanical properties of the coatings may be altered by the immersion in simulated body fluid, the local elastic properties were measured on the cross-section by means of a depth sensing Vickers microindentation technique before immersion (reference materials) and after soaking for 1 week (short term response) and 4 weeks (long term response), separately investigating the titania and the hydroxyapatite rich zones to account for the compositional gradient. The results proved that the presence of titania in the coating did not suppress the bioactivity, which, on the contrary, was inhibited by the heat treatment. However, the heat treated samples showed higher mechanical properties and reduced dissolution rates. Copyright: 2008 Institute of Materials, Minerals and Mining.

V. Cannillo, L. Lusvarghi, F. Pierli, and A. Sola, Dipartimento di Ingegneria dei Materiali e dell'Ambiente, Universita di Modena e Reggio Emilia, Modena 41100, Italy. Cited: *Adv. Appl. Ceram.*, **107**(5), p 259-267. ISSN 1743-6753.

Photocatalytic activity of oxide coatings on fired clay substrates. The coating of fired clay substrates with various metal oxides, such as anatase, rutile, zinc oxide and tin oxide was achieved using a simple spraying technique followed by a thermal treatment. The photocatalytic activity of the layer was characterized through measurement of the absorption spectrum, in the range 400-800 nm, of methylene blue deposited on top of the coating. Results show that the presence of anatase enhances the degradation of methylene blue when it is exposed to ultraviolet light. Thermal treatment at 1050 °C transforms anatase crystals into thermodynamically stable rutile. This results in a decrease of the photocatalytic activity, which can be explained by increase of the grain size and by a difference in the crystal structure. Measurements of the photocatalytic activity of ZnO and SnO_2 show that these two oxides also exhibit photocatalytic properties. In particular, ZnO is a promising alternative material to anatase. Copyright: 2008 Elsevier Ltd. All rights reserved.

M. Fassier, N. Chouard, C.S. Peyratout, D.S. Smith, H. Riegler, D.G. Kurth, C. Ducroquetz, and M.A. Bruneaux, Groupe d'Etude des Materiaux Heterogenes, Ecole Nationale Superieure de Ceramique Industrielle, 87065 Limoges, Cedex, France. Cited: *J. Eur. Ceram. Soc.*, 2009, March, **29**(4), p 565-570. ISSN 0955-2219.

Photocatalytic TiO_2 on copper alloy for antimicrobial purposes. Photocatalytic titanium dioxide (TiO_2) has been developed and extensively applied due to its non-toxicity, high catalytic activity, and strong self-cleaning characteristics. The present study employs an arc ion plating technique to deposit a strongly adhered photocatalytic TiO_2 coating onto bare Cu-35Zn substrate, which is commonly used in sanitary wares. The present report aims to create a TiO_2 coating with antimicrobial function and satisfactory mechanical properties.

The results indicate that arc ion plating can successfully deposit TiO_2 onto brass substrates that are precoated with Ni/Cr. The cross-sectional morphology of TiO_2 coating shows a fine and dense columnar structure of anatase with a growth rate of 5 μm/h. The surface microhardness of the specimen deposited with TiO_2 coating is 351.9 HV. The adhesive force of the coating is satisfactory with a critical load of 20.38 N and its wear resistance is far better than that of the brass substrate and Ni/Cr-precoated specimen. The coating's wear index obtained from a Taber test is 0.26. TiO_2 coatings can act as an ideal passive film and thereby shows a high corrosion potential and low corrosion current in aqueous sodium chloride. The photocatalytic effect of anatase TiO_2 will be activated under the incident light with energy greater than the band gap energy E_g, of TiO_2 (3.2 eV, 387.5 nm), thereby providing antimicrobial function. In general, the Ni/Cr-precoated specimen incorporated with a photocatalytic TiO_2 film can provide sufficient protective and antimicrobial functions to its substrate, rendering it highly feasible for commercial use. Copyright: 2008 Elsevier B.V. All rights reserved.

C.-J. Chung, C.-C. Chiang, C.-H. Chen, C.-H. Hsiao, H.-I. Lin, P.-Y. Hsieh, and J.-L. He, Department of Materials Science and Engineering, Feng Chia University, Taichung, 40724 Taiwan. Cited: *Appl. Catal. B: Environ.*, 2008, Dec 17, **85**(1-2), p 103-108. ISSN 0926-3373.

Plasma spray of free-standing components for bone tissue engineering. This research work deals with the development of free-standing hydroxyapatite (HA) components produced using the Atmospheric Plasma Spraying Process. The spray parameters were based on the optimal values found in previous work for the HA powder used. The deposition time used to produce the free-standing coupons was varied between 70 and 150 s. The influence of spray time on the deposit thickness and the resulting crystallinity of the coupons were investigated. The surface of the samples was characterized by means of SEM and surface roughness was measured using a laser profiler. The crystallinity of the samples was analysed using XRD. The phase content of the coupons was investigated using XRD and Raman Spectroscopy. The crystallinity and thickness of the coupons was found to increase with increasing spray time. A maximum crystallinity of 89% and maximum average thickness of 2.45 mm were obtained.

D. Garcia-Alonso, T. Levingstone, M. Parco, and J. Stokes, Materials Processing Research Centre, National Centre of Plasma Science and Technology, Dublin City University, Dublin, Ireland. Cited: *Key Eng. Mater.*, **396-398**(2009), p 695-698. ISSN 1013-9826.

Plasma-sprayed $CaTiSiO_5$ ceramic coating on Ti-6Al-4V with excellent bonding strength, stability and cellular bioactivity. Novel Ca-Si-Ti-based sphene ($CaTiSiO_5$) ceramics possess excellent chemical stability and cytocompatibility. The aim of this study was to prepare sphene coating on titanium alloy (Ti-6Al-4V) for orthopaedic applications using the plasma spray method. The phase composition, surface and interface microstructure, coating thickness, surface roughness and bonding strength of the plasma-sprayed sphene coating were analysed using x-ray diffraction, scanning electron microscopy, atomic force microscopy and the standard mechanical testing of the American Society for Testing and Materials, respectively. The results indicated that sphene coating was obtained with a uniform and dense microstructure at the interface of the Ti-6Al-4V surface and the thickness and surface roughness of the coating were approximately 150 and 10 μm, respectively. Plasma-sprayed sphene coating on Ti-6Al-4V possessed a significantly improved bonding strength and chemical stability compared with plasma-sprayed hydroxyapatite (HAp) coating. Plasma-sprayed sphene coating supported human osteoblast-like cell (HOB) attachment and significantly enhanced HOB proliferation and differentiation compared with plasma-sprayed HAp coating and uncoated Ti-6Al-4V. Taken together, plasma-sprayed sphene coating on Ti-6Al-4V possessed excellent bonding strength, chemical stability and cellular bioactivity, indicating its potential application for orthopaedic implants. Copyright: 2008 The Royal Society.

C. Wu, Y. Ramaswamy, X. Liu, G. Wang, and H. Zreiqat, Biomaterials and Tissue Engineering Research Unit, School of AMME, University of Sydney, Sydney, NSW 2006, Australia. Cited: *J. Roy. Soc. Interf.*, 2009, Feb 6, **6**(1), p 159-168. ISSN 1742-5689.

Preparation of porous TiO_2Ti composite membrane for immunoisolation. The TiO_2 membrane supported on porous Ti planar can be used as a kind of alternative material of immunoisolation membranes, which are presently prepared by polymeric materials, in order to overcome defects of conventional immunoisolation membranes. The composite membranes were prepared by sol-gel technique with tetrabutyl titanate and the withdrawal velocity was 4 mm/s. The circle of 'dip-coating-sintering' must be repeated five times. The retention rate of proteins and flux of glucose were used to evaluate the effect of immunoisolation. The result showed that the membranes, which were sintered under 700 °C, could completely retain the proteins with molecular weight over 156 kDa and the retention rate of BSA exceeded 85%. At the same time, the glucose and proteins, whose molecular weight were under 45 kDa, could all freely pass the membranes according to the concentration difference of both sides. However, the retention rate of proteins first increased and subsequently decreased with the increase of sintering temperature. The membranes, which were sintered at 600 °C, retained more proteins than the membranes sintered at other temperatures. So a better sintering temperature, which can be used as immunoisolation membrane, is about 600 °C. Copyright: 2008 Elsevier B.V. All rights reserved.

Z. Minjing, L. Gang, W. Qiang, C. Hualei, and L. Ling, School of Precision Instrument and Opto-electronics Engineering, Tianjin University, 300072 China. Cited: *Appl. Surf. Sci.*, 2008, Dec 30, **255**(5 PART 1), p 2256-2258. ISSN 0169-4332.

Structure, mechanical performance and electrochemical characterization of plasma sprayed SiO_2Ti-reinforced hydroxyapatite biomedical coatings. For achieving an excellent bioactivity and mechanical properties, silica and titanium-reinforced hydroxyapatite composite coatings were deposited onto 304 SUS substrate by using a gas-tunnel plasma spraying system. A commercial HA powder of average size 10-45 μm was blended with fused amorphous silica and titanium powders with HA:SiO_2:Ti wt.% ratios of 75:15:10, respectively. The mixed powders have been plasma sprayed at various plasma gas flow rates (Ar) of 120, 140, 160 and 170 l/min. The morphologies and structure of the resulting coatings were investigated by scanning electron microscope, x-ray diffraction and electron dispersive spectroscopy. Hardness, abrasive wear resistance and adhesive bonding strength properties of the as-sprayed composite coatings were investigated. Silica and titanium provide reinforcement via increasing the bonding strength of HA particles and abrasion resistance. A heat treatment for the sprayed coatings was carried out at a temperature of 650 °C for 2 h in ambient oxygen and the change in the phase structure was analysed by x-ray diffraction. The results showed a formation of TiO_2 (rutile) phase due to titanium oxidation at 650 °C. On the other hand, the heat treatment enhanced the crystallinity of HA coating by transferring the non-apatite tri-calcium phosphate phase into apatite phase. The corrosion resistance measurement by polarization method confirmed the improvement of corrosion resistance of the composite HA/SiO_2/Ti coatings compared with the pure HA. However, the annealed samples showed lower corrosion resistance compared with as-sprayed samples. Copyright: 2008 Elsevier B.V. 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: *Appl. Surf. Sci.*, 2008, Dec 30, **255**(5 PART 2), p 3426-3433. ISSN 0169-4332.

Surface characterization and electrochemical behavior of porous titanium dioxide coated 316L stainless steel for orthopaedic applications. Porous titanium dioxide was coated on surgical grade 316L stainless steel (SS) and its role on the corrosion protection and enhanced biocompatibility of the materials was studied. X-ray diffraction analysis (XRD), atomic force microscopy (AFM), Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDAX) were carried out to characterize the surface morphology and also to understand the structure of the as synthesized coating on the substrates. The corrosion behavior of titanium dioxide coated samples in simulated body fluid was evaluated using polarization and impedance spectroscopy studies. The results reveal that the titanium dioxide coated 316L SS exhibit a higher corrosion resistance than the uncoated 316L SS. The titanium dioxide coated surface is porous, uniform and also it acts as a barrier layer to metallic substrate and the porous titanium dioxide coating induces the formation of hydroxyapatite layer on the metal surface. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Nagarajan and N. Rajendran, Department of Chemistry, Anna University, Chennai, 600 044 India. Cited: *Appl. Surf. Sci.*, 2009, Jan 15, **255**(7), p 3927-3932. ISSN 0169-4332.

Synthesis and characterization of bioactive and antibacterial glass-ceramic Part 2—Plasma spray coatings on metallic substrates. Plasma spray bioactive glass ceramic coatings on metallic substrates have been characterized and modified by a patented ion exchange process[1] in order to introduce silver ions onto their surface and confer antibacterial properties. Both treated and untreated materials have been analyzed by means of SEM, EDS and XRD in order to verify the amount of introduced silver, and also after immersion in simulated body fluid in order to investigate bioactivity. The amount of silver released in simulated body fluid has been quantified by means of graphite furnace atomic adsorption spectrophotometry analysis. Finally cellular and microbiological test have been performed in order to verify material biocompatibility and antibacterial behavior. Copyright: 2008 Institute of Materials, Minerals and Mining.

E. Verne, S. Ferraris, M. Miola, G. Fucale, G. Maina, P. Robotti, G. Bianchi, G. Martinassos, R.A. Canuto, and C. Vitale-Brovarone, Materials Science and Chemical Engineering Department, Politecnico di Torino, Torino, Italy. Cited: *Adv. Appl. Ceram.*, **107**(5), p 245-253. ISSN 1743-6753.

Energy

A nanophase oxygen storage material: alumina-coated metal-based ceria. Nanoparticles of $Ce_{1-x}M_cO_{3-\delta}$(M = Ca or Zr) coated with Al_2O_3 with average crystallite size of 10 nm have been synthesized via solution chemistry approach under controlled chemical and hydrodynamic conditions. Their synthesis has been accomplished in three major steps: (1) simultaneous co-precipitation of cations, (2) sequential precipitation of $Al(OH)_3$ over the

former particles, and (3) calcination of the precipitated precursors to the corresponding oxides. Several compositions have been synthesized and their physicochemical properties are compared with commercial state-of-the-art material. The Al_2O_3-coating hinders the particles growth at high temperatures, resulting in materials with a large specific surface area and a restrain in the decrease of their oxygen storage capacity. Copyright: 2008 Elsevier Ltd. All rights reserved.

O. Adamopoulos, E. Bjorkman, Y. Zhang, M. Muhammed, T. Bog, L. Mussmann, and E. Lox, Functional Materials Division, Nano Characterisation Centre, Department of Microelectronics and Applied Physics, S-164 40 Stockholm, Sweden. Cited: *J. Eur. Ceram. Soc.*, 2009, March, **29**(4), p 677-689. ISSN 0955-2219.

