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Selected Abstracts of Thermal Spray Literature

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Applications

Biomaterials and Bioactive Materials

Chemical treatment for inducing bioactivity of TiO_2 coating. In this work, nano-TiO_2 powders were deposited onto Ti-6Al-4V substrates to produce coating using plasma spraying. The TiO_2 coatings were, respectively, by acid, alkali, and heat treatment to produce the bioactive surface. The bioactivity of TiO_2 coating was examined by simulated body fluids test. The results obtained indicated apatite was formed on the surfaces of nano-TiO_2 coatings treated by H_2SO_4, HCl, and HF solutions, while it could not be formed on the surface of the nano-TiO_2 coating treated by NaOH solution at low concentration. After alkali attack and heat treatment at 600 °C, the bioactivity of nano-TiO_2 coating disappeared.

Keywords: acid treatment, alkali treatment, bioactive surface, bioactivity, chemical modification, chemical treatment, computer simulation, nanostructured materials, plasma spraying, substrates, titanium dioxide

X. Zhao, X. Liu, B. Li, and C. Ding, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China. Cited: *Key Eng. Mater.*, 2007, **330-332**, p 745-748. ISSN 1013-9826.

The experiment of plasma sprayed HA coatings on carbon/carbon composites in bone. This paper dealt with plasma sprayed hydroxyapatite (HA) coatings on carbon/carbon composites (C/C) and the implantation was carried out in rabbits. Ninety days after the implantation, we found that such materials were favorable for health and no cytotoxic effects were discovered. The histological observation of osteogenic response of HA-coated C/C showed that the osteoplaque had scansorially grown along the surface of the HA coatings and the pure C/C surface had no obvious change. All these results indicate that as a potential bone-repairing material, the surface properties of the C/C have been changed by preparing the HA coatings. Also, the new materials may be preferably feasible of clinical application.

Keywords: bone, carbon-carbon composites, clinical application, coatings, histology, hydroxyapatite, implantation, osteogenic response, plasma spraying, rabbits, surface properties

N. Cao, Q.-S. Ma, J.-L. Sui, Q.-X. Wang, Y.-P. Lu, Y.-M. Chen, and M.-S. Li, School of Materials Science and Engineering, Shandong Univ., Jinan 250061, China. Cited: *Surf. Rev. Lett.*, 2006, Aug, **13**(4), p 423-428. ISSN 0218-625X.

Flame sprayed visible light-active Fe-TiO_2 for photomineralization of oxalic acid. Visible light-active Fe-doped TiO_2 was prepared by a one-step flame spray pyrolysis (FSP) technique. The properties of the photocatalysts were characterized by UV-vis diffuse-reflectance spectroscopy, x-ray diffraction (XRD), x-ray photoelectron spectroscopy (XPS), nitrogen adsorption (BET), transmission electron microscope (TEM), and zeta potential techniques. Being a bottom-up approach, the short residence time coupled with rapid quenching during FSP resulted in homogeneous Fe-doped TiO_2 for Fe/Ti ratios approximately up to 0.05. This is five times higher than that reported for particles synthesized by conventional wet techniques followed by high-temperature annealing. Under visible light irradiation ($\lambda > 400$ nm), the rate of oxalic acid mineralization by Fe-doped TiO_2 (Fe/Ti = 0.05) was 6.4 times higher than that of similarly prepared bare TiO_2 and Degussa P25. A unique Fe-leaching and re-adsorption properties were observed during the reaction. Unlike the system of bare TiO_2 spiked with dissolved Fe(III) ions, the FSP Fe-doped TiO_2 photocatalyst was found to be stable and reusable after each run with minimal loss of Fe from the surface.

Keywords: flame spray pyrolysis, flame spraying, iron compounds, nitrogen adsorption, oxalic acid, photocatalysis, pyrolysis, synthesis (chemical), titanium dioxide, transmission electron microscopy, wet techniques, x-ray diffraction

W.Y. Teoh, R. Amal, L. Madler, and S.E. Pratsinis, ARC Centre for Functional Nanomaterials, School of Chemical Engineering and Industrial Chemistry, The Univ., of New South Wales, Sydney, NSW 2052, Australia. Cited: *Catal. Today*, 2007, Feb 15, **120**(2), p 203-213. ISSN 0920-5861.

Novel hydroxyapatite/tantalum surface coating for metallic dental implant. The aim of this study was to design and produce a novel surface composite coating on metallic substrate to improve the biocompatibility of metallic dental implant and the bone osteointegration simultaneously. Stainless steel 316L (SS) was used as a metallic substrate and a novel double-layer hydroxyapatite/tantalum (HA/Ta) coating was prepared on it. Tantalum coating was made using physical vapor deposition process and HA coating was produced using plasma spraying technique on it. X-ray diffraction (XRD) and scanning electron microscopy (SEM) techniques were utilized to investigate the coating characterization. Electrochemical polarization tests were performed in two types of physiological solutions at 37 ± 1 °C to determine the corrosion behavior of the coated and uncoated specimens as indication of biocompatibility. The results indicated that the decrease in corrosion current density was significant for HA/Ta-coated specimens and was much lower than the value obtained for uncoated 316L SS. The novel double-layer HA/Ta composite coating could improve the corrosion resistance and thus the biocompatibility of 316L SS dental implant.

Keywords: biocompatibility, coating techniques, corrosion behavior, corrosion resistance, dental prostheses, hydroxyapatite, hydroxyapatite coating, physical vapor deposition, physiological solutions, surface coating, tantalum, x-ray diffraction

M.H. Fathi and F. Azam, Materials Engineering Department, Isfahan Univ. of Technology, Isfahan 84154, Iran. Cited: *Mater. Lett.*, 2007, Feb, **61**(4-5), p 1238-1241. ISSN 0167-577X.

Plasma sprayed carbon nanotube reinforced hydroxyapatite coatings and their interaction with human osteoblasts in vitro. Carbon nanotubes (CNT) possess excellent mechanical properties to play the role as reinforcement for imparting strength and toughness to brittle hydroxyapatite (HA) bioceramic coating. However, lack of processing technique to uniformly distribute multiwalled CNTs in HA coating and limited studies and sparse knowledge evincing toxicity of CNTs has kept researchers in dispute for long. In the current work, we have addressed these issues by (i) successfully distributing multiwalled CNT reinforcement in HA coating using plasma spraying to improve the fracture toughness (by 56%) and enhance crystallinity (by 27%), and (ii) culturing human osteoblast hFOB 1.19 cells onto CNT reinforced HA coating to elicit its biocompatibility with living cells. Unrestricted growth of human osteoblast hFOB 1.19 cells has been observed near CNT regions claiming assistance by CNT surfaces to promote cell growth and proliferation.

Keywords: bioceramic coatings, biocompatibility, carbon nanotubes, cells, crystallinity, growth kinetics, human osteoblasts, hydroxyapatite, hydroxyapatite coatings, inorganic coatings, mechanical properties, plasma spraying, reinforcement, titanium alloys

K. Balani, R. Anderson, T. Laha, M. Andara, J. Tercero, E. Crumpler, and A. Agarwal, Department of Mechanical and Materials Engineering, Florida International Univ., Miami, FL 33174. Cited: *Biomaterials*, 2007, Feb, **28**(4), p 618-624. ISSN 0142-9612.

Direct Write

Interdigital capacitive strain gauges fabricated by direct-write thermal spray and ultrafast laser micromachining. There is a growing demand for in situ monitoring of strain in high-temperature, harsh environment systems. Resistive strain gages, while popular and easy to implement, have several disadvantages when used at high temperatures. This work presents the design, fabrication, and initial testing of capacitive strain gages for use in high-temperature, harsh environments. The gages are fabricated using a direct-write thermal spray technology in which a computer-controlled deposition system is used to fabricate silver gage patterns onto polymer, composite, and alumina substrates to form the strain gages. Gages were also fabricated using ultrafast laser micromachining of blanket NiCr coatings thermal sprayed onto an alumina substrate. The typical gauge capacitance was 4-25 pF. Mechanical measurements performed included gauge factor, linearity, and zero shift. Temperature-based measurements include the temperature coefficient of capacitance (TCC) and thermal cycling tests. The devices show promise for use in harsh environments and in wireless strain monitoring applications.

Keywords: alumina, capacitance, capacitive strain gages, direct-write fabrication, embedded sensors, harsh environment, laser applications, laser micromachining, micromachining, strain gages, thermal effects, thermal spray

J. Li, J.P. Longtin, S. Tankiewicz, A. Gouldstone, and S. Sampath, Department of Mechanical Engineering, State Univ. of New York at Stony Brook, Stony Brook, NY 11794. Cited: *Sensors Actuators, A: Phys.*, 2007, Jan 8, **133**(1), p 1-8. ISSN 0924-4247.

Fluidized Bed

Protective spray coatings in fluidized bed systems. The continuous fluidization of solid substances (ash, coal, limestone, etc.) in fluidized bed systems results in abrasion, erosion, and even corrosion of the individual equipment components. Various protective measures are used, depending on

the conditions of usage and geometry of the parts at risk. These include cladding, small metal pins coupled with a ceramic mass, half-pipes, and SiC tiles, as well as various forms of coatings, including thermal spray coatings.

Keywords: ceramic mass, ceramic materials, corrosion resistance, equipment components, fluidized beds, protective coatings, solid substances, spraying, thermal spray coatings, wear resistance

R. Jurgensen and E. Protogerakis, Bayer Industry Services, Leverkusen, Germany. Cited: *VGB Power Technol.*, **86**(12), p 42-45, 48, 49. ISSN 1435-3199.

Marine Applications

Thermally sprayed aluminum and zinc coatings for tidal zone cathodic protection of offshore platform pile legs. The performance of thermally sprayed aluminum and zinc coatings in providing effective corrosion protection for steel structures and offshore platform pile legs was analyzed. Aluminum coatings had the advantage of passive film formation that lowers the rate of uniform corrosion. Zinc coatings remained active in most waters, enabling them to provide effective cathodic protection over a period of time. The zinc-aluminum thermal spray coatings combined the electrochemical activity of the zinc coatings and the long-term protection of aluminum coatings. The preparation of the substrate surface was important for corrosion prevention by thermally sprayed metallic coatings. The blasted surface should have a white metal blast appearance with an anchor-tooth surface profile of 50-75 μm. It was observed that the most effective protective method was to spray a zinc coating first, then an aluminum coating, and finally sealed the metal coatings with an organic coating.

Keywords: aluminum cladding, blasted surface, cathodic protection, corrosion prevention, electrochemical activity, electrochemistry, metallic coatings, offshore platform pile legs, offshore structures, organic coating, spraying, steel structures, thermal spray, thin films, tides, zinc

Y. Li, L. Jianguo, D. Jizhou, and H. Baorong, Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China. Cited: *Mater. Perform.*, 2006, Dec, **45**(12), p 16-19. ISSN 0094-1492.

Polymers

Effect of crystalline structure on the hardness and interfacial adherence of flame sprayed poly(ether-ether-ketone) coatings. Flame sprayed PEEK (poly-ether-ether-ketone) coatings, with an amorphous structure, were subjected to isothermal treatments with annealing temperatures from 180 to 300 °C and holding times from 1 to 30 min. The coating structures were studied by means of differential scanning calorimetry (DSC) and x-ray diffraction (XRD) analyses. All the annealed coatings exhibited semicrystalline structures. Coexistence of thick and thin lamellas in the spherulites of annealed coatings can be deduced. The Knoop hardness and the interfacial adhesion of the coatings were examined. The annealed coatings exhibit higher hardness than the amorphous one. The formation of the thick lamellas is a determining factor for improving the coating hardness, which could restrict the motions and slippages of the polymer chains. However, the annealed coatings exhibit a weak adherence to the substrate. Some fissures or spherical porosities could be observed, in certain zones, on the coating/substrate interface. The formation of these fissures and porosities could be ascribed to the coating residual stress and the large volume contraction during the crystallization that occurred under the annealing conditions.

Keywords: amorphous structure, crystal structure, differential scanning calorimetry, flame spraying, hardness, interfacial adhesion, organic coatings, polyether ether ketone coatings, polyether ether ketones, spherulites, surface chemistry, x-ray diffraction

G. Zhang, H. Liao, M. Cherigui, J. Paulo Davim, and C. Coddet, Laboratoire d'Etudes et de Recherches sur les Materiaux, les Procedes et les Surfaces, Universite de Technologie de Belfort—Montbeliard, 90010 Belfort, France. Cited: *Eur. Polymer J.*, 2007, March, **43**(3), p 1077-1082. ISSN 0014-3057.

