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Selected Abstracts of Thermal Spray Literature

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Applications

Biomaterials and Bioactive Materials

Adhesive and bending failure of thermal sprayed hydroxyapatite coatings: Effect of nanostructures at interface and crack propagation phenomenon during bending. Hydroxyapatite (HA) coatings have shown promising effects on rapid bone remodeling and suitable functional life in orthopedic and dental applications. However, the major problem encountered by the HA-coated implants is the failure of the coating due to its insufficient mechanical properties. The present study investigated the influence of the microstructure near to the coating/substrate interface on the adhesion of the coatings. In addition, the crack propagation behavior within the coatings was studied through four-point bend test. Results showed that nanostructures (30-110 nm) within the HA coatings were achieved by high-velocity oxyfuel (HVOF) spraying. Comparison among HVOF HA coatings, which were deposited using different starting feedstock, suggests detrimental effect of the perpendicular-to-substrate nanocuboids on adhesion of the coatings. The presence of the grains with hexagonal shape (≤250 nm in length and ≤50 nm in diameter) triggered a deteriorated adhesion. Granular nanosized grains at the interface give rise to enhanced adhesion through improved mechanical interlocking. Formation mechanism of the nanosized grains was discussed in this paper. Furthermore, the four-point bend test revealed consistent crack propagation path that the cracks actually grow within the coating with a direction parallel to the interface, and approximately several to 20 μm thick coatings were remained on the substrate. The critical strain energy release rate exhibited a value of ~1.15 kJ/m^2. During the crack propagation, kinking and trapping of the bending cracks were decided by the flaws within the coating, which were mainly located at splat interface. The interface between the first layer (with one splat thickness) and the second is believed to be the weakest zone in the nanostructured coating.

Keywords: adhesion, bending tests, coating/substrate interface, crack propagation, energy release rate, high-velocity oxyfuel spraying, hydroxyapatite, implants (surgical), microstructure, nanostructures, thermal spraying

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Adhesive and cohesive properties by indentation method of plasma sprayed hydroxyapatite coatings. Adhesive and cohesive properties of the plasma sprayed hydroxyapatite (HA) coatings, deposited on Ti-6Al-4V substrates by varying the plasma power level and spray distance (SD), were evaluated by an indentation method. The crystallinity and the porosity decreased with increasing both of these two parameters. The microhardness value, Young's modulus (E) and coating fracture toughness (K_C) were found to increase with a combinational increase in spray power and SD. The Knoop and Vickers indentation methods were used to estimate E and K_C, respectively. The critical point at which no crack appears at the interface was determined by the interface indentation test. This was used to define the apparent interfacial toughness (K_{Ca}), which is representative of the crack-initiation resistance of the interface. It was found that K_{Ca} reaches to a maximum at a medium increase in both spray power and SD, while other mechanical properties of the coatings reach the highest value with further increase in these two plasma parameters. The tensile adhesion strength of the coatings, measure by the standard adhesion test, ISO 13779-4, was shown to alter in the same manner with K_{Ca} results. It was deduced that a combinational increase in spray power and SD that leads to a higher mechanical properties in the coatings, does not necessarily tends to a better mechanical properties at the interface.

Keywords: adhesion strength, adhesives, elastic moduli, hydroxyapatite, indentation, interfaces (materials), microhardness, plasma parameters, plasma spraying, porosity, spray distance, spray power, sprayed coatings, substrates

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Destination of titanium particles detached from titanium plasma sprayed implants. Small titanium particles may detach from titanium plasma sprayed (TPS) implants during implant insertion, when no preliminary tapping is used, probably for the frictional force between titanium coating and host bone. Aim of this study was to investigate the destination of these titanium particles observed in the peri-implant environment. Twenty-four TPS screws were implanted in tibias of two sheep. Fourteen and 90 days after implantation the implants with the surrounding bone were removed and processed to be analyzed by light microscope and scanning electron microscope (secondary electron and backscattered electron probes). Small titanium particles detached from the unloaded TPS implants were observed both in the newly formed bone matrix and in marrow tissue. Histomorphometric analysis showed that both at 14 and 90 days after implantation the titanium particles appeared more concentrated in marrow tissue than in calcified bone matrix, decreasing by 66.4% over time. In particular, smaller particles (≤250 μm^2) decreased by 81.5%, whereas the larger ones (250-2000 μm^2) did not show any significant variations over time, suggesting that most of the smaller particles may undergo to ionic dissolution, probably migrating into the peri-implant marrow lacunas. A slight migration of titanium particles from the implant surface toward the more distant peri-implant tissues was also demonstrated over time.

Keywords: bone, endosseous implants, histology, implants (surgical), plasma spraying, scanning electron microscopy, titanium, titanium detachment, titanium particles, titanium plasma sprayed implants, ultrastructure

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Influence of spray parameters on the microstructure and mechanical properties of gas-tunnel plasma sprayed hydroxyapatite coatings. For biomedical applications, hydroxyapatite (HA) coatings were deposited on 304 stainless steel substrate by using a gas tunnel type plasma spraying process. The influences of spraying distances and plasma arc currents on the microstructure, hardness, and adhesion properties of HA coatings were investigated. Microstructure observation by SEM showed that HA coatings sprayed at low plasma power have a porous structure and poor hardness. HA coatings sprayed at high plasma power and short spraying distance are characterized by good adhesion and low porosity with dense structure. Hardness increased for HA coatings sprayed at shorter spraying distance and higher plasma power, mainly due to the formation of dense coatings.