Application of thermally sprayed coatings of the type WC/CoCr in reverse osmosis processes for seawater desalination. Seawater desalination based on the reverse osmosis process requires a variety of hydraulic systems. The material concepts of these hydraulic systems are designed to reliably resist the corrosive properties of seawater and brine as well as the tribological loads. Strong tribological loads typically occur during the start-up and shutdown of multi-stage high-pressure pumps. Thermally sprayed coatings can be used to increase the wear resistance and also the tribological properties of bearings. Also in pressure exchangers for energy recovery, high tribological loads occur on the surfaces of rotors which operate with a clearance gap of 40-100 μm. Today, thermally sprayed coatings are used for the surface protection of these rotors. To resist the various tribological loads, the material pairs are optimized for each case. Thermally sprayed coatings with high surface hardness have proven to be particularly successful. A coating system, based on a CoCr matrix, has been developed especially for these applications. Copyright: 2008 WILEY-VCH Verlag GmbH and Co. KGaA.

A. Dwars, W. Kochanowski, B. Schramm, and F. Sehr, KSB Aktiengesellschaft, 67227 Frankenthal, Germany. Cited: *Mater. Corros.*, 2008, November, **59**(11), p 870-877. ISSN 0947-5117.

Degradation of free-standing air plasma sprayed CoNiCrAlY coatings by vanadium and phosphorus pentoxides. Use of alternative and/or low-cost fuels such as syngas, petcoke and coal/petcoke blend in gas turbine engines requires a thorough understanding in high temperature degradation of protective coatings. Deleterious combustion by-products can deposit, adhere, melt and degrade the protective coatings and underlying structural substrates. In this investigation, degradation of air plasma sprayed (APS) free-standing CoNiCrAlY coatings in contact with two different corrosive oxide contaminants, namely V_2O_5 and P_2O_5 were examined at high temperature. Different degradation mechanisms were observed from V_2O_5 melt interaction with CoNiCrAlY at 700 °C and 900 °C. At 700 °C, formation of chromium-aluminum orthovanadate $(Cr,Al)VO_4$ was observed with no evidence of severe degradation. However, at 900 °C, extensive dissolution of CoNiCrAlY constituents by V_2O_5 was found with reaction products such as nickel-cobalt orthovanadate $(Ni,Co_3(VO_4)_2$ and $(Ni,Co)(Al,Cr_2O_4$ spinel. Interaction of P_2O_5 melt with CoNiCrAlY at 350 °C for 2 h revealed the extensive consumption of constituents through formation of polyphosphate compounds such as $(Ni,Co)(PO_3)_2$ and $(Cr,Al)(PO_3)_3$. Copyright: 2008 Elsevier B.V. All rights reserved.

P. Mohan, T. Patterson, V.H. Desai, and Y.H. Sohn, Advanced Materials Processing and Analysis Centre (AMPAC), Department of Mechanical, Materials and Aerospace Engineering, University of Central Florida, Orlando, FL 32816. Cited: *Surf. Coat. Technol.*, 2008, Dec 25, **203**(5-6), p 427-431. ISSN 0257-8972.

Thermal Barrier Coatings

Cyclic behavior of EB-PVD thermal barrier coating systems with modified bond coats. The lifetime of thermal barrier coating (TBC) systems depends on substrate, bond coat, thermally grown oxide (TGO), and ceramic top coat. In the present paper NiPtAl bond coats as well as NiCoCrAlY(X) deposited by LPPS and EB-PVD (electron-beam physical vapor deposition) underneath conventional EB-PVD yttria stabilized zirconia top coats were investigated on three different substrate alloys. Several bond coat treatments such as polishing, annealing in vacuum, and grit blasting were employed in order to study effects on TBC life, and particularly the underlying mechanisms of TGO formation. Samples were thermally cycled at 1100 °C and partly at 1150 °C. Spallation of the TBCs is mainly correlated with TGO formation that is influenced by bond coat type and pre-treatment. The longest lifetimes were achieved on a novel Hf-doped EB-PVD NiCoCrAlY-X bond coat owing to a differing TGO formation and failure mechanism. Activation energies derived from lifetimes and test temperatures were calculated to identify key failure mechanisms within these complex coating systems. Copyright: 2008 Elsevier B.V. All rights reserved.

U. Schulz, K. Fritscher, and A. Ebach-Stahl, DLR-German Aerospace Center, Institute of Materials Research, 51170 Cologne, Germany. Cited: *Surf. Coat. Technol.*, 2008, Dec 25, **203**(5-6), p 449-455. ISSN 0257-8972.

Optical nondestructive condition monitoring of thermal barrier coatings. This paper describes recent developments of the thermal barrier sensor concept for nondestructive evaluation (NDE) of thermal barrier coatings (TBCs) and online condition monitoring in gas turbines. Increases in turbine inlet temperature in the pursuit of higher efficiency will make it necessary to improve or upgrade current thermal protection systems in gas turbines. As these become critical to safe operation, it will also be necessary to devise techniques for online condition monitoring and NDE. The authors have proposed thermal barrier sensor coatings (TBSCs) as a possible means of achieving NDE for TBCs. TBSCs are made by doping the ceramic material (currently yttria-stabilized zirconia (YSZ)) with a rare-earth activator to provide the coating with luminescence when excited with UV light. This paper describes the physics of the thermoluminescent response of such coatings and shows how this can be used to measure temperature. Calibration data are presented along with the results of comparative thermal cycle testing of TBSCs, produced using a production standard air plasma spray system. The latter show the durability of TBSCs to be similar to that of standard YSZ TBCs and indicate that the addition of the rare-earth dopant is not detrimental to the coating. Also discussed is the manufacture of functionally structured coatings with discreet doped layers. The temperature at the bond coat interface is important with respect to the life of the coating since it influences the growth rate of the thermally grown oxide layer, which in turn destabilizes the coating system as it becomes thicker. Experimental data are presented indicating that dual-layered TBSCs can be used to detect luminescence from, and thereby the temperature within, subsurface layers covered by as much as 500 μm of standard TBC material. A theoretical analysis of the data has allowed some preliminary calculations of the transmission properties of the overcoat to be made, and these suggest that it might be possible to observe phosphorescence and measure temperature through an overcoat layer of up to approximately 1.56 mm thickness. Copyright: 2008 by ASME.

A.L. Heyes, J.P. Feist, X. Chen, Z. Mutasim, and J.R. Nicholls, Department of Mechanical Engineering, Imperial College London, London SW7 2AZ, United Kingdom. Cited: *J. Eng. Gas Turbines Power,* 2008, November, **130**(6). ISSN 0742-4795.

Oxide and TBC spallation in β-NiAl coated systems under mechanical loading. Thermal barrier coatings have been introduced in turbine blade technology to reduce surface temperature. But severe thermomechanical loading leads to TBC spallation and protection loss. In this work, damage localisation has been studied under thermo-mechanical solicitations on single crystal aluminide coated alloys, with and without TBC. Strong temperature dependencies have been observed for both systems. As expected, oxide spallation and TBC fracture appear to depend on the bond coat ability to accommodate strain mismatch between substrate and oxide layers. Strain triggers surface damage at low temperatures, whereas for high temperatures, bond coat relaxation slows the strain impact on damage, and modifies the rupture path. A kinematic multi-layer model has been proposed to explain the phenomenon. The substrate is assumed to impose mechanical strain to the other layers. Results are in agreement with experimental results. This work was undertaken by turbine manufacturer SNECMA (SAFRAN) and Mines ParisTech. Copyright: 2008 Elsevier B.V. All rights reserved.

M. Harvey, C. Courcier, V. Maurel, and L. Remy, SNECMA, Groupe SAFRAN, YQM 77550 Moissy-Cramayel, France. Cited: *Surf. Coat. Technol.*, 2008, Dec 25, **203**(5-6), p 432-436. ISSN 0257-8972.

Recent activities in the field of thermal barrier coatings including burner rig testing in the European union. Although thermal barrier coatings are used in industry for several decades there is still considerable demand for a further improvement of this coating system. Present research projects are for example dealing with the improvement of temperature capability and lifetime, developing of lifetime models, new processing technologies, or incorporating of additional functional properties in the coating. The present paper tries to give an overview on these recent research activities. In addition, it will also try to describe the different burner rig test facilities in Europe, which serve as an important test bed of thermal barrier coating systems. Copyright: 2008 WILEY-VCH Verlag GmbH and Co. KGaA.

R. Vaben, F. Cernuschi, G. Rizzi, A. Scrivani, N. Markocsan, L. Ostergren, A. Kloosterman, R. Mevrel, J. Feist, and J. Nicholls, IEF-1, Forschungszentrum Jiilich GmbH, 52425 Jiilich, Germany. Cited: *Adv. Eng. Mater.*, 2008, October, **10**(10), p 907-921. ISSN 1438-1656.

Sintering characteristics of plasma sprayed zirconia coatings containing different stabilizers. Zirconia powders with different types of stabilizer (Y_2O_3, Dy_2O_3 and Yb_2O_3) have been air plasma sprayed onto metallic substrates. The coatings were detached and dimensional changes during heat treatment were measured by dilatometry. Ytterbia-stabilized specimens exhibited the highest rates of shrinkage, in both in-plane and through-thickness directions. However, it was noted that these specimens had higher initial porosity levels, and a finer microstructure, than coatings containing the other stabilizers. In-plane stiffness and through-thickness thermal conductivity were also measured after different heat treatments. These increased at greater rates for specimens with higher porosity levels (i.e. the Yb-stabilized coatings). Changes in pore architecture during heat treatments were also studied. Fine scale porosity is rapidly reduced during heat treatment. This correlates with enhanced inter-splat bonding and healing of intra-splat microcracks. In general, the sintering behavior, and consequent changes in microstructure and

properties, appear to be more sensitive to the pore architecture than to stabilizer type. This is correlated with theoretical expectations that it is grain boundary and surface diffusion which will dominate the sintering behavior, rather than lattice diffusion, and these are more likely to be affected by pore structure, and possibly by the presence of certain types of impurity, than by stabilizer content. It is also noted that thermal cycling appears to retard sintering, at least in terms of the rate of shrinkage. This effect, which could be of practical significance, is briefly discussed. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Paul, A. Cipitria, S.A. Tsipas, and T.W. Clyne, Department of Materials Science and Metallurgy, Cambridge University, Cambridge, CB2 3QZ, United Kingdom. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1069-1074. ISSN 0257-8972.

Thermal cyclic lifetime and oxidation behavior of air plasma sprayed CoNiCrAlY bond coats for thermal barrier coatings. Furnace thermal cycling lifetime and microstructural degradation are reported for thermal barrier coatings (TBCs) with air plasma sprayed (APS) ZrO_2-8wt.%Y_2O_3 (YSZ) and APS CoNiCrAlY bond coats. TBCs examined in this study consisted of 600 μm-thick APS YSZ, 175 μm-thick APS CoNiCrAlYSi and 5 mm-thick Haynes 230 superalloy substrate. Furnace thermal cycling was carried out using 1-, 10- and 50-h thermal cycles that consisted of 10-min heat-up to 1121 °C, dwell at 1121 °C and followed by 10-min forced-air-quench. To further document microstructural degradation of APS CoNiCrAlY coatings, free-standing APS CoNiCrAlY coatings were produced and isothermally oxidized at 1124 °C for up to 300 h. Despite the significant internal oxidation of APS CoNiCrAlY bond coats, APS TBCs exhibited excellent thermal cycling lifetime. Microstructural evolution of TBCs with an emphasis on the development of thermally grown oxide including internal oxidation was examined by scanning electron microscopy, transmission electron microscopy (TEM) and scanning TEM. Site-specific TEM specimen was prepared by using Focus Ion Beam In situ Lift-out technique. Extensive internal oxidation was observed including formation of Al_2O_3, Al,Cr_2O_3, and (Ni,Co)Al,Cr_2O_4 identified by electron diffraction. Quantitative microscopy and a simple rule of mixture were employed to understand the excellent performance of these TBCs with APS CoNiCrAlY bond coats based on reduced thermal expansion mismatch. Copyright: 2008 Elsevier B.V. All rights reserved.

T. Patterson, A. Leon, B. Jayaraj, J. Liu, and Y.H. Sohn, Advanced Materials Processing and Analysis Center, Department of Mechanical, Materials and Aerospace Engineering, University of Central Florida, Orlando, FL 32816. Cited: *Surf. Coat. Technol.*, 2008, Dec 25, **203**(5-6), p 437-441. ISSN 0257-8972.

Measurement Methods

Characterization of heat and momentum transfer in sintered metal foams. In this study, metal foams made by the Slip Reaction Foam Sintering (SRFS)-process are investigated concerning their thermophysical and permeability properties. Since the foam is to be applied as a functional and structural element in the effusion air cooling system of a stationary gas turbine combustion chamber, these properties are of major interest for the calculation of the temperature distribution inside the combustion chamber walls, which may be critical for the employed materials. Experimental set-ups are presented, which are used to determine permeability, the volumetric heat transfer coefficient and the effective thermal conductivity. The results are presented for a wide range of foam materials. Porosity as well as the basic metal powder and the manufacturing parameters are varied. The influence of these parameters on the measured quantities is discussed. Thermal conductivity data are determined at temperatures of up to 1200 K. The obtained volumetric heat transfer coefficients are transferred to Nusselt-Reynolds plots, which allow generalization to the high temperature and high pressure regime. Correlations between the heat transfer properties and the permeability data are made. Using the acquired experimental data, a proposal is made for the calculation of the inner surface temperature of the combustion chamber as well as the temperature distribution inside the chamber wall which consists of a structural element, the metal foam and a thermal barrier coating, equipped with laser drilled micro-holes. Copyright: 2008 WILEY-VCH Verlag GmbH and Co. KGaA.