Solar Cells

Influence of $TiCl_4$ treatment on performance of dye-sensitized solar cell assembled with nano-TiO_2 coating deposited by vacuum cold spraying. Titanium tetrachloride ($TiCl_4$) treatment was employed to TiO_2 coating deposited on fluoride-doped tin oxide (FTO) conducting glass and indium oxide doped tin oxide (ITO) conducting glass, respectively. The nanocrystalline TiO_2 coating was deposited using a composite powder composed of polyethylene glycol (PEG) and 25 nm TiO_2 particles by vacuum cold spraying (VCS) process. A commercial N-719 dye was used to adsorb on the surface of TiO_2 coating to prepare TiO_2 electrode, which was applied to assemble dye-sensitized solar cell (DSC). The cell performance was measured under simulated solar light at an intensity of 100 mW/cm^2. Results show that with an FTO substrate the DSC composed of a VCS TiO_2 electrode untreated by $TiCl_4$ gives a short-circuit current density of 13.1 mA/cm^2 and an open circuit voltage of 0.60 V corresponding to an overall conversion efficiency of 4.4%. It is found that after $TiCl_4$ treatment to the VCS TiO_2 electrode with an FTO substrate, the short circuit current density of the cell increases by 31%, the open-circuit voltage increases by 60 mV and a higher conversion yield of 6.5% was obtained. However, when an ITO substrate is used to deposit TiO_2 coating by VCS, after $TiCl_4$ treatment, the conversion efficiency of the assembled cell reduces slightly due to corrosion of the conducting layer on the ITO glass by $TiCl_4$.

Keywords: coatings, dyes, electrodes, nanostructured materials, short-circuit currents, solar cells, spraying, titanium dioxide, titanium tetrachloride treatment, vacuum cold spraying

S. Fan, C. Li, G. Yang, and L. Zhang, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong Univ., Xi'an 710049, China. Cited: *Rare Metals*, 2006, Oct **25**(6 suppl. 1), p 163-168. ISSN 1001-0521.

Solid Oxide Fuel Cells

Influence of characteristics of stabilized zirconia electrolyte on performance of cermet supported tubular SOFCs. M-Al_2O_3 cermet supported tubular SOFC was fabricated by thermal spraying. Flame sprayed Al_2O_3-Ni cermet coating plays dual roles of a support tube and an anode current collector. 4.5 mol% yttria-stabilized zirconia (YSZ) and 10 mol% scandia-stabilized zirconia (ScSZ) coatings were deposited by atmospheric plasma spraying (APS) as the electrolyte in present study. The electrical conductivity of electrolyte was measured using DC method. The post-treatment was employed using nitrate solution infiltration to densify APS electrolyte layer for improvement of gas permeability. The electrical conductivity of electrolyte and the performance of single cell were investigated to optimize SOFC performance. The electrical conductivity of the as-sprayed YSZ and ScSZ coating is about 0.03 and 0.07 S/cm^1 at 1000 °C, respectively. The ohmic polarization significantly influences the performance of SOFC. The maximum output power density at 1000 °C increases from 0.47 to 0.76 W/cm^2 as the YSZ electrolyte thickness reduces from 100 to 40 μm. Using APS ScSZ coating of about 40 μm as the electrolyte, the test cell presents a maximum power output density of over 0.89 W/cm^2 at 1000 °C.

Keywords: coatings, electric conductivity, electrolytes, plasma spraying, scandia-stabilized zirconia, solid oxide fuel cells, x-ray diffraction analysis, yttria-stabilized zirconia, zirconia

C. Li, C. Li, Y. Xing, Y. Xie, and H. Long, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong Univ., Xi'an 710049, China. Cited: *Rare Metals*, 2006, Oct., **25**(6 suppl. 1), p 273-279. ISSN 1001-0521.

Diagnostics and Control

Effect of powder loading on the excitation temperature of a plasma jet in DC thermal plasma spray torch. A DC nontransferred mode plasma spray torch was fabricated for plasma spheroidization. The effect of powder-carrier gas and powder loading on the temperature of the plasma jet generated by the torch has been studied. The experiment was done at different input power levels; the temperature of the jet was within 5000-7000 K argon was used as plasma gas and powder-carrier gas. Nickel powder particles in the size range from 40 to 100 μm were processed. The temperature of the jet was estimated after flowing powder-carrier gas only into the plasma jet and with powder-carrier gas feeding powder into the flame. On introduction of powder-carrier gas and powder loading, the temperature of the jet was found to decrease appreciably down to 11%. The temperature of the plasma jet was estimated using the Atomic Boltzmann plot method.

Keywords: direct-current plasma jet, electric excitation, feeding powder, nickel, plasma diagnostics, plasma jets, plasma spheroidization, plasma spraying, plasma torches, powder loading, powder metals

G. Shanmugavelayutham, V. Selvarajan, P.V.A. Padmanabhan, K.P. Sreekumar, and N.K. Joshi, Plasma Physics Laboratory, Department of Physics, Bharathiar Univ., Coimbatore 641 046, India. Cited: *Curr. Appl. Phys.*, 2007, Feb, **7**(2), p 186-192. ISSN 1567-1739.

Influence of arc instabilities on the injection in suspension plasma spraying. Recent works have shown that suspension plasma spraying (SPS) allows depositing yttria-stabilized zirconia (YSZ) dense coatings for solid oxide fuel cells provided that the powder size distribution and plasma parameters are carefully adapted. This paper presents a further analysis of important SPS parameters that lead to control the interaction plasma jet suspension. A particular attention is paid to the treatment of liquid materials mechanically injected (suspension jet or drops) according to different working parameters such as the plasma mixture and the injection pressure. Concerning the suspension injection, by observing the suspension drops injection with a fast shutter camera triggered by a defined voltage level of the plasma torch, it is shown that plasma jet fluctuations have a strong influence on drops fragmentation.

Keywords: camera shutters, electric potential, injection pressure, plasma jets, plasma spraying, plasma torches, suspension injection, suspension plasma spraying, suspensions (fluids), yttria stabilized zirconia

R. Etchart-Salas, V. Rat, J.F. Coudert, P. Fauchais, and G. Lafougere, SPCTS-CNRS UMR 6638, Univ. of Limoges, 87060 Limoges Cedex, France. Cited: *High Temp. Mater. Process.*, 2006, **10**(3), p 407-418. ISSN 1093-3611.

Influence of spraying conditions on thermal and velocity properties of plasma sprayed hydroxyapatite. Hydroxyapatite (HA), classified as a bioactive material, was proven to be well suitable for orthopedic and dental applications due to its ability to integrate into bone structures and support bone in-growth. Therefore, it is used as a coating material for common metallic implant materials, which carry most of the load. Covered by a layer of HA, the implants are much better accepted by surrounding tissues. To date, the only reliable method of applying HA coatings to metallic implants is plasma spraying. The aim of this research was to study the conditions to which the HA powder is exposed during spraying, which, in return, highly influence the resulting quality of the final coating. The two main characteristics describing and quantifying the plasma spraying process—temperature and velocity of the HA particles—were investigated. To study the changes of both characteristics under different spraying conditions, Taguchi design of experiment together with analysis of variance (ANOVA) method were utilized. Results showed the three main parameters influencing the powder particles' in-flight properties are gun power, main gas flow, and spraying distance, while other parameters have a little (feed rate) or no effect (auxiliary gas).

Keywords: dental prostheses, dentistry, flow of fluids, gun power, hydroxyapatite, in-flight properties, orthopedics, plasma spraying

J. Cizek, K.A. Khor, and Z. Prochazka, School of Mechanical and Aerospace Engineering, Nanyang Technological Univ., Singapore, Singapore. Cited: *Mater. Sci. Eng. C*, 2007, March, **27**(2), p 340-344. ISSN 0928-4931.

Plasma spray process on-line control by artificial intelligence methodology. The development of a model-based estimation and control for regulating the particle average velocity and temperature is discussed. Plasma sprayed coating structure and in-service properties depend on the in-flight particle average characteristics. It is also dependent on the plasma jet thermodynamic properties and transport coefficients, which are controlled by the operating process parameter. Methodologies based in artificial intelligence (AI) appear as the more robust method to define and control the complex correlation between in-flight particle characteristics and the power process.

Keywords: artificial intelligence, correlation methods, particle size analysis, plasma jets, plasma sprayed coatings, plasma spraying, process parameters, sprayed coatings, thermodynamic properties, transport coefficients

A.-F. Kanta, G. Montavon, M.-P. Planche, and C. Coddet, Laboratoire d'Etudes et de Recherches sur les Materiaux les Procedes et les Surfaces (LERMPS), Universite de Technologie de Belfort-Montbeliard (UTBM), Site de Sevenans, 90010 Belfort Cedex, France. Cited: *Adv. Eng. Mater.*, 2007, Jan, **9**(1-2), p 105-113. ISSN 1438-1656.

Manufacturing

Investigation on the cutting performance of the superalloy with thermal sprayed coatings. In order to enhance the surface performance of some key parts, the technology of thermal spraying is often used in practice. By spraying superalloy powder on the surface, the parts can get good resistance to wear, corrosion, and high temperature, but how to machine these parts has become a difficult problem in production. In this paper, the cutting performance of two kinds of superalloys with thermal sprayed coatings (FZNCr-60A and BKHA) is systematically studied through some turning experiment. According to the comparison of cutting force in using different kinds of blades in the turning experiment, it is found that the better effect can be got by using the blade with bigger rake angle to turn the relative coating materials. On the basis of orthogonal turning experiment, the cutting force under the different cutting parameters has been measured, the changing rule of cutting force has been analyzed, and the empirical formula of cutting force has been presented. By summarizing the effect of cutting parameters and other factors to the turning performance of these materials, it will provides useful reference for cutting these kinds of super alloy with thermal sprayed coatings in production.

Keywords: corrosion resistance, cutting, cutting forces, empirical formulas, machining, orthogonal turning, sprayed coatings, superalloys, thermal spraying, wear resistance

D.L. Wang and X. Li, Key Laboratory for Precision and Non-traditional Machining Technology, Ministry of Education, Dalian Univ. of Technology, Dalian, China. Cited: *Key Eng. Mater.*, 2007, **329**, p 749-753. ISSN 1013-9826.

A novel arc spraying robot for rapid tooling. In order to reduce the process uncertainty and the labor intensity in manual metal arc spraying for rapid tooling, this paper presents a robot wrist design and a robot motion control method based on the cross-sectional contours and related surface normal vectors extracted from STL model, a de facto standard for representing a 3D part geometry in rapid prototyping (RP) industry. A computer-controlled five-axis robot for the rapid tooling was built by using the wrist, which drives the spraying gun. The wrist comprises a linkage that can maintain the working position of the gun while changing its spraying orientation freely. Such a design ensures that adjusting the gun along the normal of the master surface to satisfy the process requirement will not result in any position change of the spraying point. A kinematic analysis on the wrist indicates this kinematic decoupling between the positioning mechanism and the orientating mechanism. The working trajectory of the gun is generated off-line by slicing the STL model of the master pattern. To bypass the need for any teaching or NC programming, the arc spraying robot can carry out the tooling process automatically and efficiently fully based on the sliced data of the master pattern. In addition, a case study on the production of automobile body panel dies using this robotic tooling system is introduced.

Keywords: arc spraying, automobile body panels, computer aided software engineering, computer programming, inverse kinematics, mathematical models, motion control, rapid tooling, robot wrist design, robotic arms, trajectory planning, vectors

Z. He, B. Lu, J. Hong, Y. Wang, and Y. Tang, State Key Laboratory for Manufacturing Systems Engineering, Xi'an Jiaotong Univ., Xi'an 710049, China. Cited: *Int. J. Adv. Manuf. Technol.*, 2007, Jan, **31**(9-10), p 1012-1020. ISSN 0268-3768.

Measurement Methods

Aging evaluation of thermal barrier coatings by thermal diffusivity. Ceramic thermal barrier coatings (TBCs) are widely applied for protecting from combustion gases hot path components of gas turbines for both aero- and land-based applications. To prevent the detachment of TBC, it would be essential to monitor their degradation in terms of sintering kinetics. As sintering strongly affects also the thermal diffusivity of TBC, the idea is to measure the latter parameter to account for the former. The technique to measure thermal diffusivity using pulsed thermography is described, together with the model that leads to the identification of TBC diffusivity. Tests and results on specimens artificially aged are reported.

Keywords: ceramic materials, combustion, combustion gases, gas turbines, hot path components, pulsed thermography, sintering, thermal barrier coatings, thermal diffusion, thermal diffusivity, thermography (imaging)

P.G. Bison, F. Cernuschi, E. Grinzato, S. Marinetti, and D. Robba, CNR-ITC, 35127 Padova, Italy. Cited: *Infrared Phys. Technol.*, 2007, Jan, **49**(3 spec. issue), p 286-291. ISSN 1350-4495.

Emission spectroscopy analysis for the nondestructive evaluation of the health of thermal barrier coatings. Lithium oxide was selected as an emission spectroscopic marker in yttria-stabilized zirconia (YSZ) thermal barrier coatings (TBCs). The spectral response of excited lithium atoms from dip-coated YSZ containing 5, 3, 1, and 0.3 wt.% lithium oxide and plasma sprayed YSZ containing 1 wt.% lithium oxide was examined under an oxyacetylene flame. Results showed that the intensity of lithium emission spectrum is a function of the concentration of lithium oxide in the YSZ, the flame temperature, and the degree of TBC degradation. It indicates that an emission spectroscopy can be used to monitor the degradation of TBCs.