O. Reutter, J. Sauerhering, T. Fend, R. Pitz-Paal, and S. Angel, German Aerospace Center, 52243 Koln, Germany. Cited: *Adv. Eng. Mater.*, 2008, September, **10**(9), p 812-815. ISSN 1438-1656.

Evaluation of ZrO_2-24MgO ceramic coating by eddy current method. A novel study was carried out using eddy current technique for non-destructive evaluation of Thermal Barrier Coatings (TBC). For this purpose, zirconium oxide, stabilized with magnesium oxide as a top-coat, and Ni-5Al as a bond-coat were air plasma sprayed onto a nickel base alloy substrates. Microstructure and phase changes were observed during thermal treatment. Formation of nickel-oxide was noticed during the experimentation. The values of eddy current and the phase-angle changes, were correlated with the micro-structural and metallurgical phase changes, observed at the interface of bond-coat and top-coat. Copyright: 2008 Elsevier B.V. All rights reserved.

A. Nusair Khan, S.H. Khan, F. Ali, and M.A. Iqbal, Department of Physics, University of the Punjab, Lahore, Pakistan. Cited: *Comput. Mater. Sci.*, 2009, January, **44**(3), p 1007-1012. ISSN 0927-0256.

Infrared-optical properties and heat transfer coefficients of semitransparent thermal barrier coatings. Thermal barrier coatings (TBC) which are used in aircraft and land-based gas turbines for thermal insulation of thermally highly loaded components are usually semitransparent in the infrared spectral region at higher temperatures. Thus, at turbine surface conditions the total heat transfer coefficient of TBCs increases above the heat transfer coefficient caused by solid heat conduction alone. The solid thermal conductivity of electron beam physical vapor deposited (EB-PVD) partially yttria stabilized zirconia (YSZ) coatings derived from laser flash measurements were correlated with the microstructure of the coatings, which was adjusted by defined heat treatments. To obtain the contribution of the radiative transfer on the total heat transfer coefficient, infrared-optical characterizations were carried out at ambient and elevated temperatures. A theoretical model was developed which can be used to describe the heat transfer through semitransparent, absorbing and scattering media. Finally, the total heat transfer, caused by solid thermal conduction, radiative transfer and an interaction of both is derived for the coatings prepared in this work. Additionally the measurement method BBC (black body boundary conditions) which is suitable to determine spectral transmittance and emittance at elevated temperatures is introduced. Copyright: 2008 Elsevier B.V. All rights reserved.

J. Manara, M. Arduini-Schuster, H.J. Ratzer-Scheibe, and U. Schulz, Bavarian Center for Applied Energy Research (ZAE Bayern), 97074 Wurzburg, Germany. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1059-1068. ISSN 0257-8972.

On stresses induced in a thermal barrier coating due to indentation testing. Instrumented indentation has been suggested as a method to determine interfacial fracture toughness of thermal barrier coatings. However, in a previous experimental study we showed that the results are ambiguous. In this work, we investigate the experimental results by numerical simulations incorporating the material microstructure. In the numerical simulations, based on finite element analyses, the stress fields that are associated with the loading and unloading of the indenter are investigated. By comparing these stress fields to the damage observed in the experimental study, including crack path and interfacial delaminations, we explain key findings from the experimental observations. Our results suggest that indentation testing of multilayered coated structures might not induce the delamination in the overall weakest interface and therefore the test results must be evaluated with care. Copyright: 2008 Elsevier B.V. All rights reserved.

J. Yan, A.M. Karlsson, M. Bartsch, and X. Chen, Department of Mechanical Engineering, University of Delaware, Newark, DE 19716. Cited: *Comput. Mater. Sci.*, 2009, February, **44**(4), p 1178-1191. ISSN 0927-0256.

Scattering of thermal waves and non-steady effective thermal conductivity of composites with coated particles. In this study, thermal wave method is proposed to predict the non-steady effective thermal conductivity of composites with coated particles, and the analytical solution of this problem is obtained. The Fourier heat conduction law is introduced to analyze the propagation of thermal waves in the particular composite. The scattering and refraction of thermal waves by a coated particle in the matrix are analyzed, and the results of the single scattering problem are applied to the composite medium. The wave fields in different material zones are expanded by using the spherical wave functions and Legendre polynomial, and the expanded mode coefficients are determined by satisfying the boundary conditions of the coating layer. The theory of Waterman and Truell is employed to obtain the effective propagating wave number and the non-steady effective thermal conductivity of composites. As an example, the effects of the material properties of the particles, coating and matrix on the effective thermal conductivity of composites under different wave frequencies are graphically illustrated and analyzed. Analysis shows that the non-steady effective thermal conductivity under higher frequencies is quite different from the effective thermal conductivity under lower frequencies. In the region of lower frequency, the effect of the properties of the coating on the effective thermal conductivity is greater. Comparisons with the steady effective thermal conductivity obtained from other methods are also presented. Copyright: 2008 Elsevier Ltd. All rights reserved.

X.-Q. Fang, Department of Engineering Mechanics, Shijiazhuang Railway Institute, Shijiazhuang 050043, China. Cited: *Appl. Therm. Eng.*, 2009, April, **29**(5-6), p 925-931. ISSN 1359-4311.

Spray deposition of metals over circular CFRP core shafts. It was theoretically shown by the authors in a previous article that by adding a layer of metal on the outside of a carbon fiber-reinforced composite shaft, the bending natural frequencies of the shaft could be increased in some cases due to reduction of the effects of shear deformation by the metal layer. In the present study, composite shafts having a metal casing have been manufactured by spray deposition process over filament wound, fiber reinforced polymeric

shafts. The natural frequencies of the spray deposited composite shafts have been measured and found to compare well to theoretically calculated values. The experiments also confirm the shear deformation effect described above. Some manufacturing issues on the spray deposition of metals over carbon fiber-reinforced plastics are addressed. Copyright: 2009 SAGE Publication.

W. Kim, A. Argento, and P.S. Mohanty, Department of Mechanical Engineering, University of Michigan-Dearborn, Dearborn, MI 48128-2406. Cited: *J. Compos. Mater.*, 2009, February, **43**(3), p 277-287. ISSN 0021-9983.

Thermal expansion behavior of plasma sprayed Al-SiC_p composites. Al with 55 and 75 vol.%SiC powders were free mechanically mixed or ball milled as feedstock. The powder feedstock was deposited onto a graphite substrate to form near net shape of Al/SiC composites by air plasma spraying. The pores and the gaps at the Al/SiC interface as well as at the boundary of Al grains exist extensively in the as sprayed composites. Coefficient of thermal expansion (CTE) of the sprayed composites was measured in the temperature range of 25-300 °C. The composites plasma sprayed with Al-75SiC powder feedstock can reach a low CTE value of 8 times; 10^6 $°C^{-1}$. The effect of pore on the CTE of the composites has been discussed. The gap at Al/SiC interface has an influence on thermal expansion behavior only at lower test temperatures. Reduction and elimination of the gap with temperature can offset the thermal expansion of the as sprayed composites, resulting in lower CTE at the beginning of the CTE test. Roughly quantitative consideration of the effect of the interfacial gaps between Al and SiC on CET was given. Linear rule of mixture (ROM), Turner and Kerner's models were used to estimate the CTE of the sprayed composites. It was found that ROM and Kerner's model give closer CTE prediction for the present composites. Copyright: 2008 Institute of Materials, Minerals and Mining.

M.C. Gui, S.B. Kang, and K. Euh, National Lab of Advanced Composites, Institute of Aeronautical Materials, Beijing, 100095, China. Cited: *Mater. Sci. Technol.*, 2008, November, **24**(11), p 1362-1368. ISSN 0267-0836.

Thermal-sprayed dielectric coating e.m. properties evaluation via free-space measurements at microwave frequencies. At present, there is a lack of knowledge about the electromagnetic (e.m.) properties of alumina coatings in a wide microwave frequency range. In this paper, complex permittivity of thermal sprayed alumina coatings were evaluated via free-space measurements. XRD, microstructural and microhardness characterisations were performed too. The results showed that the real part of permittivity is consistent with that found for bulk alumina, being the difference due to the complexity of the coating, which is composed by multiple phases originated during the deposition process. The bond coat measurements showed that it is possible to recognise an anisotropic texture of the coating. Copyright: 2008, Inderscience Publishers.

F. Nanni, F. Cipri, F. Casadei, and T. Valente, Department of Chemical Sciences and Technologies, INSTM Research Unit, University of Rome 'Tor Vergata', 00133 Rome, Italy. Cited: *Int. J. Surf. Sci. Eng.*, **2**(5), p 385-399. ISSN 1749-785X.

Microstructure

Advanced deposition characteristics of kinetic sprayed bronze/diamond composite by tailoring feedstock properties. In this study, the effect of protective nickel film on diamond particles was studied with the goal of preventing fracture and obtaining a uniform diamond distribution in a bronze/diamond composite coating during kinetic spraying. Two types of bronze/diamond composite were deposited on aluminum substrate. For comparison with experimental results, the impact behavior between diamonds in the gas flow field was simulated by finite element analysis (using ABAQUS/Explicit 6.7-2). Size distribution and deposition efficiency of the diamond particles in the composite coatings were analyzed through scanning electron microscopy and image analysis methods. Diamond fracturing was avoided because the impact energy was mostly absorbed by the outer protective nickel film on the diamond particle during impact. The uniform distribution and deposition efficiency of diamond particles in the coating layer could also be achieved by tailoring the physical properties (density, size, etc.) of the feedstock. Copyright: 2008 Elsevier Ltd. All rights reserved.

H. Na, G. Bae, S. Shin, S. Kumar, H. Kim, and C. Lee, Kinetic Spray Coating Laboratory (NRL), Division of Materials Science and Engineering, Hanyang University, Seoul 133-791, South Korea. Cited: *Compos. Sci. Technol.*, 2009, March, **69**(3-4), p 463-468. ISSN 0266-3538.

Aluminum composite reinforced with multiwalled carbon nanotubes from plasma spraying of spray dried powders. Homogenous dispersion of carbon nanotubes (CNTs) in micron sized aluminum silicon alloy powders was achieved by spray drying. Excellent flowability of the powders allowed fabrication of thick composite coatings and hollow cylinders (5 mm thick) containing 5 wt.% and 10 wt.% CNT by plasma spraying. Two phase microstructure with matrix having good distribution of CNT and CNT rich clusters was observed. Microstructural evolution has been explained using single splat and the infiltration of CNT clusters by liquid metal. Partial CNT surface damage was observed in case of the 10 wt.% CNT coating due to CNT mesh formation and smaller size of spray dried agglomerate. Increase in the elastic modulus and improvement in the yield strength and elastic recovery properties due to CNT addition was observed by nanoindentation. Copyright: 2008 Elsevier B.V. All rights reserved.

S.R. Bakshi, V. Singh, S. Seal, and A. Agarwal, Plasma Forming Laboratory, Nanomechanics and Nanotribology Laboratory, Department of Mechanical and Materials Engineering, Miami, FL 33174. Cited: *Surf. Coat. Technol.*, 2009, Feb 25, **203**(10-11), p 1544-1554. ISSN 0257-8972.

Annealing effects on plasma-sprayed Ni: an XRPD study. The variation of the size of coherently-diffracting domains and strain due to annealing at moderate temperature (500 °C) has been estimated for plasma-sprayed Ni using x-ray Powder Diffraction (XRPD) and line broadening analysis in conjunction with classical and modified Williamson-Hall methods. It was found that annealing provokes a narrowing of Ni diffraction peaks which was basically associated to a decrease in dislocations present in the as-sprayed material. The evolution of the microstructure with temperature of plasma-sprayed Ni was studied by in situ x-ray powder diffraction (XRPD). It was found that the breadth of the Ni profiles continuously decreased with heating up to 500 °C, mainly due to healing of dislocations. These results were used to explain the irreversible decrease in electrical resistance of plasma-sprayed Ni resistors after annealing which was previously observed in our laboratory. Copyright: 2008 Elsevier B.V. All rights reserved.

M. Lassinantti Gualtieri, M. Prudenziati, and A.F. Gualtieri, Dipartimento di Fisica, Universita di Modena e Reggio Emilia, I-41100 Modena, Italy. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 345-349. ISSN 0257-8972.

Annealing effects on the intermetallic compound formation of cold sprayed Ni, Al coatings. The annealing of Ni and Al coatings under various conditions on substrates fabricated by a cold gas dynamic spray process (CDSP) were investigated. The powder particles were accelerated through a standard De Laval-type nozzle with air used as the main carrying gas. The coatings were annealed at 450-550 °C in either argon or air atmospheres for 4 h. In the case of Ni coatings during annealing both in argon and air atmospheres, intermetallic compound layers such as Al_3Ni and Al_3Ni_2 were observed at the interfaces between the Ni coating and Al substrate. Also, the intermetallic layer formation of Al_3Ni and Al_3Ni_2 at the interfaces depended on the solid-state diffusion and the annealing temperature. The intermetallic compound AlNi was obtained at the interface of Al coating on a Ni substrate by low-temperature annealing under the melting temperature. Copyright: 2008 Elsevier B.V. All rights reserved.

H. Lee, S. Lee, and K. Ko, Department of Materials Science and Engineering, Ajou University, Suwon 443-749, South Korea. Cited: *J. Mater. Process. Technol.*, 2009, Jan 19, **209**(2), p 937-943. ISSN 0924-0136.

Characteristics and heat treatment of cold-sprayed Al-Sn binary alloy coatings. In this study, Al-Sn binary alloy coatings were prepared with Al-5 wt.% Sn (Al-5Sn) and Al-10 wt.% Sn (Al-10Sn) gas atomized powders by low pressure and high pressure cold spray process. The microstructure and microhardness of the coatings were characterized. To understand the coarsening of tin in the coating, the as-sprayed coatings were annealed at 150, 200, 250 and 300 °C for 1 h, respectively. The effect of annealing on microstructure and the bond strength of the coatings were investigated. The results show that Al-5Sn coating can be deposited by high pressure cold spray with nitrogen while Al-10Sn can only be deposited by low pressure cold spray with helium gas. Both Al-5Sn and Al-10Sn coatings present dense structures. The fraction of Sn in as-sprayed coatings is consistent with that in feed stock powders. The coarsening and/or migration of Sn phase in the coatings were observed when the annealing temperature exceeds 200 °C. Furthermore, the microhardness of the coatings decreased significantly at the annealing temperature of 250 °C. EDXA analysis shows that the heat treatment has no significant effect on fraction of Sn phase in Al-5Sn coatings. Bonding strength of as-sprayed Al-10Sn coating is slightly higher than that of Al-5Sn coating. Annealing at 200 °C can increase the bonding strength of Al-5Sn coatings. Copyright: 2008 Elsevier B.V. All rights reserved.

X.-J. Ning, J.-H. Kim, H.-J. Kim, and C. Lee, Welding Research Center, Research Institute of Industrial Science and Technology, Pohang 790-600, South Korea. Cited: *Appl. Surf. Sci.*, 2009, Jan 15, **255**(7), p 3933-3939. ISSN 0169-4332.

Characterizations of AMT-200 HVOF NiCrAlY coatings. The development of high velocity oxygen-fuel (HVOF) process shows a clear trend toward the design of a new gun in which high pressure and large power are expected in order to obtain a stable flame and a high powder feed rate for industrial applications. In this work, a new HVOF gun, AMT-200, was used to prepare NiCrAlY coatings. The influences of thermal treatment and spraying parameters, i.e., oxygen/fuel gas stoichiometric ratio and spraying distance on coating structures and properties were studied. Artificial neural networks (ANN) was implemented in this study to predict the coating structural attribute (porosity, hardness). The results show that the spraying parameters play significant roles on the structures and properties of NiCrAlY coatings. Employing

optimized parameters, a dense NiCrAlY coating, with a high coating/substrate bonding strength was obtained by this system. Moreover, thermal treatment reduced significantly the coating porosity and increased greatly coating/substrate bonding strength. Copyright: 2008 Elsevier Ltd. All rights reserved.

G. Zhang, A.F. Kanta, W.Y. Li, H. Liao, and C. Coddet, LERMPS, UTBM, 90010 Belfort, Cedex, France. Cited: *Mater. Des.*, 2009, March, **30**(3), p 622-627. ISSN 0261-3069.

Cold spraying of Fe/Al powder mixture: coating characteristics and influence of heat treatment on the phase structure. In this paper, an iron/aluminum composite coating was deposited by cold spraying using iron and aluminum powder mixtures. The coating was annealed at different temperatures to aim at forming an iron aluminide intermetallic based coating. The results showed that a thick dense Fe/Al composite coating with uniformly distributed Fe and Al particles can be deposited by cold spraying. The compositions of the as-sprayed Fe/Al coating were nearly the same as that of the initial Fe/Al powder mixture. The intensive deformation of particle on impact caused elongation of the grain and disrupted the thin oxide films on powder surface. After annealing at a temperature of 600 °C, an intermediate phase Al_5Fe_2 coexisted in the deposit with remaining Fe and Al. With increasing annealing temperature to 900 °C, the deposit transformed to mainly FeAl phase with a trace of remaining Fe phase. Copyright: 2008 Elsevier B.V. All rights reserved.

H.-T. Wang, C.-J. Li, G.-J. Yang, and C.-X. Li, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China. Cited: *Appl. Surf. Sci.*, 2008, Dec 30, **255**(5 PART 1), p 2538-2544. ISSN 0169-4332.

CoNiCrAlY microstructural changes induced during Cold Gas Dynamic Spraying. The present study is part of an ongoing research project that aims to develop high performance bond coats by means of Cold Gas Dynamic Spraying (CGDS) for the manufacturing of thermal barrier coatings (TBC). The objective of this work is to investigate the microstructure of a CGDS coating and compare it to that of the original feedstock powder in order to determine whether any microstructural changes have occurred during the deposition process. CoNiCrAlY coatings were deposited using the CGDS system developed at the University of Ottawa Cold Spray Laboratory. Scanning electron microscopy, transmission electron microscopy and x-ray diffraction techniques were used to assess the phases and microstructure of the original feedstock powder and coatings produced. Contrarily to the generally accepted theory that the CGDS process does not lead to changes in the deposited material's microstructure and phase, results from the analysis performed in this study demonstrate the occurrence of important microstructural and phase changes. Evidence of grain refinement of the γ-phase matrix down to the nanometre scale as well as partial dissolution of β-phase precipitates was observed. It is believed that these changes are attributed to the severe plastic deformation encountered by the deposited particles. Copyright: 2008 Elsevier B.V. All rights reserved.

P. Richer, A. Zuniga, M. Yandouzi, and B. Jodoin, University of Ottawa, Ottawa, Ontario, Canada. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 364-371. ISSN 0257-8972.

Evaluation of detonation gun sprayed alumina titania coatings. This paper presents the results of the investigation of the structure and properties of the coatings deposited with Detonation gun technique. Alumina Titania ($Al_2O_3$3wt.%TiO_2). Coating was deposited on metallic substrates using a D-gun Technique. Sound Coating of 200 m to 220 m could be obtained. Investigation of the microstructure and characteristics of the coatings after the preparation was performed by x-ray diffraction, Scanning electron microscopy and EDX analysis. Microstructure suggested that the coating constructed mainly of alumina and Titania Splats which has also been confirmed by EDX analysis. The developed coating by this method is highly dense and tightly adherent. Copyright: 2008, Inderscience Publishers.

P.K. Sapra, S. Singh, and S. Prakash, Metallurgical and Materials Engineering Department, Indian Institute of Technology Roorkee, Roorkee-247 667 UA, India. Cited: *Int. J. Surf. Sci. Eng.*, **2**(5), p 400-408. ISSN 1749-785X.

High performance amorphous steel coating prepared by HVOF thermal spraying. Amorphous steel coating with a composition of $Fe_{48}Cr_{15}Mo_{14}C_{15}$-$B_6Y_2$ was prepared by means of high velocity oxygen fuel (HVOF) thermal spraying. Microstructural analysis gives the information about porosity, oxidation and nanocrystal precipitation. Properties including the hardness, wear, corrosion and magnetic behaviors of the coating were examined. It was shown that the microhardness and wear resistance of the coating are superior to those of electroplated Cr and Ni-based amorphous coating. In 1 M HCl aqueous solution, the coating demonstrated a low passive current density, a wide passive region and the same transpassive potential as bulk amorphous sample. Furthermore, the coating remained paramagnetic attribute in room temperature. Copyright: 2007 Elsevier B.V. All rights reserved.

H.S. Ni, X.H. Liu, X.C. Chang, W.L. Hou, W. Liu, and J.Q. Wang, Shenyang National Laboratory for Materials Science, Institute of Metal Research, CAS, Shenyang, 110016 China. Cited: *J. Alloys Compd.*, 2009, Jan 7, **467**(1-2), p 163-167. ISSN 0925-8388.

Influence of the elementary mixing scale on HVOF-sprayed coatings derived from nanostructured aluminosilicate/mullite feedstock. Aluminosilicate/mullite coatings were prepared from nanosized sources of aluminum and silicon by means of a high velocity oxy-fuel thermal spray process. X-ray diffraction, analytical electron microscopy, differential thermal analysis and Fourier transform infrared spectroscopy were used to characterize the phase composition, elementary distribution, and microstructure in the feedstock and in the coatings. It was revealed that the chemical environment of the alumina component, as well as the inherent elementary distribution in the nanoparticulate aluminosilicate feedstock, showed the greatest influence on the microstructure and the crystallization of nanosized ceramic phases in the sprayed coatings. A uniform distribution of alumina and silica in a short-range ordered monophasic-like nanostructure was the most appropriate physicochemical conditions of the feedstock to achieve nanosized crystallites of mullite in a monolithic-like aluminosilicate coating. In turn, when using diphasic feedstock, clearly heterogeneous but nanostructured coatings with a good abrasion resistance were obtained. The agglomerated and heat-treated powders were considered as the most suitable type of feedstock for providing nanostructured aluminosilicate coatings. Copyright: 2008 Elsevier B.V. All rights reserved.

J. Leivo, T.E. Varis, E. Turunen, M. Vippola, K. Rissa, U. Kanerva, J. Silvonen, and T.A. Mantyla, Department of Materials Science, Tampere University of Technology, 33101 Tampere, Finland. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 335-344. ISSN 0257-8972.

Intrinsic and extrinsic factors influencing the glass-forming ability of alloys. The factors influencing GFA (glass-forming ability), and separated as intrinsic (belonging to glass itself), and extrinsic (depending upon external conditions) factors was studied. The study also considered the solidification of metallic liquid phase by casting. The time-temperature cooling curve of pure Ni cast into Cu mold was obtained by recording the temperature of the melt with a thin K-type thermocouple, which was connected to an analog-to-digital signal converter. The thermal expansion treatment was applied to Ni and a high value of the reduced glass-transition temperature of about 0.6 was found. Intrinsic factors assume that homogeneous nucleation competes with glass formation, and include a number of fundamental and derived thermal parameters, physical properties, and a topological contribution from different atomic packing. (Edited abstract)

D.V. Louzguine-Luzgin, D.B. Miracle, and A. Inoue, WPI Advanced Institute for Materials Research, Tohoku University, Sendai, 980-8577, Japan. Cited: *Adv. Eng. Mater.*, 2008, November, **10**(11), p 1008-1015. ISSN 1438-1656.

La_2O_3-modified YSZ coatings: high-temperature stability and improved thermal barrier properties. Lanthana precursor was coated on yttria-stabilized-zirconia (YSZ) powders by wet chemical infiltration, and was introduced to the crystalline structure and grain boundaries of YSZ after plasma spraying of thermal barrier coatings (TBCs). The microstructural stability and thermal barrier properties of this new kind of TBCs were studied under different annealing conditions. It demonstrates that the La_2O_3 surface coating restrains grain growth of YSZ during both deposition and post-annealing processes, compared to a TBC obtained from commercially available unmodified YSZ powders. According to the composition analysis, lanthana partially dissolved in the zirconia matrix after heat treatment. The thermal diffusivity of YSZ coating significantly decreased after lanthana modification, typically from 0.354 $mm^2\ s^{-1}$ for an unmodified sample to 0.243 $mm^2\ s^{-1}$, reflecting a decrease of 31%. Even after annealed at 1200 °C for 50 h, the thermal diffusivity of modified coatings still shows a reduction of 25% than unmodified samples. Copyright: 2008 Elsevier B.V. All rights reserved.

Y. Liu, Y.F. Gao, S.Y. Tao, X.M. Zhou, and H.J. Luo, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1014-1019. ISSN 0257-8972.

Microstructural characteristics and formation mechanism of Al_2O_3-13 wt.% TiO_2 coatings plasma-sprayed with nanostructured agglomerated powders. Nanostructured Al_2O_3-13 wt.% TiO_2 coatings were prepared by plasma spraying with agglomerated powders. The microstructural characteristics of the feedstock and the coating were investigated by using scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and x-ray diffractometry (XRD). Moreover, the microstructural formation mechanism of the coating was analyzed. The results show that the ceramic coating consists of both fully melted regions and partially melted regions, and the fully melted region has a lamellar-like structure as the conventional coating. In terms of microstructures, the partially melted regions can be divided into liquid-phase sintered regions (a three-dimensional net or skeleton-like structure: Al_2O_3-rich submicron particles embedded in the TiO_2-rich matrix) and solid-phase sintered regions (remained nano-particles). The fully melted region, liquid-phase sintered region and solid-phase sintered region of the coating derive from the region of the feedstock, where the corresponding temperature during plasma spraying is beyond 2045 °C (melting point of Al_2O_3), between 1840 °C (melting point of TiO_2) and 2045 °C and below 1840 °C, respectively. The formation of the solid-phase and liquid-phase sintered regions in the partially melted region is attributed to the melting point difference of $A1_2O_3$ and TiO_2. Copyright: 2008 Elsevier B.V. All rights reserved.

D. Wang, Z. Tian, L. Shen, Z. Liu, and Y. Huang, College of Mechanical and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, China. Cited: *Surf. Coat. Technol.*, 2009, Feb 25, **203**(10-11), p 1298-1303. ISSN 0257-8972.

Microstructural characteristics and mechanical properties of HVOF sprayed NiCrAl coating on superalloys. High velocity oxy-fuel (HVOF) process sprayed NiCrAl coatings on superalloys were characterized by various techniques such as optical microscopy, x-ray diffraction (XRD) and scanning electron microscopy/energy dispersive spectroscopic analysis (SEM/EDS) to render an insight into their microstrucural features and assess its suitability for high temperature corrosion resistance applications. The as sprayed coatings were found to be dense with splat like layered morphology. The XRD analysis of the coating showed the presence of Ni (fcc) as a prominent phase with Cr and Al as minor phases. The porosity of the coatings was calculated from its optical micrographs and found to be less than 1.7%. The measured hardness and average bond strength of the coatings were found to be in the range of 278-351 Hv and 59 MPa, respectively. The observed microstructral characteristics, higher bond strength, and hardness of HVOF sprayed NiCrAl coating show that it may act as an effective barrier to provide high temperature protection to the superalloys. Copyright: 2008 Elsevier B.V. All rights reserved.