Keywords: acetylene, emission spectroscopy, lithium compounds, lithium oxide, oxyacetylene flame, plasma spraying, thermal barrier coatings, yttria-stabilized zirconia, yttrium compounds

G. Chen, K.N. Lee, and S.N. Tewari, Chemical Engineering Department, Cleveland State Univ., Cleveland, OH 44115. Cited: *J. Mater. Sci.*, 2006, Oct, **41**(20), p 6855-6860. ISSN 0022-2461.

Pore network architecture in plasma sprayed ceramic coatings. A combination of two techniques was implemented to quantify the morphology and the connectivity of the complex pore-crack network architecture of thermal sprayed coatings: image analysis coupled to stereological protocols permits quantification of the coating porous morphology, that is to say the porosity level (with a discrimination between globular pores and cracks), the orientation, and the linear density of cracks; electrochemical impedance spectroscopy permits quantification of the pore connectivity (the open porosity level). These techniques were applied to characterize the pore structure of gray alumina (Al_2O_3-13TiO_2) coatings and yttria partially stabilized zirconia (Y-PSZ) Thermal barrier coatings (TBCs), respectively, manufactured implementing air plasma spraying and hybrid plasma spraying (which combines plasma spraying and in situ laser remelting).

Keywords: alumina, ceramic coatings, cracks, electrochemical methods, image analysis, morphology, plasma spraying, pore network, porosity, refractory materials, spray coating techniques, thermal barrier coatings, thermal sprayed coatings, titanium dioxide

G. Antou and G. Montavon, SPCTS—UMR CNRS 6638, Faculty of Sciences, Univ. of Limoges, 87060 Limoges, France. Cited: *High Temp. Mater. Process*, 2006, **10**(2), p 161-184. ISSN 1093-3611.

Radioisotope method for monitoring the level of wear for protective coatings made from chromium and aluminum on gas turbine blades. A radioisotope method is given for estimating the level of wear for protective coatings made from Al and Cr on gas turbine blades based on measuring the

thickness of a coating that may change as a result of oxidation. A two-channel measuring system is developed, making it possible to perform rapid analysis.

Keywords: braking radiation, gas turbines, metal coatings, oxidation, protective coatings, radioisotopes, spectrometers, thickness measurement, thickness meters, wear of materials

V.I. Bochenin, Kurgan State Univ., Kurgan, Russian Federation. Cited: *Measure. Techniques*, 2006, Oct, **49**(10), p 1007-1010. ISSN 0543-1972.

Thermographic inspection of TBC coated gas turbine blades: discrimination between coating overthicknesses and adhesion defects. When performing in-field tests on thermal barrier coatings (TBCs) deposited on gas turbine blades, the main problem encountered is the difficulty to correctly interpret the experimental data. The coating thickness changes, which are not regarded as anomalies, are one of the most common sources of false alarms. They are very challenging to recognize because, unlike stains, eroded areas, and optical property variations, they are not detectable in the visible band. Furthermore, their thermal signal is similar to the one produced by an adhesion defect. In this paper, a procedure to reliably discriminate thickness changes and real defects is proposed. The approach is based on the analysis of the apparent effusivity profile. Preliminary results are presented and discussed.

Keywords: coating thickness, gas turbine blades, gas turbines, infrared detectors, optical property variations, thermal barrier coatings, thermal signal, thermography (imaging), turbomachine blades

S. Marinetti, D. Robba, F. Cernuschi, P.G. Bison, and E. Grinzato, CNR-ITC PD, 35127 Padova, Italy. Cited: *Infrared Phys. Technol.*, 2007, Jan, **49**(3 spec. issue), p 281-285. ISSN 1350-4495.

Microstructure

Interdiffusion analysis for NiAl versus superalloys diffusion couples. Solid-to-solid diffusion couples, β-NiAl (*B2*) versus various commercial superalloys (i.e., CM247, GTD-111, IN-939, IN-718, and Waspalloy) were examined to quantify the rate of Al interdiffusion as a function of initial superalloy composition. The diffusion couples were assembled with Invar steel jig encapsulated in Ar by sealing in quartz capsules and annealed at 1050 °C for 96 h. Concentration profiles measured by electron probe microanalysis in the single-phase β-NiAl region were used to determine interdiffusion fluxes and effective interdiffusion coefficients of individual components in the single-phase β-NiAl side of the couple. The values determined using experimental concentration profiles of the single-phase β-NiAl side of the couple were used to predict effective interdiffusion coefficients in multiphase superalloy side of the couple based on mass balance and local continuity of interdiffusion fluxes. Microstructural and compositional stability of protective coatings (e.g., NiCoCrAlY and NiAl) as a function of superalloys composition are discussed based on effective interdiffusion coefficients predicted from diffusion couple studies.

Keywords: annealing, diffusion, interdiffusion, microstructure, multicomponent, multiphase, nickel alloys, protective coatings, superalloys

E. Perez, T. Patterson, and Y. Sohn, Advanced Materials Processing and Analysis Center, Department of Mechanical, Materials and Aerospace Engineering, Univ. of Central Florida, Orlando, FL. Cited: *J. Phase Equilib. Diffusion*, 2006, Dec, **27**(6), p 659-664. ISSN 1547-7037.

Interfacial phenomena in thermally sprayed multiwalled carbon nanotube reinforced aluminum nanocomposite. The interfacial phenomena in thermally sprayed (plasma and high-velocity oxyfuel spraying) hypereutectic Al-Si composite with multiwalled carbon nanotube (MWCNT) reinforcement have been analyzed both theoretically and experimentally. The formation of an ultrathin β-SiC reaction layer at the interface is confirmed. Plasma sprayed composite exhibits a thicker SiC layer (~5 nm) than the high-velocity oxyfuel sprayed composite (~2 nm). The presence of SiC layer formation is also corroborated in a chemical vapor deposition experiment where Si was deposited on MWCNTs. The formation of β-SiC is responsible for the improved wettability of the molten Al-Si alloy matrix with MWCNT reinforcement.

Keywords: aluminum alloys, carbon nanotubes, deposition, interfaces (materials), interfacial wetting, metallic matrix composites, multiwalled carbon nanotubes, nanostructured materials, oxyfuel sprayed composites, reinforcement, thermal spraying

T. Laha, S. Kuchibhatla, S. Seal, W. Li, and A. Agarwal, Mechanical and Materials Engineering, Florida International Univ., Miami, FL 33174. Cited: *Acta Mater.*, 2007, Feb, **55**(3), p 1059-1066. ISSN 1359-6454.

Microstructure and mechanical properties of spray deposited Al-10.8Zn-2.8Mg-1.9Cu alloy after two-step aging treatment at 110 and 150 °C. The microstructure and mechanical properties of a spray deposited Al-10.8Zn-2.8Mg-1.9Cu alloy were investigated after a two-step aging treatment at 110 and 150 °C. The results indicate that GP zones and η′ are major precipitates for the alloy under the two-step aged condition. Discontinuous grain-boundary precipitates are favorable for stress-corrosion cracking resistance in the overaged condition, which reduces its strength about 7% compared to the peak-aged condition.

Keywords: aging treatment, aluminum copper alloys, Al-Zn-Mg-Cu alloys, grain boundaries, heat treatment, mechanical properties, microstructure, precipitation (chemical), sprayed coatings, stress-corrosion cracking resistance

F. Wang, B. Xiong, Y. Zhang, B. Zhu, H. Liu, Z. Wang, and X. He, State Key Laboratory for Fabrication and Processing of Nonferrous Metals, General Research Institute for Nonferrous Metals, Beijing 100088, China. Cited: *Mater. Charact.*, 2007, Jan, **58**(1), p 82-86. ISSN 1044-5803.

Microstructure of plasma sprayed Al_2O_3-ZrO_2 composite coatings. Thermal barrier coatings of Al_2O_3-ZrO_2 were prepared by air plasma spraying on the surface of 20G steel. Phase constitution, microstructures, and elemental distributions of the coatings were studied by x-ray diffraction, scanning electron microscope, and electron probe x-ray microanalysis. The results show that the plasma spray coating mainly consists of α-Al_2O_3, c-ZrO_2, and t-ZrO_2. The bond state of the interface between the top layer and bond layer is fine, and the bond layer has a good combination with the substrate. ZrO_2 and Al_2O_3 structures can closely integrate together and form compact top layer system.

Keywords: alumina, bond layer, composite coatings, composite materials, electron probe x-ray microanalysis, microstructure, plasma spraying, scanning electron microscopy, steel, thermal barrier coatings, x-ray diffraction, yttrium compounds, zirconia

C. Chen, L. Chen, L. Zhang, B. Qi, and T.-Q. Lei, School of Materials Science and Engineering, Shandong Univ., Ji'nan 250061, China. Cited: *Surf. Rev. Lett.*, 2006, Oct, **13**(5), p 545-549. ISSN 0218-625X.

Transmission electron microscopy of plasma sprayed ceramic deposits. Microstructure of plasma sprayed deposits is usually very complex containing solidified lamellas, microcracks, unmelted particles, and small voids. Internal structure of solidified lamellas is often composed of narrow columnar grains or can be amorphous. A powerful tool to study fine microstructures of the coatings and the complexities of the substrate/coating interfaces is the transmission electron microscope. However, preparation of electron transparent foils, which require thickness below 500 mm, is very difficult especially in case of ceramic coatings on metal substrates. Traditional sample preparation techniques rely on extended ion milling that tends to generate ion-induced artifacts in the samples. The modified wedge polishing technique introduced in the paper significantly reduces the time required for final ion-milling step. Several samples prepared by the wedge polishing method are documented.

Keywords: amorphous materials, ceramic coatings, ceramic deposits, interfaces (materials), ion milling, ion-induced artifacts, lamellas, microcracks, microstructure, plasma spraying, transmission electron microscopy

T. Chraska, Institute of Plasma Physics, Academy of Sciences of the Czech Republic, 182 00 Prague 8, Czech Republic. Cited: *Acta Technica CSAV*, **51**(4), p 403-413. ISSN 0001-7043.

Modeling

Mechanical Modeling

Determination of nonlinear properties of thermal sprayed ceramic coatings via inverse analysis. A robust procedure to estimate nonlinear mechanical properties of thermally sprayed (TS) ceramic coatings is introduced. Such a method is valuable particularly for TS coatings since each may possess unique properties depending on its processing condition. Traditionally, their responses have been assumed to be linear elastic (isotropic or anisotropic) except in very high temperature environments where softening may occur. However, recent inspections revealed their properties to be more accurately characterized as nonlinear elastic. It appears their distinctive morphology consisting of cracks and interfaces are responsible for such a response. In this work, a versatile procedure to identify nonlinear properties of thermally sprayed coatings is developed. First, a suitable stress-strain model is proposed and then a nonlinear bimaterial beam solution is derived. Afterward, an inverse analysis technique is utilized to process the measured curvature-temperature to extract the unknown parameters. Prior to implementing in actual specimens, a detailed simulation study is performed to verify the accuracy of the method as well as robustness. This computational analysis closely replicates deposition processes of TS coatings. With the successful verification, actual curvature measurement of TS yttria-stabilized zirconia (YSZ) coating is used to determine the nonlinear properties. The estimated results clearly reveal a significant nonlinearity of the TS coating. The main advantage of this procedure is that it requires essentially no specimen preparation and allows continuous measurements after TS deposition. Furthermore, the data interpretation does not require complex computational models and calculations. This streamlined process makes the present method attractive when evaluations of many specimens are required. The present procedure can be also extended to identify nonlinear properties of other coatings/films on substrates.

Keywords: anisotropy, ceramic coatings, computational methods, inverse analysis, Kalman filtering, mathematical models, nonlinear bimaterial beams, sprayed coatings, substrate-curvature measurement, thermally sprayed coating

T. Nakamura and Y. Liu, Department of Mechanical Engineering, State Univ. of New York at Stony Brook, New York, NY 11794. Cited: *Int. J. Solids Struct.*, 2007, March 15, **44**(6), p 1990-2009. ISSN 0020-7683.

Identification of elastic-plastic anisotropic parameters using instrumented indentation and inverse analysis. Mechanical responses of thin films or coatings often display anisotropic behaviors because of their unique microstructures. However, their small size scales can also make determination of material properties difficult. The present paper introduces a simple yet versatile procedure with advanced data interpretation scheme to identify key anisotropic parameters. This procedure utilizes instrumented indentations and an inverse analysis to extract unknown parameters of elastic-plastic transversely isotropic materials. In particular, it postprocesses load-displacement records of depth-sensing indentations to obtain best estimates of Young's moduli and yield stresses along longitudinal and transverse directions, respectively. Major advantages of this method are the minimal specimen preparations and the straightforward testing procedure. To enhance the accuracy, the method utilizes two differently profiled indenter heads, spherical and Berkovich. Prior to actual testing, detailed simulations were performed to verify the method's applicability and robustness. In the experiment, a thermally sprayed NiAl coating that possesses process-induced anisotropic features is considered. The load-displacement records of spherical and Berkovich nanoindentations are postprocessed with the proposed inverse analysis scheme. The estimated results predict dissimilar responses along the longitudinal and transverse directions. Separate tests are also conducted with microindenter heads under larger loads. They demonstrate lesser anisotropic effects but with more compliant responses. These results are attributed to the unique morphology of thermally sprayed coatings, which inherently exhibit size and anisotropic effects.

Keywords: anisotropy, computer simulation, elastic-plastic transversely isotropic, indentation, instrumented nanoindenter, inverse problems, Kalman filtering, microstructure, plastic coatings, spherical and Berkovich indenters, thermally sprayed coatings, thin films

T. Nakamura and Y. Gu, Department of Mechanical Engineering, State Univ. of New York at Stony Brook, Stony Brook, NY 11794. Cited: *Mech. Mater.*, 2007, April, **39**(4), p 340-356. ISSN 0167-6636.

Influence of tapered brittle coatings on stresses in layered structures: relevance to failure of dental crowns. This paper uses finite element analysis to examine stresses in loaded curved bilayer structures. The model system consists of glass shells, both constant thickness and tapered, filled with dental composite. These systems, simulating brittle crowns on tooth dentine, are loaded with ultracompliant disk indenters, and hard spherical indenters for comparison, along the (convex) axis of symmetry. The resulting maximum principal stress patterns are analyzed. Previous studies have generally utilized hard spherical indenters of various radii indenting constant thickness coatings, and examined stresses leading to crack initiation. However, the peak stresses observed in this traditional contact problem—inducing surface cone cracking or flexure-induced radial cracking—occurred close to or inside the (small) contact area and do not explain the margin failures in dental crowns commonly observed by dentists. Furthermore, the effect of varying coating thickness, especially tapering toward thinner margins, has not previously been examined. The use of an ultracompliant indenter distributes the indentation force over a large contact area, generating a compressive zone underneath the contact, and, consequently, previously insignificant stresses at the support margin become dominant, and the focus shifts to the support margin, rather than the area close to the contact. In this study, balsa wood is used as the disk indenter model material, with a modulus several orders of magnitude lower than the indented materials. Stress patterns from the same systems indented by hard spherical indenters are included for comparison. The specific focus is the effect of tapered coatings, examining stress patterns from several geometries. Results confirm not only a shift in the peak maximum principal stress from the near-contact area (under hard spherical indenters) to the margin area (under ultracompliant indenters), but also show that coating taper can have a significant influence on the margin stress under a soft indenter. In the same systems indented by a hard indenter, coating taper has very little effect on the more localized stresses induced.

Keywords: computational geometry, computer simulation, crack initiation, dental crown, dental materials, finite element method, margin geometry, protective coatings, soft indenter, stress analysis

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Micromechanics-based thermoelastic model for functionally graded particulate materials with particle interactions. Thermoelastic behavior of functionally graded particulate materials is investigated with a micromechanical approach. Based on a special representative volume element constructed to represent the graded microstructure of a macroscopic material point, the relation between the averaged strains of the particle and matrix phases is derived with pair-wise particle interactions, and a set of governing equations for the thermoelastic behavior of functionally graded materials is presented. The effective coefficient of thermal expansion at a material point is solved through the overall averaged strain of two phases induced by temperature change under the stress-free condition and is shown to exhibit a weak anisotropy due to the particle interactions within the graded microstructure. When the material gradient is eliminated, the proposed model predicts the effective coefficient of thermal expansion for uniform composites as expected. If the particle interactions are disregarded, the proposed model recovers the Kerner model. The proposed semianalytical scheme is consistent and general and can handle any thermal loading variation. For example, the thermal stress distributions of graded thermal barrier coatings are solved for two types of thermal loading: uniform temperature change and steady-state heat conduction in the gradation direction.

Keywords: composite micromechanics, constitutive behavior, functionally graded materials, heat conduction, microstructure, particulate reinforced materials, steady state, thermal expansion, thermal stress, thermoelasticity

H.M. Yin, G.H. Paulino, W.G. Buttlar, and L.Z. Sun, Department of Civil and Environmental Engineering, Newmark Laboratory, Univ. of Illinois at Urbana-Champaign, Urbana, IL 61801. Cited: *J. Mech. Phys. Solids*, 2007, Jan, **55**(1), p 132-160. ISSN 0022-5096.

A physics-based life prediction methodology for thermal barrier coating systems. A novel mechanistic approach is proposed for the prediction of the life of thermal barrier coating (TBC) systems. The life prediction methodology is based on a criterion linked directly to the dominant failure mechanism. It relies on a statistical treatment of the TBC morphological characteristics, nondestructive stress measurements, and on a continuum mechanics framework to quantify the stresses that promote the nucleation and growth of microcracks within the TBC. The last of these accounts for the effects of TBC elasto-viscoplastic properties of the constituents, the stiffening of the ceramic due to sintering and the oxidation at the interface between the thermally insulating yttria-stabilized zirconia (YSZ) layer and the metallic bond coat. The mechanistic approach is used to investigate the effects on TBC life of the properties and morphology of the top YSZ coating, metallic low-pressure plasma sprayed bond coat, and the thermally grown oxide. Its calibration is based on TBC damage inferred from nondestructive fluorescence measurements using piezospectroscopy and on the numerically predicted local TBC stresses responsible for the initiation of such damage. The potential applicability of the methodology to other types of TBC coatings and thermal loading conditions is also discussed.

Keywords: continuum mechanics, elasto-viscoplastic properties, failure analysis, finite element modeling, life prediction models, morphology, nondestructive examination, nondestructive stress measurements, nucleation, statistical methods, stress analysis, thermal barrier coatings

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Stress analysis of composite material embedded with optical fiber sensor. Fiber optic sensor with small size, light weight, and immunity to electromagnetic interference can be embedded and integrated into the host material to form a smart structure system. One must recognize that optical fibers are foreign entities to the host structure and therefore will alter the stress state in the vicinity of the embedded sensor irrespective of the small size of the fiber. This is a result of the material and geometric discontinuity introduced by the embedded optical fiber. In this study, the local stress fields in the vicinity of the embedded fiber are examined. The host material is considered to be a composite with reinforced fiber parallel to the optical fiber. The geometry in the vicinity of the embedded fiber is modeled by four concentric cylinders that represent the optical fiber, protective coating, resin, and host material, respectively. In this investigation, the host structure is subjected to longitudinal normal stress and transverse hydrostatic stress. The effects of the coating and host material on the stress distribution in the vicinity of the embedded optical fiber are presented through a parametric study.

Keywords: composite materials, embedded optical fibers, embedded sensors, embedded systems, fiber optic sensors, hydrostatic stress, intelligent buildings, reinforced fibers, signal interference, stress analysis, stresses

S.-C. Her and B.-R. Yao, Department of Mechanical Engineering, Yuan-Ze Univ., Chung-Li, Taiwan. Cited: *Key Eng. Mater.*, 2006, **326-328**, p 59-62. ISSN 1013-9826.

Particle Impact

Modeling the impact of a molten metal droplet on a solid surface using variable interfacial thermal contact resistance. An analytical model of the true area of contact between molten metal and a rough, solid surface has been used to calculate thermal contact resistance and to predict how it changes with surface roughness, substrate thermal properties, and contact pressure. This analytical model was incorporated into a three-dimensional, time-dependent numerical model of free-surface flows and heat transfer. It was used to simulate impact, spreading, and solidification of molten metal droplets on a solid

surface while calculating contact resistance distributions at the liquid-solid interface. Simulations were done of the impact of 4 mm diam molten aluminum alloy droplets and 50 μm diam plasma sprayed nickel particles on steel plates. Predicted splat shapes were compared with photographs taken in experiments and simulated substrate temperature variation during droplet impact was compared with measurements.

Keywords: heat resistance, heat transfer, liquid metals, mathematical models, numerical analysis, photographs, solid surface, substrates, surface chemistry, surface roughness, thermal contact resistance

M. Xue, Y. Heichal, S. Chandra, and J. Mostaghimi, Department of Mechanical and Industrial Engineering, Center for Advanced Coating Technologies, Univ. of Toronto, Toronto, ON M5S 3G8, Canada. Cited: *J. Mater. Sci.*, 2007, Jan, **42**(1), p 9-18. ISSN 0022-2461.

Molecular dynamics analysis of elementary process of coating by a high-temperature, high-speed droplet (Flattening process and atomic behavior of a droplet). Three-dimensional molecular dynamics simulation was conducted to clarify at an atomic level the flattening process of a high-temperature droplet impacting a substrate at high speed. The droplet and the substrate were assumed to consist of pure aluminum, and the Morse potential was postulated between a pair of aluminum atoms. By visualizing the analytical results, the processes of melting and solidification, temperature distribution, deformation velocity, and potential energy of atoms of the droplet were clarified. The following conclusions were obtained: (1) Transfer of the droplet atoms to the horizontal direction in the flattening process increases in proportion to the horizontal distance from the central axis of the droplet. (2) The increase of the flattening ratio of the droplet ends as soon as solidification of the droplet starts from the outside edge of the droplet. This behavior indicates the end of flattening.

Keywords: aluminum, computer simulation, droplet, flattening process, high-temperature effects, melting, molecular dynamics, pulsed laser deposition, solidification, sprayed coatings, temperature distribution

J. Shimizu, E. Ohmura, Y. Kobayashi, S. Kiyoshima, and H. Eda, Faculty of Engineering, Ibaraki Univ., Hitachi, Ibaraki 316-8511, Japan. Cited: *JSME Int. J., Ser. C: Mech. Syst., Mach. Elements Manuf*, 2006, Dec 15, **49**(2), p 505-511. ISSN 1344-7653.

Numerical investigations on effects of impact velocity and spray angle of particle on its deformation behavior in cold spraying. The cold spraying process is analyzed by numerical modeling of the impact between a single spherical particle and a substrate; the effects of impact velocity and spray angle of a particle on the particle and substrate deformation behavior were investigated. It was found that much localized stress, localized strain, and localized heating are present near the particle/substrate interface. When impact velocity exceeds a critical velocity, a jet-type flow of material at the interface was formed. High particle/substrate contact pressures and better-developed interfacial jets appear to be the major factors controlling the strength of interfacial bonding. As the particle impact velocity or spray angle increases, the length of interfacial jets increases, and it may strengthen the bonding of the particle and the substrate.

Keywords: cold effects, cold spraying, deformation, deformation behavior, elementary particles, jets, numerical methods, numerical modeling, pressure effects, spray angle, spraying, strain, velocity measurement

X. Zhang, X. Wang, Y. Li, and G. Chen, Department of Materials Science and Engineering, Nanjing Univ. of Science and Technology, Nanjing 210094, China. Cited: *Surf. Rev. Lett.*, 2006, Oct, **13**(5), p 613-620. ISSN 0218-625X.

Process Modeling

Modeling and simulation of plasma jet by lattice Boltzmann method. In order to find a simple and efficient simulation for plasma spray process, an attempt at modeling was made to calculate velocity and temperature field of the plasma jet by hexagonal seven-bit lattice Boltzmann method (LBM) in this paper. Utilizing the methods of Chapman-Enskog expansion and multiscale expansion, the authors derived the macro equations of the plasma jet from the lattice Boltzmann evolution equations on the basis of selecting two opportune equilibrium distribution functions. The present model proved to be valid when the predictions of the current model were compared with both experimental and previous model results. It is found that the LBM is simpler and more efficient than the finite difference method (FDM). There is no big variation of the flow characteristics, and the isotherm distribution of the turbulent plasma jet is compared with the changed quantity of the inlet velocity. Compared with the velocity at the inlet, the temperature at the inlet has a less influence on the characteristics of plasma jet.

Keywords: Chapman-Enskog expansion, computer simulation, finite difference method, isotherms, lattice Boltzmann method, mathematical models, multi-scale expansion, plasma jets, plasma spraying, turbulent flow, velocity

H. Zhang, S. Hu, G. Wang, and J. Zhu, State Key Lab of Plastic Forming Simulation and Die and Mold Tech., Huazhong Univ. of Science and Technology, Wuhan 430074, China. Cited: *Appl. Math. Model.*, 2007, June, **31**(6), p 1124-1132. ISSN 0307-904X.

Numerical modeling of arc behavior in a dc plasma torch. This paper describes a three-dimensional time-dependent model of a direct current (dc) plasma torch when the arc operates in the restrike mode. The model is based on the simultaneous solution of the conservation equations of mass, momentum, energy, electric current, and electromagnetic equations. It makes it possible to predict the effect of the operating parameters of the plasma torch on the motion of the attachment root on the anode surface and the time evolution of the gas flow fields inside the nozzle. The simulations, carried out for a conventional plasma spray torch, show that the model gives the good tendencies when a torch parameter is varied, and that the predicted values of gas temperature and velocity at the nozzle exit agree with the experimental values.