R.A. Mahesh, R. Jayaganthan, and S. Prakash, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, India. Cited: *J. Alloys Compd.*, 2009, Jan 22, **468**(1-2), p 392-405. ISSN 0925-8388.

Microstructural evaluation of ZrO_2-MgO coatings. Zirconium oxide, stabilized with magnesium oxide, as a topcoat a coat and Ni-5Al as a bondcoat were air plasma sprayed onto a nickel base alloy substrates. Microstructural and phase changes were observed during the thermal treatment. Formation of nickel-oxide was noticed during the experimentation. Chemical composition profile for the given system, at high temperature, were determined and discussed in this paper. Microstructural characterization was carried out by scanning electron and optical microscopes, whereas phase analysis was carried out by x-ray diffractometer (XRD). Copyright: 2008 Elsevier B.V. All rights reserved.

A.N. Khan and I.N. Qureshi, Metallurgy Division, Rawalpindi, Pakistan. Cited: *J. Mater. Process. Technol.*, 2009, Jan 1, **209**(1), p 488-496. ISSN 0924-0136.

The thermal stability of porous alumina/stainless steel catalyst support obtained by spray pyrolysis. Active porous alumina coatings were obtained by deposition of boehmite sol on stainless steel (SS) substrate by spray pyrolysis method. The temperature and the doping of polyethylene glycol (PEG) and La^{3+} in the boehmite sol effects on the textural and structural properties and surface morphology of alumina coatings on stainless steel samples are presented. It was found that the addition of polyethylene glycol combined with La^{3+} to the boehmite sol before spraying improves the thermal stability of porous alumina coatings. X-ray diffraction patterns of a doped sample, even after 5 h at 1000 °C, point out to the presence only of δ-Al_2O_3, with a S_{BET} of 74 m^2/g. XPS data and SEM photographs of coated samples show that alumina were well deposited on the metallic supports. The absence of any lanthanum compounds indicates very well homogeneous dispersion of La^{3+}-ions on the surface of alumina crystallites. AFM images show sphere like alumina grains and agglomerates with surface roughness from 60 to 180 nm, depending on temperature and doping. Surface roughness of doped alumina samples was higher than that of non-doped. It was pointed out that spray pyrolysis method enables preparation of alumina layers with relatively high specific surface area, suitable for applications as catalysts supports. Copyright: 2008 Elsevier B.V. All rights reserved.

T. Novakovic, N. Radic, B. Grbic, V. Dondur, M. Mitric, D. Randjelovic, D. Stoychev, and P. Stefanov, IChTM, Department of Catalysis and Chemical Engineering, 11000 Belgrade, Serbia. Cited: *Appl. Surf. Sci.*, 2008, Dec 30, **255**(5 PART 2), p 3049-3055. ISSN 0169-4332.

Modeling

Atomistic Modeling

Atomistic modeling of Pt additions to NiAl. Modeling of the behavior of Pt additions to NiAl alloys is performed using a quantum approximate technique suitable for the study of site preference, phase structure, bulk properties and the coefficient of thermal expansion for the B2 NiAlPt phase field. An atom-by-atom analysis yields insight into the quantitative and qualitative changes in these properties as a function of Pt concentration. Copyright: 2008 Elsevier Ltd. All rights reserved.

M.F. Del Grosso, H.O. Mosca, and G. Bozzolo, Ohio Aerospace Institute, Cleveland, OH 44142. Cited: *Intermetallics,* November 2008/December 2008, **16**(11-12), p 1305-1309. ISSN 0966-9795.

LaBi under high pressure and high temperature: a first-principle study. By employing the first-principles method of the full potential linear augmented plane waves (FPLAPW), the structural, elastic and the electronic properties of LaBi are investigated. It is found that this compound has a semiconducting small and indirect gap. Through the quasi-harmonic Debye model, in which the phononic effects are considered, we have obtained successfully the thermodynamic properties such as thermal expansion coefficient, Debye temperature and specific heats in the whole pressure range from 0 to 10 GPa and temperature range from 0 to 1600 K. Copyright: 2008 Elsevier B.V. All rights reserved.

F. Driss Khodja, A. Boudali, K. Amara, B. Amrani, A. Kadoun, and B. Abbar, Departement de physique et chimie industrielle, Institut des Sciences et Technologie, Centre Universitaire de Mascara, Mascara 29000, Igeria. Cited: *Phys. B: Condens. Matter,* 2008, Dec 15, **403**(23-24), p 4305-4308. ISSN 0921-4526.

Theoretical investigations of structural, elastic and thermodynamic properties for PtN_2 under high pressure. We have investigated structural and elastic properties of PtN_2 under high pressures using norm-conserving pseudopotentials within the local density approximation (LDA) in the frame of density-functional theory. Calculated results of PtN_2 are in agreement with experimental and available theoretical values. The a/a_0, V/V_0, ductility/brittleness, elastic constants C_{ij}, shear modulus C prime, bulk modulus B, shear modulus G, Young's modulus E, Poisson's ratio σ; and anisotropy factor A as a function of applied pressure are presented. Through the quasi-harmonic Debye model, we also study thermodynamic properties of $PtN_2>$. The thermal expansion versus temperature and pressure, thermodynamic parameters X (X = Debye temperature or specific heat) with varying pressure P, and heat capacity of PtN_2 at various pressures and temperatures are estimated. Copyright: 2008 Elsevier B.V. All rights reserved.

H. Fu, W.F. Liu, F. Peng, and T. Gao, College of Physics and Electronic Information, Luoyang Normal College, Luoyang 471022, China. Cited: *Phys. B: Condens. Matter,* 2009, Jan 15, **404**(1), p 41-46. ISSN 0921-4526.

Mechanical Modeling

Ab initio calculations of elastic constants and thermodynamic properties of NiAl under high pressures. We have investigated the structural and elastic properties of NiAl under high pressures using norm-conserving pseudopotentials within the generalized gradient approximation correction (GGA) in the frame of density functional theory. The calculated pressure dependence of the normalized volume is in excellent agreement with the experimental results. The elastic constants and anisotropy as a function of applied pressure, the ratio of the normalized volume V/V_0 with the applied pressure are presented. The variations of bulk modulus, anisotropy and the brittleness with the pressure are investigated. Through the quasi-harmonic Debye model, we also study the thermodynamic properties of NiAl. The thermal expansion versus temperature and pressure, the thermodynamic parameters (Debye temperature and specific heat) with pressure P, and the heat capacity of NiAl at various pressures and temperatures are estimated. Copyright: 2008 Elsevier B.V. All rights reserved.

H. Fu, D. Li, F. Peng, T. Gao, and X. Cheng, Department of Physics, Luoyang Normal College, Luoyang 471022, China. Cited: *Comput. Mater. Sci.*, 2008, December, **44**(2), p 774-778. ISSN 0927-0256.

Comparison of Young-Laplace pore size and microscopic void area distributions in topologically similar structures: a new method for characterising connectivity in pigmented coatings. Scanning electron microscopy (SEM) combined with image analysis can provide a quantitative description of the area distribution of a porous structure, such as a paper coating. This is one of the few techniques where one can limit the measurement area strictly to the coating layer, fully excluding the base paper. It has been found that SEM cross-sectional porosity, defined as visible relative void area, and mercury porosimetry results agreed qualitatively to some degree but differed quantitatively. From an understanding of the differences in observations provided by the two methods, it is realized that comparison of void area distribution and intruded pore volume distribution, the latter including effects of entrance geometry to pores (mercury porosimetry and pore shielding), effectively describes the 2D to 3D transformation between the cross section and the pore network structure, i.e., a description of connectivity, in the unique case where the topology of the pore structure skeleton remains similar. Such structures are termed homeomorphisms. By studying the pore structural parameters of pigmented tablet structures, consisting of natural ground calcium carbonate with progressively increasing dose of latex binder, it is shown that the pore structural parameter of connectivity, and, hence, effective tortuosity/permeability, derived independently using the pore network model, Pore-Cor, can be deduced by forming the differences and correlations (convolution) between the two pore size distribution methods. Copyright: 2008 Springer Science+Business Media, LLC.

P.A.C. Gane, M. Salo, J.P. Kettle, and C.J. Ridgway, Omya Development AG, 4665 Oftringen, Switzerland. Cited: *J. Mater. Sci.*, 2009, January, **44**(2), p 422-432. ISSN 0022-2461.

Dynamic stress intensity factor of a crack perpendicular to the weak-discontinuous interface in a nonhomogeneous coating-substrate structure. A mechanical model was established for the antiplane dynamic

fracture problem of a functionally graded coating-substrate structure with a coating crack perpendicular to the weak-discontinuous interface. The problem was reduced to a Cauchy singular integral equation by the methods of Laplace and Fourier integral transforms. Erdogan's collocation method and the Laplace numerical inversion proposed by Miller and Guy were used to calculate the dynamic stress intensity factors. Three conclusions were drawn through parametric studies: (a) unlike the conclusion drawn for an interfacial crack, reducing the weak discontinuity of the interface will not necessarily decrease the dynamic stress intensity factor (DSIF) of the coating crack perpendicular to the interface; (b) increasing the stiffness of the substrate when that of the coating is fixed, or decreasing the stiffness of coating when that of the substrate is fixed, will be beneficial for the reduction of the DSIF of a coating crack perpendicular to the interface; and (c) the free surface has a greater influence on the DSIF than the interface does, and the effect of the interface on the DSIF is greater than that of the material stiffness in the crack-tip region. Copyright: 2008 Springer-Verlag.

Y.-D. Li, K.Y. Lee, and N. Zhang, School of Mechanical Engineering, Yonsei University, Seoul 120-749, South Korea. Cited: *Arch. Appl. Mech.*, 2009, February, **79**(2), p 175-187. ISSN 0939-1533.

Elastic bending analysis of bilayered beams by an alternative two-variable method. An alternative two-variable method is used to reanalyze thermoelastic bending problems of bilayered beams subjected to external moments and internal stresses. The differences among zero-stress axis, zero-strain axis (i.e., neutral axis), bending axis, centroidal axis, and the parameter conditions for null/single/dual zero-stress axes are investigated analytically and numerically. Comparisons of thermoelastic stress predictions by the present model with Stoney's model and Hsueh's model are discussed in a representative case of GaAs top coat/Si substrate wafers. Results showed that the neutral axis does not coincide with the zero-stress axis in the general case, and the numbers and the locations of zero-strain or zero-stress axes depend on not only elastic modulus, thickness and/or thermal expansion coefficient ratios between the film and the substrate but also mechanical/thermal loading ratio. Copyright: 2008 Elsevier Masson SAS. All rights reserved.

N.-H. Zhang and J.-Z. Chen, Shanghai Institute of Applied Mathematics and Mechanics, Shanghai University, Shanghai 200072, China. Cited: *Eur. J. Mech. A/Solids*, 2009, March/April, **28**(2), p 284-288. ISSN 0997-7538.

FEA of residual stress during HVOF thermal spraying. Due to the recent advances in thermal spraying technology, considerable research emphasis has been placed on the development of models capable of predicting deposition mechanisms at various stages during the process. In order to gain a deeper knowledge of the mechanisms involved in thermal spraying, it is necessary to isolate the factors affecting these constitutive properties (e.g., residual stress generation) and in doing so quantify the effect of the individual factors. Finite element analysis (FEA) is used in the present research to predict the residual stress generated in a WC-Co deposit produced via the HVOF process. The model is compared to an analytical technique and validated experimentally, the result of which provides a thermo-mechanical modeling procedure with an accuracy greater than 80% of that found experimentally. Combining FEA techniques with analytical and experimental results will enhance the understanding of residual stress in thermal spray techniques. Copyright: 2008 ASM International.

J. Stokes and L. Looney, Materials Processing Research Centre, National Centre for Plasma Science and Technology, Dublin City University, Dublin, Ireland. Cited: *J. Mater. Eng. Perform.*, 2009, February, **18**(1), p 21-25. ISSN 1059-9495.

Finite-element investigation of fracture behaviour in elastic-plastic film bonded to elastic substrate. In the present work, the finite element method is used to calculate the J integral and the size of plastic zone at the interfacial crack tip in aluminum film bonded to a ceramic substrate. The plastic behavior of the stress-strain curve of the aluminum is approximated by a Ramberg-Osgood function and the ceramic has a linear elastic behavior. The effects of the metal thickness and the crack length on the variation of the J integral at the crack tip were highlighted. Copyright: 2008 Elsevier B.V. All rights reserved.

M. Belhouari, S. Gouasmi, B. Bachir Bouiadjra, T. Achour, and A. Amiri, Department of Mechanical Engineering, University of Sidi Bel Abbes, Sidi bel Abbes 22000, Algeria. Cited: *Comput. Mater. Sci.*, 2008, December, **44**(2), p 835-837. ISSN 0927-0256.

Predictive tools for the design of erosion resistant coatings. Aerospace industry is seeking to develop high performance coatings for the protection against erosion by solid particles. However, with many new materials used and tested for different applications and operation under different conditions, conducting experiments for each one of them is becoming increasingly difficult. In the present work, we propose practical semi-empirical and numerical predictive methods to determine erosion resistance of tribological coatings. The paper presents data obtained by finite element (FE) calculations that can be compared with those obtained by classical theories developed for the erosion of materials. The simulation-based approach allows one to express the functional dependence of erosion on the coating properties, and to quantitatively predict the erosion rate. We determined a proportionality coefficient for a wide range of hard coatings. This coefficient was then used, in combination with the semi-empirical expression derived from FE simulations, to determine the erosion rate of different coatings. In addition to the existing erosion theories that tend to emphasize hardness, H, and Young's modulus, E, as the main parameters defining erosion resistance, we focus here on the role of the H/E and H^3/E^2 ratios. We demonstrate that the latter characteristics allow one to rank coatings with respect to their erosion performance. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Hassani, M. Bielawski, W. Beres, L. Martinu, M. Balazinski, and J.E. Klemberg-Sapieha, Department of Engineering Physics, Ecole Polytechnique de Montreal, Quebec H3C 3A7, Canada. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 204-210. ISSN 0257-8972.

Simplified models for residual stress prediction in thermally sprayed coatings. Residual stress in thermally sprayed coatings is known to cause a range of problems, notably debonding, cracking, and spallation. The focus in this paper is on the development of simple analytical models for the prediction of residual stress that arise from spraying a steel-alloy coating onto a copper-alloy substrate. This is a material combination that has been used recently to enhance the thermal and mechanical efficiency of the pressure die casting process although problems with debonding have been reported in the literature. Three analytical models are developed and investigated, where each represent combinations of assumptions for coating and substrate material behaviors during coating manufacture. The sensitivity of these combinations on residual stress, developed for a range of process parameters (deposited layer thickness, interval of layer deposition and the number of layers in a coating, i.e., block deposition versus multi-layer deposition for a desired coating thickness) is recorded. In agreement with experimental and finite-element modeling results from a previous study, the results from all the three models assessed in the current study indicate a progressive change in average interfacial residual stress from compressive towards tensile with an increase in the thickness of the deposited layer; and a tensile interfacial stress in a two-layer coating, which increases with an increase in the interval of deposition between the two layers. The observations from the results suggest an increase in potential for coating debonding with an increase in both deposited layer thickness and layer deposition interval. The results further suggest higher potential for coating debonding with block deposition compared with multi-layer deposition for a desired coating thickness. In terms of stress magnitudes, the model that performs best is one where the assumption that a currently deposited coating layer yields during its quenching phase and adopts elastic behavior afterwards; and the strain generated in the substrate during the quenching phase is from thermal effect only while in the other phases afterwards, is from both thermal and elastic effects. Copyright: IMechE 2008.

A.M. Kamara and K. Davey, School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester M60 1QD, UK. Cited: *Proc. Instit. Mech. Eng. C J. Mech. Eng. Sci.*, 2008, November, **222**(11), p 2053-2068. ISSN 0954-4062.

Thermo-elastic moduli of periodic multilayers with wavy architectures. The recently developed parametric finite-volume direct averaging micromechanics theory for periodic materials is employed to investigate the effective moduli and thermal expansion coefficients of lamellar composites with wavy architectures. In the parametric version, a reference square subvolume is mapped onto a quadrilateral subvolume in the actual discretized microstructure to accurately capture the in situ microstructural details. The mapping is used to construct local stiffness matrices of quadrilateral subvolumes which are employed in the local/global stiffness matrix solution strategy for the unit cell problem within a homogenization framework. Complete set of homogenized moduli and thermal expansion coefficients of multilayers comprised of alternating soft and hard laminae with two types of waviness is generated for the first time as a function of the volume content of the hard phase for two amplitude-to-wavelength ratios. The observed changes in the homogenized mechanical and thermal properties relative to the reference flat-layer configuration depend on the wavy microstructure orientation and become greater with increasing amplitude-to-wavelength ratios. Examination of local stress fields explains the differences observed in the homogenized moduli of multilayers with sinusoidal and corrugated waveforms for the two amplitude-to-wavelength ratios. Copyright: 2008 Elsevier Ltd. All rights reserved.

H. Khatam and M.-J. Pindera, Civil Engineering Department, University of Virginia, Charlottesville, VA 22904-4742. Cited: *Compos. B Eng.*, 2009, January, **40**(1), p 50-64. ISSN 1359-8368.

Process Modeling

Characteristics and thermal efficiency of a non-transferred DC plasma spraying torch under low pressure. Current-voltage (I-V) characteristics of a non-transferred DC arc plasma spray torch operated in argon at vacuum are reported. The arc voltage is of negative characteristics for a current below 200 A, flat for a current between 200 and 250 A and positive for a current beyond 250 A. The voltage increases slowly with the increase in carrier gas of arc. The rate of change in voltage with currents is about 3-4 V/100 A at a gas flow rate of about 1-1.5 V/10 standard liter per minute (slpm). The I-V char-

acteristics of the DC plasma torch are of a shape of hyperbola. Arc power increases with the argon flow rate, and the thermal efficiency of the torch acts in a similar way. The thermal efficiency of the non-transferred DC plasmatron is about 65-78%.

B. Shicong, G. Wenkang, Y. Minyou, X. Ping, and Z. Xiaodong, Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China. Cited: *Plasma Sci. Technol.*, 2008, Dec 1, **10**(6), p 701-705. ISSN 1009-0630.

Effect of plasma spray parameters on in-flight particle characteristics and in situ alumina formation. In the present study, mechanically alloyed Al-12Si and SiO_2 powder was deposited onto an aluminum substrate by atmospheric plasma spraying (APS) to obtain a hypereutectic Al-Si based in situ alumina formed composite coating. The effect of process parameters (arc current, spray distance, nozzle type, oxygen gas support and substrate cooling) on in-flight particle characteristics (temperature and velocity) and in situ alumina formation were investigated. It has been observed that while arc current and nozzle inner-diameter strongly affects the in-flight particle characteristics and in situ alumina formation, the effect of oxygen gas support is insignificant. Also, the results show that the substrate cooling considerably hinders alumina formation. Copyright: 2008 Elsevier B.V. All rights reserved.

C. Tekmen, Y. Tsunekawa, and M. Okumiya, Toyota Technological Institute, Materials Processing Lab, Tempaku, Nagoya 468-8511, Japan. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 223-228. ISSN 0257-8972.

Influence of substrate hardness on deposition behavior of single porous WC-12Co particle in cold spraying. Deposition of a dense coating with solid particles by cold spraying requires sufficient deformation of impacting particles and previously deposited underlying particles. The cermet particles and subsequent coating with a high hardness are difficult to deform upon impact. To increase the ability of deformation, the cermet spray particles with a porous structure are used to fulfill the requirements of deformation on impact. To understand the deposition mechanism, the deposition behaviors of single WC-Co spray particles impacting on the substrates with different hardness during cold spraying were examined using WC-12Co powders with different porosities. The substrates with different hardness including stainless steel, nickel-based self-fluxing alloy coatings were employed to examine the effect of substrate deformation on the cermet particle deposition. It was found that the WC-Co cermet particles with the porosities of 30% and 44% could be deposited on the substrate of different hardness from 200 to 800 kgf/mm^2. The deposition of the particles is mainly attributed to the deformation of powders themselves. The properly designed porous cermet powder with certain hardness is necessary to deposit hard WC-Co cermet coating. Copyright: 2008 Elsevier B.V. All rights reserved.

P.-H. Gao, C.-J. Li, G.-J. Yang, Y.-G. Li, and C.-X. Li, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi 710049, China. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 384-390. ISSN 0257-8972.

Numerical simulation of collision process of reactive flame sprayed particles with substrate. TiC-TiB_2 multi-phased coatings were prepared with Ti-B_4C-C as the reactive raw materials. The method of finite element was used to investigate the rule of temperature change of the deposits which came from the single spray particle colliding with the substrate in different state. So the influence of it on the bonding strength between the coatings and substrates was illustrated. It was shown that as for the deposit which came from the collision of the completely reactive spray particle with the substrate, it has relatively lower temperature and larger temperature difference. So it is hard to make the surface of the substrate melted and form metallurgical bonding. As for the deposit which came from the collision of as-reactive spray particle with the substrate, it has relatively higher temperature with uniform distribution. So it can realize the metallurgical bonding with the substrate. The collisions of those spray particles whose SHS reaction has just been ignited with the substrate will lead to the reaction terminate. The results of the numerical simulation are consistent with the experiments on the whole. Copyright: 2008 American Scientific Publishers. All rights reserved.

H.W. Liu, L. Zhang, W.B. Hu, and J.J. Wang, Institute of Advanced Materials, Ordnance Engineering College, Hebei, Shijiazhuang 050003, China. Cited: *J. Comput. Theor. Nanosci.*, 2008, August, **5**(8), p 1551-1555. ISSN 1546-1955.

Process map for plasma sprayed aluminum oxide-Carbon nanotube nanocomposite coatings. Plasma sprayed aluminum oxide coatings are commonly used for liners, heat exchangers, crucibles, and thermal heaters. Aluminum oxide nanotube (CNT) powder feedstock has been plasma sprayed to gain a nanocomposite coating with improved fracture toughness. It was observed during the process that the CNT-reinforced nanocomposites can be successfully synthesized through plasma spraying. A diagnostic sensor was used to develop a process map for plasma sprayed aluminum oxide nanotube nanocomposite coating. Field emission-scanning electron microscope was also used to analyze the images of the cross-sections plasma sprayed coatings. The properties of plasma sprayed coatings depends on degree of melting, impact and flattening of splat, CNT content, and its degree of dispersion in spray dried particles. Composite spray drying caused reduced thermal effect due to uniform CNT dispersion. (Edited abstract)

K. Balani and A. Agarwal, Department of Mechanical and Materials Engineering, Florida International University, Miami, FL. Cited: *Met. Finish.*, 2008, October, **106**(10), p 45-51. ISSN 0026-0576.

Postprocessing

Fast Regime-Fluidized Bed Machining (FR-FBM) of Atmospheric Plasma Spraying (APS) TiO_2 coatings. This paper deals with the development and application of a new technique, Fast Regime-Fluidized Bed Machining (FR-FBM), for the easy-to-automate finishing of as-deposited Atmospheric Plasma Spraying (APS) TiO_2 coatings on AISI 1040 steel substrates. The effects of leading FBM operational parameters, namely, abrasive size, jet pressure and processing time, were evaluated by using a full factorial Design of Experiments. Machinability of APS APS-TiO_2 coatings was found to be highly dependent on jet pressure and on abrasive mesh size as they affect the contact conditions between the abrasive and machined surface as well as the finishing force. By modifying these conditions, FR-FBM allows 3- to 4-fold improvements in roughness parameters of as-deposited APS APS-TiO_2 coatings and imparts minimal defects or alterations to the machined surface, whilst maintaining its ability to guarantee the respect of the closest geometrical tolerances. Copyright: 2008 Elsevier B.V. All rights reserved.

M. Barletta, G. Rubino, S. Guarino, G. Bolelli, L. Lusvarghi, and A. Gisario, Dipartimento di Ingegneria Meccanica, Universita di Roma 'Tor Vergata', 00133 Roma, Italy. Cited: *Surf. Coat. Technol.*, 2008, Dec 25, **203**(5-6), p 855-861. ISSN 0257-8972.

Powder

Production of aluminum foams with Ni-coated TiH_2 powder. Aluminum foams with Ni-coated TiH_2 powders were produced by an electroless coating technique producing uniform coatings disregarding particle shape and size. The results show that Ni-coating strength on TiH_2 powders is able to withstand the powder mixing and compactation stages. Al foams produced from the passivated TiH_2 show densities similar as those produced from the Ni-coated TiH_2 at 300 s. Foams from passivated TiH_2 display densities from 0.75 to 0.80 cm^{-3}, while foams produced from Ni coated and as-received TiH_2 reach lower densities. Pore structures and maximum expansions are developed for as-received and passivated TiH_2 condition between 480 and 495 s. The average area of pores is 60.6%, which is very similar to the foams produced with as-received TiH_2. (Edited abstract)

P.M. Proa-Flores and R.A.L. Drew, Department of Mining and Materials Engineering, McGill University, Montreal, QC H3A 2B2, Canada. Cited: *Adv. Eng. Mater.*, 2008, September, **10**(9), p 830-834. ISSN 1438-1656.

Transparent $MgAl_2O_4$ spinel from a powder prepared by flame spray pyrolysis. The densification of an $MgAl_2O_4$ spinel powder prepared by flame spray pyrolysis was examined in order to determine whether it is suitable for fabricating transparent parts using a sinter/HIP approach. It was found that the powder exhibits excellent sinterability. Firing pressed powder compacts to 1650 °C/2 h in air increases the bulk density to 99.9% TD. Similar densification, within the precision range of He picnometry, but a higher level of light transmission, is obtained by firing for 80 h at 1400 °C. By HIPing, both specimens, sintered at 1650º; and 1400 °C, are made transparent but the level of transparency attained is higher in the case of specimens presintered according to the latter conditions. Such specimens (2 mm thick) exhibit, after HIPing at 1500 °C/3 h (Ar, 200 MPa), a real in-line transmission (RIT) of 63% (635 nm), an average grain size of 2.2 μm, and a hardness of 13.2 GPa. After HIPing at 1700 °C, the RIT attains a value of 77%, while the average grain increases to 17 μm and the Vickers hardness slightly decreases to 12.8 GPa. Copyright: 2008 The American Ceramic Society.

A. Goldstein, A. Goldenberg, Y. Yeshurun, and M. Hefetz, Israel Ceramic and Silicate Institute, Haifa 32000, Israel. Cited: *J. Am. Ceram. Soc.*, 2008, December, **91**(12), p 4141-4144. ISSN 0002-7820.