Keywords: anodes, computer simulation, electric arcs, electric currents, gas flow fields, gas temperature, mathematical models, Maxwell equations, momentum, numerical modeling, plasma jets, plasma spraying, plasma torches

C. Chazelas, E. Moreau, G. Mariaux, and A. Vardelle, Laboratoire Sciences des Procedes Ceramiques et de Traitements de Surface, ENSIL, 87068 Limoges Cedex, France. Cited: *High Temp. Mater. Process.*, 2006, **10**(3), p 393-406. ISSN 1093-3611.

Optimal robot path for minimizing thermal variations in a spray deposition process. This paper describes a method for determining the optimal robot path that minimizes thermal variations over a surface during a spray deposition process, where the deposited material is hotter than the surface. An analytical expression is formed for the amplitude of the thermal modes of the surface temperature profile. This expression is then used to determine the optimal robot velocity, scan angle, and start position. Experimental results from a metal spray deposition process are used to confirm the analysis.

Keywords: deposition, distributed parameter control systems, materials processing, optimal control systems, robot programming, spatially distributed systems, spray deposition, spraying, temperature control

P.D.A. Jones, S.R. Duncan, T. Rayment, and P.S. Grant, Department of Engineering Science, Oxford Univ., Oxford OX1 3PJ, United Kingdom. Cited: *IEEE Trans. Control Systems Technol.*, 2007, Jan, **15**(1), p 1-11. ISSN 1063-6536.

A simplified analytical model for dc plasma spray torch: influence of gas properties and experimental conditions. A simplified analytical model is proposed to evaluate some characteristics of the arc jet generated with a dc plasma torch, in the restricted area of atmospheric plasma spraying conditions. The plasma inside the anode nozzle is considered to be stationary and is divided into the arc column and a surrounding cold layer that electrically insulates the plasma from the nozzle wall. Radiation and processes related to the arc attachment at the electrodes are not explicitly taken into account. Heat conduction is evaluated by using Kirchoff's potential, which is described, as it is done also for the electrical conductivity, as a function of the gas specific enthalpy instead of temperature. The model is used to calculate the specific enthalpy radial distribution. From that, and by introducing a mean isentropic coefficient, it is possible to calculate the axial velocity of the plasma jet at the nozzle exit and to evaluate the different pressure contributions. The comparison between predicted and previously measured plasma jet velocities shows good agreement for various experimental conditions.

Keywords: anodes, electric conductivity, enthalpy, enthalpy radial distribution, gas dynamics, heat conduction, isentropic coefficient, Kirchoff's potential, plasma jet velocity, plasma jets, plasma spraying, plasma torches

V. Rat and J.F. Coudert, SPCTS-CNRS UMR 6638, Univ. of Limoges, 87060 Limoges Cedex, France. Cited: *J. Phys. D: Appl. Phys.*, 2006, Nov 21, **39**(22), p 4799-4807. ISSN 0022-3727.

Postprocessing

Alloying of cold sprayed Al-Ni composite coatings by post-annealing. A new cold spray coating technique for thick aluminum coating with finely dispersed aluminum-nickel intermetallic compounds was tested. For easy powder preparation and high yield, rather than using of aluminum/compound mixture feedstock, the spraying of pure aluminum and nickel powders mixture followed by post-annealing was suggested. The powder composition of aluminum and nickel was 75:25, and 90:10 (wt.%) to expect full consumption of pure nickel into intermetallic compounds. After aluminum-nickel composite coatings, the nickel particles were finely dispersed and embedded in the aluminum matrix with a good coating yield. Above 450 °C of post-annealing temperature, the Al_3Ni and Al_3Ni_2 phases were observed in the cold sprayed aluminum-nickel coatings. The nickel particles in the aluminum matrix were fully consumed via compounding reaction with aluminum at 550 °C of the annealing temperature.

Keywords: alloying, aluminum, annealing, composite coatings, composite materials, feedstocks, intermetallics, nickel, post-annealing temperature, powder composition, sprayed coatings

H.Y. Lee, S.H. Jung, S.Y. Lee, and K.H. Ko, Department of Materials Science and Engineering, Ajou Univ., Suwon 443-749, South Korea. Cited: *Appl. Surf. Sci.*, 2007, Jan 30, **253**(7), p 3496-3502. ISSN 0169-4332.

Bonding zone morphologies characteristics of laser remelted HA coatings. The low bonding strength between plasma sprayed hydroxyapatite (HA) coatings and substrates is one of the problems, which should be solved. In this paper, the as-sprayed HA coatings were retreated by laser remelting. The microstructure and element analysis in coatings were studied by electron probe microanalyzer (EPMA) and the accessory of energy spectrum analyzer. The results show that the bonding state can be improved greatly after laser remelting, and it is a metallurgical combination between transition layers and substrates. Generally, with the increase of laser power and the decrease of scanning speed, the bonding state between the surface and transition layer will be improved much more, but the value of calcium/phosphorus ratio will deviate much more from 1.67. In this experiment, the optimum technological parameter is that the laser power is 600 W and the scanning speed is 11.2 mm/s.

Keywords: bonding state, bonding strength, coatings, electron probe microanalyzer, element analysis, hydroxyapatite, laser applications, laser remelting, microstructure, morphology, plasma spraying, spectrum analyzers

D. Wang, C. Chen, Q. Bao, L. Zhang, and T. Lei, School of Materials Science and Engineering, Shandong Univ., Ji'nan 250061, China. Cited: *Surf. Rev. Lett.*, 2006, Oct, **13**(5), p 655-660. ISSN 0218-625X.

Influence of annealing on the grain growth and thermal diffusivity of nanostructured YSZ thermal barrier coating. The nanostructured zirconia coatings were deposited by atmospherically plasma spraying. Scanning electron microscopy (SEM), transmission electron microscopy (TEM), and x-ray diffraction were used to investigate the microstructure of the zirconia coatings. Thermal diffusivity values at normal temperatures have been evaluated by laser flash technique. Effect of annealing on the microstructure evolution of the zirconia coating has been performed. The grains and thermal diffusivity are increased with increasing annealing time and temperature. The grain growth is according to the GRIGC (the grain rotation induced grain coalescence) mechanism. The increase in thermal diffusivity is attributed to the grain growth and the decrease in porosity of nanostructured zirconia coatings.

Keywords: annealing, grain growth, grain size, nanostructured materials, plasma spraying, scanning electron microscopy, thermal barrier coatings, thermal diffusivity, transmission electron microscopy, x-ray diffraction analysis, zirconia

N. Wang, C. Zhou, S. Gong, and H. Xu, Department of Materials Science and Engineering, Beijing Univ. of Aeronautics and Astronautics, Beijing 100083, China. Cited: *J. Mater. Sci. Technol.*, 2006, Nov, **22**(6), p 793-797. ISSN 1005-0302.

Surface changes of plasma sprayed hydroxyapatite coatings before and after heat treatment. Plasma sprayed and heat-treated hydroxyapatite (HA) coatings, produced from fine HA powder (38-75 μm) under a spraying power of 45 kW (in short FCs) and coarse HA powder (75-106 μm) under a spraying power of 35 kW (in short CCs) have been investigated, especially in terms of their surface characteristics. The x-ray diffraction results show that most of amorphous and decomposed phases transform into crystalline HA and the crystallinities of coatings are improved. The surface morphology of the coatings has been examined by electron probe microanalyzer and field emission scanning electron microscope. At high magnifications the as-sprayed FCs, with new nanosize particles and a netlike aggregated lamellar texture are observed on the surface. After heat treatment at 650 °C, the nanograde particles of FCs have a tendency to grow and increase in quantity. While the netlike aggregation disperses into a uniform petal-like texture similar to a porous structure with a high surface roughness. Energy dispersive spectra show that these particles and netlike structure are primarily composed of calcium and phosphorous with adequate amount of oxygen, and the calcium/phosphorus ratio is 1:75, that is, exceeding that of pure HA.

Keywords: crystal atomic structure, crystallinities, heat treatment, hydroxyapatite, hydroxyapatite coatings, nanograde particles, phase transitions, plasma spraying, surface changes, surface reactions, x-ray diffraction analysis

Y.M. Chen, Y.P. Lu, and M.S. Li, School of Materials Science and Engineering, Shandong Univ., Ji'nan 250061, China. Cited: *Surf. Eng.*, 2006, Dec, **22**(6), p 462-467. ISSN 0267-0844.

Surface modification of vacuum plasma sprayed titanium coating via two different treatments. Vacuum plasma sprayed (VPS) titanium coatings were deposited, and their surface modification processes were performed by NaOH solution treatment and alkali-heat-calcification, respectively. The simulated body fluid test indicated that apatite was formed on the surfaces of Ti coatings. A netlike structure was observed on the surfaces of Ti coatings treated by alkali-heat-calcification, whose bioactivity is much better than that treated by NaOH aqueous solution simply.

Keywords: apatite, bioactivity, calcification (biochemistry), hydroxyapatite, plasma spraying, simulated body fluids, sprayed coatings, surface treatment, titanium, titanium coatings, vacuum

Y.K. Chen, X.B. Zheng, H. Ji, C.X. Ding, and S.W. Lee, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China. Cited: *Key Eng. Mater.*, 2007, **330-332**, p 533-536. ISSN 1013-9826.

Processing

Cold gas dynamic manufacturing: a nonthermal approach to freeform fabrication. This paper reports on the development of a novel freeform fabrication technique using a cold spray (CS) system. In the CS process, metallic powder particles are accelerated in a supersonic gas jet and impacted with a substrate at speeds in excess of 600 m/s. The nonmelting nature of its deposition mechanism ensures that the sprayed material is free from thermally induced tensile stresses, while the underlying substrate remains unchanged. The process is seen as a viable method for additive manufacturing because of its high deposition rates and controllable spray jet. A process was developed to investigate the potential of nonthermal freeform fabrication and was coined cold gas dynamic manufacturing (CGDM). Here, additive and subtractive techniques were combined to enable the production of complex geometries. Whereas most CS facilities concentrate on the application of wear or corrosion-resistant coatings, CGDM is dedicated to the production of freeform components, while still retaining an inherent coating ability. The process can produce functional forms using novel manufacturing strategies that are unique to CS. This paper presents information on the process and details the various strategies employed during component fabrication. It was possible to construct components from many materials, including titanium, which exhibited freeform surfaces, internal channels, and embedded devices. A breakdown of the process economics is also provided, with and without helium recycling.

Keywords: cold spray, corrosion resistance, embedded devices, embedded systems, gas dynamics, helium recycling, jets, molds, sacrificial materials, supersonic flow, tensile stress, titanium

J. Pattison, S. Celotto, R. Morgan, M. Bray, and W. O'Neill, Innovative Manufacturing Research Centre, Institute for Manufacturing, Department of Engineering, University of Cambridge, Cambridge, United Kingdom. Cited: *Int. J. Mach. Tools Manuf.*, 2007 March, **47**(3-4), p 627-634. ISSN 0890-6955.

Combination of flame synthesis and high-throughput experimentation: the preparation of alumina-supported noble metal particles and their application in the partial oxidation of methane. Mono and multi-noble metal particles on Al_2O_3 were prepared in one step by flame spray pyrolysis (FSP) of the corresponding noble metal precursors dissolved in methanol and acetic acid (v/v 1:1) or xylene. The noble metal loading of the catalysts was close to the theoretical composition as determined by WD-XRF and LA-ICP-MS. The preparation method was combined with high-throughput testing using an experimental setup consisting of eight parallel fixed-bed reactors. Samples containing 0.1-5 wt.% noble metals (Ru, Rh, Pt, Pd) on Al_2O_3 were tested in the catalytic partial oxidation of methane. The ignition of the reaction toward carbon monoxide and hydrogen depended on the loading and the noble metal constituents. The selectivity of these noble metal catalysts toward CO and H_2 was similar under the conditions used (methane:oxygen ratio 2:1, temperature from 300 to 500 °C) and exceeded significantly those of gold and silver containing catalysts. Selected catalysts were further analyzed using XPS, BET, STEM-EDXS, and XANES/EXAFS. The catalysts exhibited generally a specific surface area of more than 100 m^2/g and were made up of ~10 nm alumina particles on which the smaller noble metal particles (1-2 nm, partially oxidized state) were discernible. XPS investigation revealed an enrichment of noble metals on the alumina surface of all samples. The question of alloy formation was addressed by STEM-EDXS and EXAFS analysis. In some cases, particularly for Pt-Pd and Pt-Rh, alloying close to the bulk alloys was found, in contrast to Pt-Ru being only partially alloyed. In situ x-ray absorption spectroscopy on selected samples was used to gain insight into the oxidation state during ignition and extinction of the catalytic partial oxidation of methane to hydrogen and carbon monoxide.