Properties

Corrosion

Evaluation of cyclic hot corrosion behaviour of detonation gun sprayed Cr_3C_2-25%NiCr coatings on nickel- and iron-based superalloys. In the present investigation, Cr_3C_2-NiCr cermet coatings were deposited on two Ni-based superalloys, namely superni 75, superni 718 and one Fe-based superalloy superfer 800H by detonation-gun thermal spray process. The cyclic

hot-corrosion studies were conducted on uncoated as well as D-gun coated superalloys in the presence of mixture of 75 wt.% $Na_2SO_4 + 25$ wt.% K_2SO_4 film at 900 °C for 100 cycles. Thermogravimetric technique was used to establish the kinetics of hot corrosion of uncoated and coated superalloys. X-ray diffraction, FE-SEM/EDAX and x-ray mapping techniques were used to analyze the corrosion products for rendering an insight into the corrosion mechanisms. It was observed that Cr_3C_2-NiCr-coated superalloys showed better hot-corrosion resistance than the uncoated superalloys in the presence of 75 wt.% $Na_2SO_4 + 25$ wt.% K_2SO_4 film as a result of the formation of continuous and protective oxides of chromium, nickel and their spinel, as evident from the XRD analysis. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Kamal, R. Jayaganthan, and S. Prakash, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, India. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1004-1013. ISSN 0257-8972.

Investigations on role of HVOF sprayed Co and Ni based coatings to combat hot corrosion. This paper aims to investigate the hot corrosion resistance of high velocity oxy-fuel (HVOF) sprayed cobalt based (Stellite-6) and nickel based (Ni-20Cr) coatings deposited on the superalloy Superni-718 (Ni-19Cr-18-5Fe-5-13Ta-3-05Mo-0-9Ti-0-5Al-0-18Mn-O-18Si-O-15Cu-0-04C) in the $Na_2SO_4$60%V_2O_5 salt environment at 900 °C under cyclic conditions. The x-ray diffractometry, scanning electron microscopy/energy dispersive analysis and electron probe microanalyser techniques were used to study the corrosion products with respect to their morphology, phase composition and element concentration. The thermogravimetric technique was used to establish the kinetics of corrosion. The bare alloy underwent severe hot corrosion attack. The Ni-20Cr coating shows excellent hot corrosion resistance with negligible spallation, whereas Stellite-6 coating reveals less hot corrosion resistance and more spallation. The hot corrosion resistance of Ni-20Cr coating has been attributed to the formation of oxides of chromium, nickel and spinel of nickel chromium. The oxides of silicon, chromium, cobalt and spinels of cobalt-chromium and nickel-chromium have contributed for hot corrosion resistance of Stellite-6 coatings. Copyright: 2008 Institute of Materials, Minerals and Mining.

T.S. Sidhu, S. Prakash, and R.D. Agrawal, S.B.S. College of Engineering and Technology, Ferozepur 152004, Punjab, India. Cited: *Corros. Eng. Sci. Technol.*, 2008, December, **43**(4), p 335-342. ISSN 1478-422X.

Physicochemical properties of steel surfaces with titanium nitride ion-plasma sprayed coating. In neutral media, the regularities of the electrochemical corrosion of a steel, that had been sprayed by ionic plasma with titanium nitride, are studied. It is shown that the coating porosity is the principal factor determining its protective properties. Quantitative data on the effect of operation conditions on the coating porosity and corrosion-electrochemical behavior in liquids are given. Empirical formulas describing the kinetics of increasing the number of corrosion craters are obtained. Guidelines concerning the using of the ion-plasma coatings in the protecting of lean alloy steels against corrosion are formulated. Copyright: 2008 MAIK Nauka.

A.I. Kostrzhitskii, T.V. Cheban, and R.A. Podolyan, Odessa National Academy of Food Technologies, Odessa 65039, Ukraine. Cited: *Protect. Met.*, 2008, November, **44**(6), p 603-606. ISSN 0033-1732.

Structure and corrosion behavior of 316L stainless steel coatings formed by HVAF spraying with and without sealing. 316L stainless steel (SUS316L) coatings were sprayed on carbon steel substrate by a high-velocity air fuel (HVAF) process. Powder feed rate and particle size were varied systematically to investigate their effects on microstructure, oxide content and adhesion strength of the coatings. When the powder feed rate and particle size increased, the oxide content in the coatings decreased from 7 to 3%, while the adhesion strength decreased from 34 to 17 MPa. The corrosion resistance of the coatings was evaluated for sealed and unsealed coating conditions by salt spray test for up to 500 h. A large amount of corrosion products appeared on the unsealed coatings after 20 h, whereas no corrosion products were observed on the sealed coatings sprayed with the powder of the largest particle size, even after 500 h. Moreover, the above characteristics of the HVAF coatings were compared with those of a SUS316L coating sprayed by a high-velocity oxy-fuel process. Copyright: 2008 Elsevier B.V. All rights reserved.

Z. Zeng, N. Sakoda, T. Tajiri, and S. Kuroda, Kurashiki Boring, Kiko. Co., Ltd., Okayama 719-0233, Japan. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 284-290. ISSN 0257-8972.

Erosion & Wear

Effect of CeO_2 addition on the microstructure, hardness, and abrasive wear behavior of flame-sprayed Ni-based coatings. This article describes the effect of addition of CeO_2 on the microstructure, hardness, and abrasive wear behavior of Ni-based flame-sprayed coatings. These coatings are economical but not frequently used because of their high porosity, low hardness, and bigger grain size. The mechanical and tribological properties of the coatings are governed by the microstructure, grain size, and distribution of various elements. Rare earth elements (oxides) refine the microstructure. The commercially available Ni-based powder was modified with the addition of CeO_2 (0.4, 0.8, 1.2, 1.6, and 2 wt.%). The conventional Ni-based coatings and those containing various amounts of CeO_2 were compared in terms of grain size and distribution of various elements, hardness, porosity, and abrasive wear behavior. The addition of an optimal amount of CeO_2 (0-8 wt.%) refines the grain size and improves hardness and abrasive wear resistance of the coatings. X-ray diffraction of the conventional and modified coating with an optimum addition of CeO_2 (0.8 wt.%) was also carried out to identify the various phases present in the coating. Copyright: IMechE 2008.

S.P. Sharma, D.K. Dwivedi, and P.K. Jain, Department of Mechanical and Industrial Engineering, IIT Roorkee, Roorkee 247667, India. Cited: *Proc. Instit. Mech. Eng. J: J. Eng. Tribol.*, 2008, November, **222**(7), p 925-933. ISSN 1350-6501.

High temperature erosion of Cr_3C_2-NiCr thermal spray coatings—the role of phase microstructure. Cr_3C_2-NiCr thermal spray coatings are extensively applied to mitigate erosion at temperatures above 450-550 °C. The aim of this work was to extend the current comparison based knowledge towards a mechanistic interpretation of the high temperature erosion of Cr_3C_2 based thermal spray coatings. Coatings that span the range of industrial quality were assessed. They were eroded under high temperature (700 °C and 800 °C), aggressive (impact velocity 225-235 m/s) conditions designed to simulate the high velocity erodent impacts within a turbine environment. The influence on the erosion response of high temperature induced changes in the coating microstructure and composition with extended in-service exposure was assessed by heat treating selected samples to generate a steady state microstructure prior to testing. In spite of the marked variation in coating microstructure the erosion rates were comparable across the range of coatings tested. The significance of this conclusion is discussed in terms of the erosion mechanism. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Matthews, B. James, and M. Hyland, School of Engineering and Advanced Technology, Massey University, Auckland, New Zealand. Cited: *Surf. Coat. Technol.*, 2009, Jan 25, **203**(9), p 1144-1153. ISSN 0257-8972.

Some studies on slurry erosion of flame sprayed Ni-Cr-Si-B coating. *Purpose* The paper's aim is to investigate the sand slurry erosive wear behavior of Ni-Cr-Si-B coating deposited on mild steel by flame spraying process under different test conditions. *Design/methodology/approach* Flame sprayed coatings of Ni-Cr-Si-B were developed on mild steel substrate The slurry pot tester was used to evaluate wear behavior of the coating and mild steel. The erosive wear test was conducted using 20% and 40% silica sand slurry at three rotational speeds (600, 800 and 1,000 rpm). *Findings* Slurry erosive wear of the coating showed that in case of 20% silica sand slurry weight loss increases with increase in rotational speed from 600 to 1,000 rpm while in case of 40% silica sand slurry weight loss first increases with increase in rotational speed from 600 to 800 rpm followed by marginal decrease in weight loss with further increase in rotational speed from 800 to 1,000 rpm. Increase in wear resistance due to thermal spray coating of Ni base alloy on mild steel was quantified as wear ratio (weight loss of mild steel and that of coating under identical erosion test conditions). Wear ratio for Ni-Cr-Si-B coating was found in range of 1.4-2.8 under different test conditions. The microstructure and microhardness study of coating has been reported and attempts have been to discuss wear behavior in light of microstructure and microhardness. Scanning electron microscope (SEM) study of wear surface showed that loss of material from the coating surface takes place by indentation, crater formation and lip formation and its fracture. *Practical implications* It would assist in estimating the erosion wear performance of flame sprayed Ni-Cr coatings and their affects of wear resistance. *Originality/value* Erosion wear of flame sprayed coatings in sand slurry media medium is substantiated by extensive SEM study. Copyright: Emerald Group Publishing Limited.

R. Arji, D.K. Dwivedi, and S.R. Gupta, Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee, India. Cited: *Ind. Lubr. Tribol.*, 2009, **61**(1), p 4-10. ISSN 0036-8792.

The role of microstructure in the mechanism of high velocity erosion of Cr_3C_2-NiCr thermal spray coatings: Part 1—As-sprayed coatings. Carbide based thermal spray coatings are routinely applied to mitigate erosion under industrial conditions. However, the mechanism of erosion response under aggressive high velocity impact conditions remains unclear. In this work Cr_3C_2-25%NiCr thermal spray coatings were eroded at an impact velocity of 150 m/s by 20-25 μm alumina grit. Coatings were deposited by High Velocity Air Fuel (HVAF) and High Velocity Oxygen Fuel (HVOF) thermal spray techniques to generate a range of coating quality spanning that applied industrially. In Part 1 of this two-part series, the mechanism of erosion as a function of coating composition and microstructure variation is discussed. The HVOF coating underwent significant in-flight dissolution of the carbide phase. The erosion response of the supersaturated NiCr matrix was characterised by brittle cracking and fracture. The HVAF coating retained a high carbide content with minimal phase dissolution. However, the rapid solidification of the matrix material made the coating prone to brittle interphase cracking during impact. On a larger scale, splat based erosion mechanisms played a significant role, especially in the HVOF coating. The mechanisms of impact response of these coatings were dependent upon the depth of erodent penetration and could not, therefore, be extrapolated from erosion testing at lower velocities. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Matthews, B. James, and M. Hyland, School of Engineering and Advanced Technology, Massey University, Auckland, New Zealand. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1086-1093. ISSN 0257-8972.

The role of microstructure in the mechanism of high velocity erosion of Cr_3C_2-NiCr thermal spray coatings: Part 2—Heat treated coatings. In Part 1 of this two part series the variation in erosion mechanisms as a function of as-sprayed coating microstructure was presented. The oxidation resistance of Cr_3C_2-NiCr coatings means that they are used in high temperature applications where WC-Co based systems are no longer suitable. High temperature exposure has been shown to generate microstructural development in these coatings, leading to variations in coating hardness. In this work the effect of such coating development on the high velocity erosion response is investigated. The HVAF and HVOF coatings of Part 1 were heat treated for up to 30 days at 900 °C to generate a range of coating microstructures up to steady state. Erosion was performed under the same conditions as in Part 1. Heat treatment increased the ductility of the NiCr phase, enabling ductile erosion deformation to occur. Intersplat sintering reduced the significance of splat based erosion mechanisms and forced mass loss to become dictated by the phase microstructure. Such developments improved the quantified erosion resistance of both coating systems relative to the as-sprayed conditions. The coating microhardness was shown to be a poor indicator of erosion response across the range of coating microstructures investigated. Copyright: 2008 Elsevier B.V. All rights reserved.

S. Matthews, B. James, and M. Hyland, School of Engineering and Advanced Technology, Massey University, Auckland, New Zealand. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1094-1100. ISSN 0257-8972.

Tribological studies on PVD/HVOF duplex coatings on Ti6Al4V substrate. In the present work, tribological performances of duplex coatings (Ti/TiN PVD and WC-Co HVOF) on Ti6Al4V substrates were investigated by analytical modelling and experimental assessment of mechanical/tribological properties. An analytical study of the contact stress distribution under a spherical indenter was performed, considering changes in stress distribution after adoption of the WC-Co intermediate coating as a load support layer. Experimental activities consisted of micro- and nanoindentation testing, HRC adhesion test and ball-on-disc sliding wear test (Alumina counterpart) under dry atmosphere. Morphology of the worn surface and layer failure mechanisms (i.e., wear mechanisms, coating surface and sub-surface delamination, crack propagation modes, role of interfaces) were then analysed by FIB-SEM techniques. Results showed that the use of a WC-Co interlayer with intermediate hardness and stiffness provides a more effective distribution of contact strain, with a significant increase of load carrying capacity and wear resistance of samples. A correlation between results of simulations, H/E and H^3/E^2 ratios and wear resistance of coatings is finally proposed. Copyright: 2008 Elsevier B.V. All rights reserved.

E. Bemporad, M. Sebastiani, M.H. Staia, and E. Puchi Cabrera, University of Rome ROMA TRE, Mechanical and Industrial Engineering Department, 00146 Rome, Italy. Cited: *Surf. Coat. Technol.*, 2008, Dec 25, **203**(5-6), p 566-571. ISSN 0257-8972.

Wear characterization of thermal spray welded Ni-Cr-B-Si-RE alloy coatings. The present contribution reports the tribological properties of Ni-Cr-B-Si-RE alloy coatings, thermal spray welded onto steel substrate. A study was conducted that characterized the critical normal loads and sliding speed on the wear behavior of a Ni-Cr-B-Si-RE alloy. The worn surfaces of the Ni-Cr-B-Si-RE alloy coatings were examined with a field emission gun scanning electron microscopy (FEGSEM), energy dispersive spectroscopy (EDS) and x-ray photoelectron spectroscopy (XPS). The results show that an adhered oxide debris layer was formed on the worn surface in friction which contributed to decreased wear. Wear rate of the coatings increased with the load, but decreased with the sliding speed in the range of 0.02-0.08 m/s, then increases a little at 0.1 m/s sliding speed. The average friction coefficient is about 0.48, and decreased with the load, but increased with sliding speed at first, and then tended to slight decrease. Wear mechanism is dominated by a large amount of counterpart material transferred to the coating. Copyright: 2008 Elsevier B.V. All rights reserved.

Z. Zhang, Z. Wang, and B. Liang, Mechanical Engineering Department, Lanzhou Polytechnical College, Lanzhou, Gansu 730050, China. Cited: *J. Mater. Process. Technol.*, 2009, Feb 1, **209**(3), p 1368-1374. ISSN 0924-0136.

Mechanical

Anelastic behavior of plasma-sprayed zirconia coatings. Low-temperature thermal cycling of plasma-sprayed zirconia coatings reveals unique mechanical responses in their curvature measurements, namely nonlinear and cyclic hysteresis, collectively termed as anelastic. These features arise from the inherent layered, porous, and cracked morphology of thermal-sprayed ceramic materials. In this paper, the mechanisms of anelasticity are characterized by crack closure and frictional sliding models, and stress-strain relations of various thermal-sprayed zirconia coatings were determined via an inverse analysis procedure. These results demonstrate process conditions such as powder morphology and spray parameters significantly influence the mechanical behaviors of coatings. The unique anelastic responses can be used as valuable parameters in identifying coating quality as well as process reliability in manufacturing. Copyright: 2008 The American Ceramic Society.

Y. Liu, T. Nakamura, G. Dwivedi, A. Valarezo, and S. Sampath, Department of Mechanical Engineering, Center for Thermal Spray Research, State University of New York at Stony Brook, NY 11794. Cited: *J. Am. Ceram. Soc.*, 2008, December, **91**(12), p 4036-4043. ISSN 0002-7820.

Deposition and characterization of HVOF thermal sprayed functionally graded coatings deposited onto a lightweight material. There is a significant interest in lightweight materials (like aluminum, magnesium, titanium, and so on) containing a wear resistance coating, in such industries as the automotive industry, to replace heavy components with lighter parts in order to decrease vehicle weight and increase fuel efficiency. Functionally graded coatings, in which the composition, microstructure, and/or properties vary gradually from the bond coat to the top coat, may be applied to lightweight materials, not only to decrease weight, but also to enhance components mechanical properties by ensuring gradual microstructural (changes) together with lower residual stress. In the current work, aluminum/tool-steel functionally graded coatings were deposited onto lightweight aluminum substrates. The graded coatings were then characterized in terms of residual stress and hardness. Results show that residual stress increased with an increase in deposition thickness and a decrease in number of layers. However, the hardness also increased with an increase in deposition thickness and decrease in number of layers. Therefore, an engineer must compromise between the hardness and stress values while designing a functionally graded coating-substrate system. Copyright: 2008 ASM International.

M. Hasan, J. Stokes, L. Looney, and M.S.J. Hashmi, Materials Processing Research Centre (MPRC), Dublin City University, Dublin, Ireland. Cited: *J. Mater. Eng. Perform.*, 2009, February, **18**(1), p 66-69. ISSN 1059-9495.

Fatigue strength of HVOF sprayed Cr_3C_2-25NiCr and WC-10Ni on AISI 4340 steel. The fatigue strength of coated material is significantly influenced by internal residual stresses. Chromium coatings are used in applications to guarantee protection against wear and corrosion, combined with chemical resistance and good lubricity. The reduction in the fatigue strength of base material and since this technology presents detrimental environmental and health effects, resulted in the search on coatings viewed as being capable of replacing hard chrome plating. Thermally sprayed HVOF coatings are being considered to replace galvanic chromium deposits in industrial applications with, at least, comparable performance with respect to wear and corrosion resistance. The aim of the present study is to compare the influence of Cr_3C_2-25NiCr and WC-10Ni coatings applied by HVOF process and hard chromium electroplating on the fatigue strength, abrasive wear and corrosion resistance of AISI 4340 steel. S-N curves were obtained in axial fatigue tests for base material, chromium plated and HVOF coated specimens. Experimental data showed higher axial fatigue resistance for HVOF coated specimens in comparison to electroplated chromium. The wear weight loss tests indicated better results for the HVOF thermal spray processing in comparison to the chromium electroplating. An increase in the corrosion resistance of steel protected with WC-10Ni HVOF coatings occurred with increased coating thickness. For Cr_3C_2-25NiCr HVOF coating, results indicate clearly the higher salt spray resistance. Copyright: 2008.

R.C. Souza, H.J.C. Voorwald, and M.O.H. Cioffi, Fatigue and Aeronautical Materials Research Group-Department of Materials and Technology, UNESP, CEP 12516 410 Guaratingueta, SP, Brazil. Cited: *Surf. Coat. Technol.*, 2008, Nov 25, **203**(3-4), p 191-198. ISSN 0257-8972.

Mechanical-indentation analysis of the microstructure and properties of plasma-sprayed ZrO_2-based coatings. The relationship between the mechanical properties of plasma-sprayed thermal-barrier coatings and the properties of feedstock powders is studied. These powders have the same chemical composition and are obtained by hydroxide coprecipitation followed by air-drying and by a cryochemical method. Information on TBC failure mechanisms is used to pose and solve the problem of increasing the plasticity and, consequently, the stress relaxation coefficient of the ceramic coating. The finer structure of the cryochemical powder sprayed coating also improves its crack-resistance. The minor reduction in the hardness of the cryopowder-sprayed coating should not deteriorate the performance of the thermal-barrier coating. Copyright: 2008 Springer Science+Business Media, Inc.

V.Y. Oliker, A.A. Pritulyak, V.F. Gorban, and V.L. Sirovatka, Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Kiev, Ukraine. Cited: *Powder Metall. Met. Ceram.*, 2008, July, **47**(7-8), p 477-481. ISSN 1068-1302.

Microhardness variation in heat-treated conventional and nanostructured NiCrC coatings prepared by HVAF spraying. A nanostructured NiCrC coating for high temperature erosion-corrosion protection was prepared by high velocity air-fuel (HVAF) spraying. While previous studies on nanostructured materials were most focused on the short-term development in microstructure and properties during heat treatment, no systematic investigation of the microhardness variation as a function of microstructural development

during long-term heat treatment has been presented. In this work, HVAF-sprayed nanostructured NiCrC coating was heat treated at 650 °C for up to 200 h in air. The coating microstructures have been characterized by scanning electron microscopy, transmission electron microscopy, high resolution scanning electron microscopy and x-ray diffraction analysis. A Vickers microhardness tester was employed to determine the hardness variation of the coatings. In addition, conventional coarse-grained NiCrC coating produced by HVAF technique with the identical composition was also studied for comparison. The results indicated that the nanostructured NiCrC coating possessed a very compact and uniform microstructure, and exhibited good thermal stability during long-term heat treatment. The grain growth during thermal exposure caused the softening of the coating; however the carbide precipitation and content increasing resulted from phase transformation compensated the decrease by grain coarsening, and further led to the increase in the overall coating hardness. Copyright: 2008 Elsevier B.V. All rights reserved.

K. Tao, X. Zhou, H. Cui, and J. Zhang, State Key Laboratory for Advanced Metals and Materials, University of Science and Technology Beijing, Beijing 100083, China. Cited: *Surf. Coat. Technol.*, 2009, Feb 25, **203**(10-11), p 1406-1414. ISSN 0257-8972.

Young's modulus measurement and study of the relationship between mechanical properties and microstructure of air plasma sprayed alloy 625. The present study is a continuation of the previous research on fabrication of sandwich structures suitable for high temperature applications. The overall performance of sandwich constructions depends on the material properties of skin and core, and their geometrical characteristics. The sandwich structure consisting of a Ni alloy foam covered by alloy 625 is expected to be a good candidate for high temperature applications. Amongst various methods of applying alloy 625 skin on the foam core, thermal spray techniques are the most promising for the rapid deposition of thick sections on the both sides of the foam structure. Microstructural characteristics of alloy 625 coatings on Ni alloy foam have been previously reported. The objective of this investigation was to characterize the mechanical behavior of air plasma sprayed (APS) alloy 625 coatings deposited on Ni alloy foam. The results of tensile tests performed on the free standing as-sprayed and heat treated alloy 625 coating samples are reported. Furthermore this paper examines the available models relating the microstructure to the elastic modulus, E, of the coatings to predict mechanical behavior of alloy 625 coating. Finally, numerical results from finite element analyses performed on the coatings are presented in this study. Comparison between the results of the tensile tests, theoretical models, and numerical simulations obtained from finite element methods will help us to understand microstructural basis of the mechanical characteristics of alloy 625 coating structure. Copyright: 2008 Elsevier B.V. All rights reserved.

F. Azarmi, T. Coyle, and J. Mostaghimi, Department of Mechanical Engineering and Applied Mechanics, North Dakota State University. Cited: *Surf. Coat. Technol.*, 2009, Jan 15, **203**(8), p 1045-1054. ISSN 0257-8972.

Oxidation

High performance SiC oxidation protective coating with ZrO_2 particle dispersion for carbon/carbon composites. A study was conducted to demonstrate the preparation of a novel and effective silicon carbide (SiC) oxidation protective coating with ZrO_2 for carbon/carbon (C/C) composites by slurry and pack cementation. The microstructure and the oxidation resistance of the as-prepared coating at 1873 K in air were mainly investigated. ZrO_2 is provided with high melting point, and its toughening mechanism of phase transformation at high temperature can increase the toughness of SiC coating. Introducing the ZrO_2 particles into the SiC coating could effectively improve the high temperature oxidation resistance of SiC coating. After oxidation in air at 1873 K for 100 h and thermal cycling between 1873 K and room temperature for 8 cycles, the weight loss of the coated sample was only 1.75%. The weight loss of the coated specimen can also be attributed to the formation of holes and microcracks in the coating. (Edited abstract)

Y.-L. Zhang, H.-J. Li, Q.-G. Fu, and K.-Z. Li, Carbon/Carbon Composites Research Center, Northwestern Polytechnical University, Xi'an 710072, China. Cited: *Adv. Eng. Mater.*, 2008, October, **10**(10), p 986-989. ISSN 1438-1656.

Review

Application variables for arc-spray coatings: a review. A report, entitled, 'An Evaluation of Application and Surface Preparation Parameters for Thermal Spray Coatings', reviews several variables that can affect the quality of arc-spray metal coatings. The report deals with the findings of the US Army Corps of Engineers investigations of the application variables of these coatings on steel. The review focuses on arc-spray metal coating, due to its portability and better production rate. Some of these variables, include the equipment and its setup, spray parameters, and surface preparation. It is suggested that a review of variables that affect the quality of applications of arc-spray metal coatings, can be useful to owners and specifiers, as the application of metallizing increases in the field. Some of the equipment variables investigated, include the actual equipment used and type of metal and wire diameter. (Edited abstract)

T. Race, Kaked, LLC. Cited: *J. Protect. Coat. Linings*, 2008, December, **25**(12), p 39-43. ISSN 8755-1985.

Barrier coatings for type C/SiC ceramic-matrix composites (Review). The change in the compositions of thermal barrier and antioxidant coatings for C-SiC composite materials was examined. Data are reported on the compositions and properties of bi-, tri-, and multilayer coatings. The mechanism of the barrier effect of several compositions is elucidated. The prospects for use of the new compositions of barrier coatings for increasing the temperature of use of the composite materials are demonstrated. Copyright: 2008 Springer Science+Business Media, Inc.

P.D. Sarkisov, N.V. Popovich, L.A. Orlova, and Y.E. Anan'eva, D. I. Mendeleev Russian Chemical Engineering University, Moscow, Russian Federation. Cited: *Glass Ceram. (English translation of Steklo i Keramika)*, 2008, September, **65**(9-10), p 366-371. ISSN 0361-7610.

Warm spraying—a novel coating process based on high-velocity impact of solid particles. In recent years, coating processes based on the impact of high-velocity solid particles such as cold spraying and aerosol deposition have been developed and attracting much industrial attention. A novel coating process called 'warm spraying' has been developed, in which coatings are formed by the high-velocity impact of solid powder particles heated to appropriate temperatures below the melting point of the powder material. The advantages of such process are as follows: (1) the critical velocity needed to form a coating can be significantly lowered by heating, (2) the degradation of feedstock powder such as oxidation can be significantly controlled compared with conventional thermal spraying where powder is molten, and (3) various coating structures can be realized from porous to dense ones by controlling the temperature and velocity of the particles. The principles and characteristics of this new process are discussed in light of other existing spray processes such as high-velocity oxy-fuel spraying and cold spraying. The gas dynamics of particle heating and acceleration by the spraying apparatus as well as the high-velocity impact phenomena of powder particles are discussed in detail. Several examples of depositing heat sensitive materials such as titanium, metallic glass, WC-Co cermet and polymers are described with potential industrial applications. Copyright: 2008 National Institute for Materials Science.

S. Kuroda, J. Kawakita, M. Watanabe, and H. Katanoda, Composites and Coatings Center, National Institute for Materials Science, Tsukuba, Ibaraki 305-0047, Japan. Cited: *Sci. Technol. Adv. Mater.*, 2008, Jul 1, **9**(3). ISSN 1468-6996.