Keywords: alloys, alumina, catalysts, catalytic partial oxidation, flame spray pyrolysis, high throughput experimentation, in situ x-ray absorption spectroscopy, methane, nanostructured materials, noble metal nanoparticles, oxidation, precious metals, pyrolysis, transmission electron microscopy

S. Hannemann, J.-D. Grunwaldt, P. Lienemann, D. Gunther, F. Krumeich, S.E. Pratsinis, and A. Baiker, Institute for Chemical and Bioengineering, ETH Zurich, 8093 Zurich, Switzerland. Cited: *Appl. Catalysis A: Gen.*, 2007, Jan 10, **316**(2), p 226-239. ISSN 0926-860X.

Development of a preoxidation treatment to improve the adhesion between thermal barrier coatings and NiCoCrAlY bond coatings. High-temperature coating systems, consisting of a René N5 superalloy, a Ni-23Co-23Cr-19Al-0.2Y (at.%) bond coating (BC), and a yttria (7 wt.%)-stabilized zirconia (YSZ) thermal barrier coating (TBC), were thermally cycled to failure for seven different controlled preoxidation treatments and one commonly employed industrial preoxidation treatment to establish the preferred microstructures of the thermally grown oxide (TGO) on a NiCoCrAlY bond coating after preoxidation. It was found that the failure of the coating system occurred along the TGO/BC interface when the TGO attained a critical thickness,

except if a $NiAl_2O_4$ spinel layer developed contiguous to the TBC/TGO interface. Then, the coating system failed at a smaller TGO thickness along the $NiAl_2O_4/\alpha$-Al_2O_3 interface. The value for the TGO thickness at failure increased for a larger area fraction of Y-rich oxide pegs at the TGO/BC interface after preoxidation. A desired slow-growing oxide layer on the BC surface was promoted when the presence of the oxides $NiAl_2O_4$, θ-Al_2O_3, $Y_3Al_5O_{12}$ at the TGO surface after preoxidation was avoided. The α-Al_2O_3 layer, which developed adjacent to the BC upon thermal cycling, grew at a low rate if the initial oxide at the onset of oxidation consisted of θ-Al_2O_3 instead of α-Al_2O_3. Based on these results, a preoxidation treatment is proposed for which the lifetime of the entire coating system during service is enhanced.

Keywords: adhesion, alumina, bond coating, high-temperature applications, interfaces (materials), microstructure, oxidation, oxide pegs, preoxidation, spinel layers, superalloys, thermal barrier coatings, thermal cycling, yttrium compounds, zirconia

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Flame sprayed superparamagnetic bare and silica-coated maghemite nanoparticles: synthesis, characterization, and protein adsorption-desorption. Superparamagnetic maghemite (γ-Fe_2O_3) nanoparticles of tunable diameters and silica-coated maghemite (SiO_2/γ-Fe_2O_3) nanoparticles of controllable morphology were successfully synthesized using a one-step flame spray pyrolysis (FSP) technique. The physical, chemical, and magnetic properties of γ-Fe_2O_3 and SiO_2/γ-Fe_2O_3 nanostructures were characterized and compared with those of silica-coated FSP γ-Fe_2O_3 produced by a conventional sol-gel method. Bovine serum albumin (BSA) adsorption-desorption was investigated as a model to demonstrate the feasibility of synthesized superparamagnetic nanoparticles for bioadsorption and bioseparation. Protein adsorption was observed to follow the Langmuir isotherm, with the highest binding capacity of 348 mg of BSA/g of particle and a dissociation constant of 0.0159 g/L attainable for FSP γ-Fe_2O_3 (d_{XRD} = 14 nm) in 10 mM formate buffer. Electrostatically governed BSA orientations were proposed for different particle-buffer systems. Shifting the pH of suspension with K_2HPO_4 enabled effective recovery of adsorbed BSA.

Keywords: bovine serum albumin, flame spray pyrolysis, flame spraying, nanostructured materials, proteins, silica, silica-coated maghemite, sprayed coatings, superparamagnetism, synthesis (chemical), tunable diameters

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Glass-ceramic functionally graded materials produced with different methods. Functionally graded materials (FGMs) are innovative composite materials characterized by a gradual spatial change in composition, microstructure, and related properties. This work was focused on glass-alumina functionally graded materials, produced via percolation of molten glass into a sintered polycrystalline alumina substrate and via plasma spraying. The glass composition, belonging to the CaO-ZrO_2-SiO_2 system, was purposely designed to minimize the difference between the coefficients of thermal expansion of the constituent phases, which may induce thermal residual stresses in service or during fabrication. The ingredient materials as well as the resultant FGMs were carefully characterized. In particular, a great attention was devoted to the microstructural investigation of the penetration profile.

Keywords: alumina, composition, crystal microstructure, functionally graded materials, glass ceramics, molten glass, percolation (solid state), plasma spraying, polycrystalline alumina substrate, polycrystalline materials, residual stresses, sintering, thermal coefficient, thermal expansion

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Laser hybrid plasma spray processes: tools to adjust coating structural characteristics. Five groups of closely interrelated operating parameters (power parameters, feedstock injection parameters, geometric parameters, kinematics parameters, and environmental parameters) have to be optimized and controlled during atmospheric plasma spraying (APS) to control the coating structure and its properties in service. Nevertheless, in some cases, the multiple possible combinations of operating parameters do not permit to reach the required coating structural characteristics. Auxiliary systems, such as lasers, can help to decouple interrelated effects and introduce new degrees of freedom to the process. Combining a plasma torch with a laser beam forms a hybrid process. In such a case, several strategies can be implemented, depending on the one hand on the laser irradiation characteristics and, on the other hand, on the location of the laser irradiation area in regards with the particle impact footprint on the surface. This paper intends to develop several works carry out on laser hybrid plasma spray processes. Substrate surface and coating interface ablation, substrate surface and coating layers preheating, and coating layers remelting are presented. Mechanisms resulting from laser irradiation are detailed and some resulting coating structures analyzed.

Keywords: adhesion, atmospheric plasma spraying, coating cohesion, coating layers, degrees of freedom (mechanics), feedstock injection, feedstocks, in situ laser irradiation, laser beam effects, laser beams, laser hybrid plasma spray, plasma spraying, plasma torches, pore network architecture

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Low porosity and fine coatings produced by a new type nozzle of high velocity arc spray gun. The new designed high-velocity arc spray gun with three different nozzles is developed to match the DZ400 arc spray system, which can produce the coatings with the structure of superfine and low porosity. This system can be used to spray three normal wires such as 4 Cr13, FeCrAl, and 7 Cr13 (flux cored wires). Using the scanning electron microscope (SEM) to analyze shape and particles size that sprayed by the nozzles with different parameters, as well as with the S-3500 N SEM and the energy spectrum analytic (ESA) instrument to identify the content of the oxides, porosity, and thickness of the coatings, we get the result that the porosity in the coatings of solid wire is less than 3%, of the flux-cored wires is less than 5%, and the distribution of the coatings sprayed by the nozzle with secondary supplementary airflow is typically shown in the form of high-density lamellar splat structure and the average lamellar thickness is around 5 μm.

Keywords: coatings, coatings structure, electric arcs, nozzles, nozzles structure, oxides content, porosity, spray guns, structures (built objects), surface roughness, thickness, twin wire arc spray

R. Wang, T. Zhang, L. Xu, and X. Huang, Surface Engineering Technology Institute, Chinese Academy of Agricultural Mechanization Sciences, Beijing 100083, China. Cited: *China Weld.*, 2006, Sept, **15**(3), p 51-54 [in English]. ISSN 1004-5341.

Phase transformation of ultrafine rare earth oxide powders synthesized by radio frequency plasma spraying. Inductively coupled radio frequency plasma spraying was used to prepare ultrafine powders of Sm_2O_3, Dy_2O_3, and Lu_2O_3. These three materials were studied because they are effective dopants in multilayer ceramic capacitors (MLCC) to improve lifetime. The as-sprayed powders consist of both micron-sized monodispersed spherical particles and nanosized particles in various shapes. In addition to the spheroidization effect, plasma treatment leads to an increase of the monoclinic phase fraction associated with a corresponding decrease of the amount of the cubic phase. The degree of this phase change was found to depend sensitively on the sprayed oxides, decreasing with increasing atomic number of the rare earth element, which is associated with their thermodynamic stability. Furthermore, the monoclinic high-temperature equilibrium phase induced by plasma treatment remains stable at room temperature and even during annealing at a temperature of 900 °C.

Keywords: annealing, dysprosium compounds, inductively coupled plasma, lutetium compounds, multilayer ceramic capacitors, phase transitions, plasma spraying, plasma treatment, powder coatings, samarium compounds, spheroidization effect, synthesis (chemical), thermodynamic stability, ultrafine rare earth oxide powders

X.L. Sun, A.I.Y. Tok, R. Huebner, and F.Y.C. Boey, School of Materials Science and Engineering, Nanyang Technological Univ., Singapore 639798, Singapore. Cited: *J. Eur. Ceram. Soc.*, 2007, **27**(1), p 125-130. ISSN 0955-2219.

RF plasma processing of ultrafine Sm-Lu mixed oxide powder. Ultrafine Sm-Lu mixed oxide powder with an overall composition $Sm_{1.0}Lu_{1.0}O_3$ was processed by inductive radio-frequency plasma treatment using two different approaches: spraying a mixture of pure Sm_2O_3 and Lu_2O_3 with and without sintering pretreatment. Due to the insufficient reaction time and contact, the mixture sprayed without sintering shows only a marginal reaction between the two materials. Therefore, an alternative approach was adopted. The mixed oxide was first synthesized by solid-state reaction at 1600 °C. Then, the as-sintered pellets were crushed and ground, followed by plasma treatment. In this way, ultrafine particles of $Sm_{1.0}Lu_{1.0}O_3$ mixed oxide were obtained.

Keywords: composition, mixed-oxide powders, particles (particulate matter), plasma spraying, plasma treatment, powder metals, samarium alloys, sintering, sintering pretreatment, synthesis (chemical), ultrafine powders

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Thermal stability and catalytic activity of flame-made silica-vanadia-tungsten oxide-titania. Vanadia (0.9 or 2 wt.%) and silica (0-5 wt.%) doping of flame-made tungsten oxide-titania nanostructured catalyst powders (anatase, 100 m^2/g, 10 wt.% WO_3) is investigated. The effect of dopants on structural and chemical properties of these powders were analyzed by nitrogen adsorption, x-ray diffraction (XRD), temperature programmed reduction (TPR), transmission electron microscopy (TEM), and Raman spectroscopy. After calcination for 20 h at 700 °C in air, the thermally most stable composite powder conserved its specific surface area (SSA) to 90 m^2/g and its anatase content to 96 wt.%. Tungsten oxide and vanadia form thin polymeric layers

(~1 nm) on the surface of the titania support. Adding silica improves the thermal and crystal stability of the catalysts even at higher reactor temperatures. As a result both NO conversion and the rate of selective catalytic reduction (SCR) with NH_3 were increased.

Keywords: catalyst activity, deNOx, flame spray pyrolysis, nanostructured materials, silica, thermodynamic stability, titania, titanium dioxide, transmission electron microscopy, tungsten oxide, vanadia, x-ray diffraction

R. Jossen, M.C. Heine, S.E. Pratsinis, S.M. Augustine, and M.K. Akhtar, Particle Technology Laboratory, Institute of Process Engineering, Department of Mechanical and Process Engineering, 8092 Zurich, Switzerland. Cited: *Appl. Catal. B: Environ.*, 2007, Jan 15, **69**(3-4), p 181-188. ISSN 0926-3373.

Twin-structured yttria-stabilized t′ zirconia coatings deposited by plasma spray physical vapor deposition: microstructure and mechanical properties. In this work, we report a twin-structured yttria-stabilized t′ zirconia (YSZ) coating that was fabricated through an advanced plasma spray physical vapor deposition process with a high-power hybrid plasma spraying system. The as-deposited YSZ structure, entirely different from those deposited by conventional atmospheric plasma spraying and electron beam physical vapor deposition, is characterized by coarse grains of over 5 μm size that compose the entire coating, differently sized t′-ZrO_2 twins that fill the coarse grains, and micron-scaled lenticular t′ colonies in which twins on the submicrometer scale arrange alternatively. The indentation tests show that both the nanohardness and microhardness of the peculiar coating are markedly higher than those of the ordinary YSZ coatings, even comparable with those of the sintered YSZ polycrystal bulks.

Keywords: coarse grains, coating techniques, conventional atmospheric plasma spraying, electron beam physical vapor deposition, electron beams, physical vapor deposition, plasma spray physical vapors, plasma spraying, polycrystals, sintering, zirconia

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Properties

Corrosion

An 18-year exposure test of thermal sprayed Zn, Al, and Zn-Al coatings in marine environment. The thermal spray committee of the Japan Association of Corrosion Control (JACC) has been conducting a marine corrosion test of thermal sprayed zinc, aluminum, and zinc-aluminum coatings since 1986. The coating was applied to 12 steel pipes by arc and flame spraying to varied thicknesses and subjected to various postspray treatments. The samples were set vertically into seawater at a port located approximately 80 km south of Tokyo. The corrosion performance of these coatings has been inspected annually by recording their appearance and thickness at the sea-air, splash, and tidal zones. No significant changes were observed for the first several years of exposure. After 7 years, however, zinc coatings with and without sealing started to suffer degradation in the immersed portion. Contrary to this, most of the aluminum and zinc-aluminum coatings still exhibit superb corrosion performance. In order to place the test in a proper perspective, a special team of about 20 members was formed to conduct a survey on corrosion prevention through thermal spray technology in fiscal year 2001, collecting more than 170 published reports and asking experts to contribute reviews on various aspects of this technology. In this paper, the corrosion performance of sprayed coatings in the exposure test during 18 years will be summarized, and discussion will be made by comparing the test results with the published data collected by the survey.

Keywords: aluminum, coating thickness, corrosion prevention, corrosion protection, field exposure tests, marine corrosion, protective coatings, sacrificial anodes, seawater, steel structures, thermal sprayed coatings, tidal zones

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Corrosion behavior of TiO_2 coated by plasma spraying in seawater. TiO_2 ceramic coating was deposited via air plasma spraying (APS). The microstructure and composition of the coating were investigated with SEM and XRD, respectively. The results showed that the air plasma sprayed TiO_2 coating possessed a porous structure with both joined and isolated small pores. The electrochemical impedance spectroscopy (EIS) was measured in the frequency range from 3 mHz to 10 kHz with a sinusoidal voltage perturbation of 10 mV amplitude at room temperature. An equivalent circuit of EIS was proposed to model the morphological structure of TiO_2 ceramic coating. The resistance of APS-processed TiO_2 coatings to corrosion was evaluated by an average corrosion rate. The results show that the TiO_2 coating has good resistance to corrosion.

Keywords: air plasma spraying (APS), average corrosion rate, ceramic coatings, microstructure, plasma spraying, scanning electron microscopy, seawater corrosion, spectroscopy, TiO_2 ceramic coating, titanium dioxide

Y. Fan and Y. Yin, Institute of Material Science and Engineering, Ocean Univ. of China, Qingdao, China. Cited: *InterCeram: Int. Ceram. Rev.*, 2006, Nov, **55**(6), p 426-430. ISSN 0020-5214.

Electrical

Anisotropic electrical conduction from heterogeneous oxidation states in plasma sprayed TiO_2 coatings. Microstructural and electrical characterizations of air plasma sprayed TiO_2 coatings were carried out to investigate the details of deoxidation during the spray process and the changes following air annealing. The coatings were found to behave as an n-type semiconductor indicating the presence of oxygen vacancies. Direct-current resistivity measurements in plane (q; IP) and through thickness (q; TT) of the coatings as a function of annealing time and temperature showed remarkably large anisotropies (q; TT q; IP) of up to 105. Impedance spectroscopy of the specimens coupled with microstructural analysis revealed that the origin of this anisotropy lies in the heterogeneous deoxidation and reoxidation behavior of the coatings. Due to rapid quenching, the high-temperature deoxidation state is preserved in the splat boundaries making them more conductive than the bulk of the splat in the as-sprayed coating. Upon annealing in air, the splat boundaries get selectively oxidized due to faster surface diffusion of oxygen and become more insulating. This behavior, together with the layered morphology of plasma sprayed coatings, results in anisotropy.

Keywords: air annealing, anisotropy, diffusion, electric conductivity, microstructural analysis, microstructure, oxidation, plasma spraying, sprayed coatings, surface diffusion, surfaces, temperature deoxidation, titanium dioxide

A. Sharma, A. Gouldstone, S. Sampath, and R.J. Gambino, Center for Thermal Spray Research, Department of Materials Science and Engineering, State Univ. of New York at Stony Brook, Stony Brook, NY 11794-2275. Cited: *J. Appl. Phys.*, 2006, **100**(11). ISSN 0021-8979.

Ionic conductivity and its temperature dependence of atmospheric plasma sprayed yttria-stabilized zirconia electrolyte. In this study, yttria-stabilized zirconia (YSZ) electrolytes were deposited using 8 and 4.5 mol% YSZ powders by atmospheric plasma spraying (APS). The ionic conductivity of the obtained YSZ electrolytes was measured by the means of DC measurement and AC impedance spectroscopy, in a temperature range of 600-1000 °C. The ionic conductivity of 8 mol% YSZ coating is about 50% higher than that of 4.5 mol% YSZ coating. Furthermore, for the same specimen, the ionic conductivity in the parallel direction is about twice higher than that in perpendicular direction. The anisotropy of the ionic conductivity is attributed to the APS coating structure characteristics. In the studied temperature range, a significant temperature dependence of ionic conductivity was observed for the two electrolytes. The traditional Arrhenius equation was employed to analyze the ionic conductivity data and the nonlinear Arrhenius behavior was observed. The intragrain-intergrain conductivity model and dissociation-migration energy model were employed to discuss the observed temperature dependency of electrical conductivity of plasma sprayed YSZ deposits, and the dissociation-migration energy model was more reasonable to explain this temperature dependence.

Keywords: atmospheric plasma spraying, dissociation, electric properties, electrolytes, ionic conduction, nonlinear Arrhenius behavior, plasma spraying, protective coatings, yttria-stabilized zirconia, zirconia

C. Zhang, C.-J. Li, G. Zhang, X.-J. Ning, C.-X. Li, H. Liao, and C. Coddet, State Key Laboratory for Mechanical Behavior of Materials, School of Materials Science and Engineering, Xi'an Jiaotong Univ., Xi'an, Shaanxi 710049, China. Cited: *Mater. Sci. Eng. B: Solid-State Mater. Adv. Technol.*, 2007, Feb 25, **137**(1-3), p 24-30. ISSN 0921-5107.

Mechanical

Characterization of WC-VC-Co thermal spray powders and coatings. The composition and microstructure of agglomerated and sintered WC-VC-Co thermal spray powders and of the high-pressure/high-velocity oxyfuel (HP/HVOF) coatings produced from the powders were analyzed and compared to those of agglomerated and sintered commercial WC-Co thermal spray powders of equal Co mass fraction and of the commercial WC-Co coatings that were deposited under the same conditions as the WC-VC-Co coatings. The results of the analyses helped to explain the abrasion resistance of WC-VC-Co coatings being superior to that of WC-Co coatings.

Keywords: agglomeration, composition, high-pressure/high-velocity oxyfuel, mass fraction, microstructure, sintering, sprayed coatings, thermal spray powders, wear resistance

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Comparative characteristic and erosion behavior of NiCr coatings deposited by various high-velocity oxyfuel spray processes. The purpose of this study is to analyze and compare the mechanical properties and microstructure details at the interface of high-velocity oxyfuel (HVOF) sprayed

NiCr-coated boiler tube steels, namely ASTM-SA-210 grade A1, ASTM-SA213-T-11, and ASTM-SA213-T-22. Coatings were developed by two different techniques, and in these techniques liquefied petroleum gas was used as the fuel gas. First, the coatings were characterized by metallographic, scanning electron microscopy/energy-dispersive x-ray analysis, x-ray diffraction, surface roughness, and microhardness, and then were subjected to erosion testing. An attempt has been made to describe the transformations taking place during thermal spraying. It is concluded that the HVOF wire spraying process offers a technically viable and cost-effective alternative to HVOF powder spraying process for applications in an energy-generation power plant with a point view of life enhancement and to minimize the tube failures because it gives a coating having better resistance to erosion.

Keywords: chromate coatings, deposition, energy dispersive spectroscopy, erosion, high-velocity oxyfuel, liquefied petroleum gas, microhardness, microstructure, NiCr powder, NiCr wire, scanning electron microscopy

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Comprehensive investigations on the influence of gun current of plasma spraying on the properties of silicon carbide films. Polycrystalline silicon carbide films have been prepared by the gas tunnel type plasma spraying method (GTPS). The effect of gun current on microstructure and mechanical properties was investigated. Scanning electron microscopy, x-ray diffraction, energy dispersive spectroscopy, nanoindentation, and abrasive wear were used to characterize the structure, thickness, composition, and the mechanical properties of SiC films. Microstructural studies revealed that the formation of cubic silicon carbide (C-SiC) at higher gun currents from 120 to 140 A. The SiC films have good-adhesion, dense, smooth, and compact morphology. Hardness of SiC films strongly improved from 23 to 31.5 GPa as the gun current increased from 0 to 140 A. SiC films formed at higher gun current exhibits better wear resistance than that deposited at low gun current, mainly due to SiC films become more hard and more dense. The crystalline cubic silicon carbide films with good morphology and mechanical properties have been obtained from the GTPS method, which makes it a suitable material for high-temperature thermoelectric and mechanical applications.

Keywords: abrasive wear, energy dispersive spectroscopy, gas tunnel type plasma spraying, hardness, microstructure, plasma spraying, silicon carbide, thermoelectric materials, thermoelectricity, thin films, x-ray diffraction analysis

N.F. Fahim and A. Kobayashi, Joining and Welding Research Institute, Osaka Univ., Ibaraki, Osaka 567-0047, Japan. Cited: *Mater. Sci. Eng. B: Solid-State Mater. Adv. Technol.*, 2007, Feb 25, **137**(1-3), p 131-137. ISSN 0921-5107.

Effects of TiO_2 on the mechanical properties of the Al_2O_3-TiO_2 plasma sprayed coating. Plasma sprayed ceramic coatings are successfully used in many industrial applications, where high wear and corrosion resistance with thermal insulation are required. In this study, various types of Al_2O_3-TiO_2 plasma sprayed coatings in different compositions (Al_2O_3-13 wt.%TiO_2, Al_2O_3-40 wt.%TiO_2, and Al_2O_3-50 wt.%TiO_2) were prepared on an AISI 304L austenitic stainless steel substrate. The effects of TiO_2 addition on the properties of the coating were investigated in terms of microhardness and fracture toughness values. The results obtained from experimental work were evaluated with standard characterization techniques. The results indicated that an increase in TiO_2 amount improves fracture toughness and lowers the microhardness values of the coatings.

Keywords: alumina, austenitic stainless steel, ceramic coatings, characterization, fracture toughness, microhardness, plasma sprayed coatings, plasma spraying, sprayed coatings, stainless steel, titanium dioxide

R. Yilmaz, A.O. Kurt, A. Demir, and Z. Tatli, Technical Education Faculty, Sakarya Univ., Sakarya, Turkey. Cited: *J. Eur. Ceram. Soc.*, 2007, **27**(2-3), p 1319-1323. ISSN 0955-2219.

Integrated characterization of cold sprayed aluminum coatings. Cold spray (CS) technology is a recent development for producing dense, oxide-free metallic and cermet coatings with attributes not achievable by established atmospheric thermal spray (TS) techniques. Little or no thermal component (i.e., high temperature) is introduced in the CS process; deposit formation relies mainly on dynamic compaction as particles impact the substrate. In this paper, we discuss and evaluate the relationships between the microstructure, properties and residual stresses in CS Al coatings, combining indentation, dilatometry, resistivity measurements, and neutron diffraction techniques. In addition, we provide mechanistic arguments for the evolution of such characteristics with postdeposit annealing.

Keywords: aluminum, aluminum coatings, brittle coatings, cohesion, cold spray, ductility, microstructure, residual stresses, sprayed coatings, substrates, thermal effects, thermal spray

W.B. Choi, L. Li, V. Luzin, R. Neiser, T. Gnaupel-Herold, H.J. Prask, S. Sampath, and A. Gouldstone, Materials Science and Engineering, Heavy Engineering 130, State Univ. of New York, Stony Brook, NY. Cited: *Acta Mater.*, 2007, Feb, **55**(3), p 857-866. ISSN 1359-6454.

Structure, mechanical, and sliding wear properties of WC-Co/MoS_2-Ni coatings by detonation gun spray. At present, more and more investigations are being carried out to improve properties of thermal spray coatings, in particular for the dry contact situation. We have deposited a series of WC-Co/MoS_2-Ni coatings by detonation gun (D-gun) spray, using a commercial WC-Co powder and a MoS_2-Ni powder, with a proper spray condition in view of both powders. The structure, mechanical, and sliding wear properties of these coatings were characterized. The results by SEM, EMPA, XRD, and XRF indicate that the MoS_2 composition was kept and distributed homogeneously in the WC-Co/MoS_2-Ni coatings and its content is a little higher than the feed powder. The results also indicate that hardness, fracture toughness, and adhesion of the WC-Co/MoS_2-Ni coatings decrease with the increasing MoS_2 content in the coating, while porosity and roughness the same, comparing with a pure WC-Co coating deposited under the same condition. It is found that this WC-Co/MoS_2-Ni coating possesses self-lubricating property. Furthermore, the MoS_2 composition in the WC-Co/MoS_2-Ni coatings shows a contribution in lowering wear rate under dry sliding conditions when its content is lower than 4.9 wt.%. However, the wear rate is higher when the content is 7.2 wt.%, which indicate that the MoS_2 content should be proper for an improvement of the D-gun sprayed WC-Co/MoS_2-Ni coating on wear resistance.

Keywords: adhesion, detonation gun spraying, fracture toughness, porosity, scanning electron microscopy, self-lubricating composites, self-lubricating property, sliding wear properties, sprayed coatings, thermal spray coatings, wear resistance, x-ray diffraction analysis

H. Du, C. Sun, W. Hua, T. Wang, J. Gong, X. Jiang, and S.W. Lee, Division of Surface Engineering of Materials, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China. Cited: *Mater. Sci. Eng. A*, 2007, Feb 15, **445-446**, p 122-134. ISSN 0921-5093.

Study of the amplitude-dependent mechanical behavior of yttria-stabilized zirconia thermal barrier coatings. Widely used in turbines for propulsion and power generation, thermal barrier coatings (TBCs) increase the efficiency of turbine engines by allowing them to work at higher temperatures, due to their thermal insulating properties. Typically, TBC systems consist of a metallic bondcoat (BC) and a ceramic topcoat (TC). Previous research has revealed that ceramic TCs possess an amplitude-dependent mechanical behavior and that they can be used as damping treatments, due to their good damping properties. The microstructure and the properties of ceramic TCs vary significantly depending on the employed deposition technique. This work investigates the differences in the mechanical behavior of yttria-stabilized zirconia (YSZ with 8 wt.% yttria) TC deposited by atmospheric plasma spraying (APS) and electron beam-physical vapor deposition (EB-PVD), by means of tests run with the amplitude-dependent damping (ADD) test rig and of scanning electron microscopy (SEM) analysis.

Keywords: atmospheric plasma spraying, electron beam-physical vapor deposition, mechanical properties, nondestructive evaluation, nondestructive examination, physical vapor deposition, plasma spraying, scanning electron microscopy, thermal barrier coatings, thermal insulating materials, thermal insulating properties, thermodynamic properties, yttrium compounds, zirconia

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Study on influence of porosity, pore size, spatial, and topological distribution of pores on microhardness of as plasma sprayed ceramic coatings. Plasma sprayed ceramic coatings invariably form with at least 5-10% porosity due to inherent deficiency in the spray technology. On many occasions, the volume fraction, size, and distribution of the pores alone do not suffice to predict properties such as microhardness. The spatial and topological arrangement of the pores in the precinct of intended hardness measurement area appears to be the most important parameters that could be directly correlated to hardness. In this paper, an attempt was made to measure the topological and spatial distribution of the pores mathematically, respectively, with Voronoi cells and Euclidean distance mapping. The influence of pores on microhardness of the coatings was determined at loads of 2.97, 4.9, and 9.8 N from 10 locations at every specified load. At intermediate and higher loads the influence of cluster and neighbor distance between pores could be easily elucidated. Hardness was found to be larger on occasions and for those locations that would result in large number of Voronoi cells corresponding to a cell area of 5000 pixels. Similarly, in terms of Euclidean distances, the hardness was found to be larger from areas that showed large number of widely separated pores.

Keywords: ceramic coatings, Euclidean distance mapping, microhardness, plasma spray coatings, plasma spraying, pore size, porosity, spatial distribution, sprayed coatings, Voronoi cell area

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Tribological properties of HVOF as-sprayed and heat treated Co-Mo-Cr-Si coatings. HVOF sprayed Co-28%Mo-17%Cr-3%Si alloy tribological performance was tested in the as-sprayed condition and after thermal treatments at 200, 400, 600 °C for 1 h. As-sprayed coating possesses low hardness, undergoes adhesive wear against 100Cr6 steel and displays a high-friction coefficient causing relevant thermal effects. The 600 °C heat treatment increases microhardness, thus preventing adhesive wear and reducing friction.

Keywords: adhesive wear, cobalt alloys, friction, heat treatment, high-friction coefficient, microhardness, sprayed coatings, tribology, wear of materials

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Wear and oxidation behavior of shrouded plasma sprayed fly ash coatings. In a wide variety of applications, mechanical components are subjected to severe conditions, such as high load, speed, or temperature and hostile chemical environment. Thus, their surface modification is necessary in order to protect them against various types of degradation. Thermal spraying has emerged as an important tool of increasingly sophisticated surface engineering technology. Plasma spraying is a rather simple process from a practical point of view. In the present investigation, the fly ash coating has been obtained by shrouded plasma spray process on carbon steel. The coating was characterized with relative to important behavioral parameters. Wear, oxidation, and salt corrosion behavior have also been evaluated. The coating has found to possess much higher hardness values than base steel, and its porosity is slightly higher than the range of porosity for plasma spray coatings. The coating was effective to increase the oxidation and salt corrosion resistance of the given carbon steel. However, the wear resistance of fly ash coated steel was observed to be lesser than the bare steel probably due to coarse grain size.

Keywords: carbon steel, degradation, fly ash, hardness, oxidation, plasma spraying, porosity, shrouded plasma, sprayed coatings, steel corrosion, surface engineering, surface treatment, thermal spraying, wear of materials

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Oxidation

Cyclic oxidation behavior of some plasma sprayed coatings in Na_2SO_4-60%V_2O_5 environment. Cyclic oxidation behavior of plasma sprayed NiCrAlY, Ni-20Cr, Ni_3Al, and Stellite-6 coatings was investigated in an aggressive environment of Na_2SO_4-60%V_2O_5 by thermogravimetric techniques for 50 cycles. These coatings were deposited on a nickel-base superalloy, namely Superni 600; 10Fe-15.5Cr-0.5Mn-0.2C-Bal Ni (wt.%). X-ray diffraction, scanning electron microscopy/energy dispersive x-ray (SEM/EDX), and electron probe microanalyzer (EPMA) techniques were used to analyze the oxidation products. The uncoated superalloy suffered accelerated oxidation in the form of intense spallation of its oxide scale. After deposition of the NiCrAlY coating, the superalloy showed a minimum mass gain, whereas after application of the Stellite-6 coating, a maximum mass gain was observed among the coatings studied. All of the coatings were found to be useful in reducing the spallation of the substrate superalloy. Moreover, the coatings were successful in maintaining continuous surface contact with the base superalloy during the cyclic oxidation. The phases revealed for the oxidized coatings were mainly the oxides of chromium and/or aluminum and the spinels containing nickel-chromium/cobalt-chromium/nickel-aluminum mixed oxides, which are reported to be protective against high-temperature oxidation/hot corrosion.

Keywords: deposition, hot corrosion, NiCrAlY, oxidation, plasma sprayed coatings, plasma spraying, protective coatings, sprayed coatings, Stellite 6, thermogravimetric analysis, x-ray diffraction analysis

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Some observations on the high-temperature oxidation behavior of plasma sprayed Ni_3Al coatings. High-temperature oxidation resistance of the superalloys can be greatly enhanced by plasma sprayed coatings, and this is a growing industry of considerable economic importance. The purpose of these coatings is to form long-lasting oxidation protective scales. In the current investigation, Ni_3Al powder was prepared by mechanical mixing of pure nickel and aluminum powders in a ball mill. Subsequently, Ni_3Al powder was deposited on three nickel-base superalloys: Superni 600, Superni 601, and Superni 718 and, one iron-base superalloy, Superfer 800H by shrouded plasma spray process. Oxidation studies were conducted on the coated superalloys in air at 900 °C under cyclic conditions for 50 cycles. Each cycle consisted of 1 h heating followed by 20 min of cooling in air. The thermogravimetric technique was used to approximate the kinetics of oxidation. All the coated superalloys nearly followed parabolic rate law of oxidation. X-ray diffraction, SEM/EDAX, and EPMA techniques were used to analyze the oxidation products. The Ni_3Al coating was found to be successful in maintaining its adherence to the superalloy substrates in all the cases. The oxide scales formed on the oxidized coated superalloys were found to be intact and spallation-free. XRD analysis revealed the presence of phases like NiO, Al_2O_3, and $NiAl_2O_4$ in the oxide scales, which are reported as protective oxides against high-temperature oxidation. The XRD results were further supported by SEM/EDAX and EPMA.

Keywords: energy dispersive spectroscopy, high-temperature oxidation, inorganic coatings, nickel alloys, oxidation resistance, oxide scales, plasma spray coatings, plasma spraying, protective coatings, scanning electron microscopy, sprayed coatings, superalloys, thermogravimetric analysis, x-ray diffraction analysis

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Thermal Barrier Coatings

Detection of microdamage evolution of air plasma sprayed Y_2O_3-ZrO_2 thermal barrier coating through TGO stress measurement. The microdamage evolution behavior in air plasma sprayed 8 mass% Y_2O_3 stabilized ZrO_2 thermal barrier coating (APS-TBC) after isothermal heat exposure at 1150 °C up to 200 h was observed. Residual stress of thermally grown oxide (TGO) layer was measured through the TBC layer using Cr^{3+} luminescence spectroscopy, and the measured stress levels were compared with microdamage evolution behavior stored in the TBC system. With heat exposure time of longer than 10 h, microfracture behaviors were noted in the TBC layer. In-plane residual stress of the TGO layer increased for up to 50 h of heat exposure time and, thereafter, diminished with further increase. These behaviors are strongly correlated with the thickness and the residual stress of the TGO layer. This decrease in the TGO stress well contrasts with the evolution of the microfracture behavior, which is also related to the thickness and undulation of the formed TGO layer. The change of TGO stress, σ_{tgo}, depending on the average thickness of the TGO layer, $\bar{h}_{tgo}$, that is, $d\sigma_{tgo}/d\bar{h}_{tgo}$ is a useful indicator of the damage evolution in TGO: $d\sigma_{tgo}/d\bar{h}_{tgo} > 0$: slight damage stage, $d\sigma_{tgo}/d\bar{h}_{tgo} \leq 0$: microfracture evolution stage. The result suggests that Cr^{3+} luminescence spectroscopy is a good indicator for micro damage evolution in the TBC layer and is a useful tool for nondestructive evaluation (NDE) of APS-TBC systems.

Keywords: cracks, damage evolution, damages, luminescence spectroscopy, nondestructive examination, plasma spraying, residual stresses, sprayed coatings, thermal barrier coatings, thermally grown-oxide layers, yttrium alloys

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Development of plasma sprayed thermal barrier coatings with low thermal conductivity and high oxidation resistance. The continuous increase of the turbine inlet temperature in gas turbines necessitates new thermal barrier coatings (TBCs) with enhanced temperature capability and longer lifetime. This paper reviews our recent challenges to develop new plasma sprayed TBC systems for the next generation of land-based gas turbine engines. It is shown that the addition of small amounts of La_2O_3 is effective in reducing the thermal conductivity of Y_2O_3-stabilized ZrO_2 plasma sprayed top coats. It is also revealed that precise control of the oxygen partial pressure of the preoxidation atmosphere leads to an improvement of the oxidation resistance of MCrAlY bond coats. The newly developed TBCs show much longer thermal cycle life than that of conventional coatings.

Keywords: lanthanum compounds, oxidation resistance, oxygen partial pressure, partial pressure, phase stability, plasma spraying, sintering, thermal barrier coatings, thermal conductivity, thermal cycle life, thermal cycling, zirconia

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Fatigue behavior of a thermal barrier coated superalloy at 800 °C. Fatigue testing of thermal barrier coated (TBC), bond coated only and bare Superni C263 superalloy was conducted at 800 °C in air. Results reveal that the endurance limits for the TBC and bond coated substrate was substantially higher than that of the base alloy, while the opposite was found for high stress, low cyclic lifetimes. It appears that the increase in endurance limit for the TBC and bond coated superalloy is due to load shifting to the bond coat, and the premature failure for these two materials is possibly due to high stress crack imitation/growth in the TBC/bond coat layers.

Keywords: bond coated superalloy, crack propagation, durability, fatigue testing, substrates, superalloys, thermal barrier coatings

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Preparation of insulating refractory materials by plasma spray technology. The study covers results of production of high thermal resistant granules, fibers, and ceramic coatings by plasma spray technology. Aluminum hydroxide, pure kaolin, and their mixtures with 20%, 50%, and 80% quartz sand, yttria partially (10 wt.%) stabilized zirconia and titanium dioxide were injected into air plasma jet generated by DC linear plasma torch. Hard ceramic granules and fibers were produced in the plasmachemical reactor, which is directly connected with a plasma torch. The coatings were deposited on polished titanium alloy and stainless steel sheets. Determination of microstructure, elemental, and phase composition of the resulting products was carried out using scanning electron microscopy and x-ray diffraction analysis, respectively, along with studies of mechanical properties of the material. As the data of this study show, the use of plasma spraying technology has significant consequence in the formation of high thermal resistant refractory products that represent a new approach in the domain of mineral fiber and granules preparation.

Keywords: aluminum hydroxide, ceramic coatings, granular materials, kaolin, microstructure, mineral fiber, plasma spraying, plasma torches, plasma-chemical reactors, refractory materials, scanning electron microscopy, thermal insulating materials, thermal resistant coating, titanium alloys, titanium dioxide, x-ray diffraction, zirconia

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