Keywords: adhesion, arc currents, coatings, gas tunnel type plasma spraying, hardness, hydroxyapatite, medical applications, microstructure, plasma spraying, porosity, spraying distance, stainless steel

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Phase transformation of plasma sprayed hydroxyapatite coating with preferred crystalline orientation. Highly oriented hydroxyapatite coatings (HACs) were obtained on titanium substrates through a radiofrequency thermal plasma spraying (TPS) method. XRD patterns showed that the HACs had crystallites with [00l] preferred orientation vertical to the coating surface. XRD results also indicated that tetracalcium phosphate crystallites in the as-sprayed HAC were oriented in the (100) direction. XRD peaks corresponding to tetracalcium phosphate, tricalcium phosphate, and calcium oxide were absent after heat and hydrothermal treatment. The orientation degree of the HAC was influenced little by such post heat treatments. Considering the crystallographic relationship between the tetracalcium phosphate in the as-sprayed HAC and the HA crystallites formed in the heat-treated HAC, these XRD results indicate that the tetracalcium phosphate in the as-prepared coatings transformed topotaxially into HA during the post heat treatment. TEM and SEM analyses of the highly oriented HAC were conducted. The characteristic lamellar structure of TPS deposits was observed in cross sections of the HAC. A prismatic texture was also observed in magnified SEM images. TEM observation showed that 200-800 nm wide prismatic crystallites were formed in HA splats, and their longitudinal axis was oriented vertically to the coating surface. SAD patterns showed that the longitudinal axis of the prismatic crystallites corresponded to the [001] zone axis of the HA crystal.

Keywords: coatings, crystal orientation, crystallization, heat treatment, hydroxyapatite, hydroxyapatite coating, phase transitions, plasma spraying, scanning electron microscopy, tetracalcium phosphate crystallites, titanium substrates, topotaxy, x-ray diffraction analysis

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A preliminary report on a novel electrospray technique for nanoparticle-based biomedical implants coating: Precision electrospraying. The compatibility and biological efficacy of biomedical implants can be enhanced by coating their surface with appropriate agents. For predictable functioning of implants in situ, it is often desirable to obtain an extremely uniform coating thickness without effects on component dimensions or functions. Conventional coating techniques require rigorous processing conditions and often have limited adhesion and composition properties. In the present study, the authors report a novel precision electrospraying technique that allows both degradable and nondegradable coatings to be placed. Thin metallic slabs, springs, and biodegradable sintered microsphere scaffolds were coated with poly(lactide-coglycolide) (PLAGA) using this technique. The effects of process parameters such as coating material concentration and applied voltage were studied using PLAGA and poly(ethylene glycol) coatings. Morphologies of coated surfaces were qualitatively characterized by scanning electron microscopy. Qualitative observations suggested that the coatings were composed of particles of various size/shape and agglomerates with different porous architectures. PLAGA coatings of uniform thickness were observed on all surfaces. Spherical nanoparticle poly(ethylene glycol) coatings (462-930 nm) were observed at all concentrations studied. This study found that the precision electrospraying technique is elegant, rapid, and reproducible with precise control over coating thickness (μm to mm) and is a useful alternative method for surface modification of biomedical implants.

Keywords: adhesion, biocompatibility, biodegradation, biomaterials, biomedical implants, chemical analysis, coatings, electrospray, nanoparticles

S.G. Kumbar, S. Bhattacharyya, S. Sethuraman, and C.T. Laurencin, Department of Orthopaedic Surgery, University of Virginia, Charlottesville, VA 22903. Cited: *J. Biomed. Mater. Res.—Part B Appl. Biomater.*, 2007, April, **81**(1), p 91-103. ISSN 1552-4973.

Deposition

A laser-induced thermal spray printing process for phosphor layer deposition of PDP. An efficient printing process, called laser-induced thermal spray printing (LITSP), is introduced in this work to deposit the phosphor layer of the plasma display panel. LITSP is a noncontact printing process, which transfers the phosphor paste from the donor plate to the substrate by the bubble pressure induced by laser heating. The mechanism of the LITSP is analyzed through numerical calculation and experiments. The temperature distribution of the donor plate is calculated to explain the paste ejection phenomena, and the proper paste composition and laser heating condition are determined experimentally. The entire phosphor paste is ejected successfully from the etched hole of the donor plate when the etched hole bottom is heated.

Keywords: bubble pressure, laser heating, noncontact printing processes, phosphor paste, phosphors, plasma display devices, temperature distribution, thermal printing, thermal spraying

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Functional

Atmospheric plasma sprayed cobalt ferrite coatings for magnetostrictive sensor applications. Cobalt ferrite powder was synthesized by chemical coprecipitation followed by a heat treatment at 1100 °C for 10 h and was subsequently deposited onto titanium and alumina substrates using atmospheric plasma spraying technique. X-ray diffraction results indicate that the as-deposited coating consists of spinel and wustite phase. The hysteresis loop measurements show that the coating has a relatively low saturation magnetization and a coercivity of 1270 Oe for in-plane direction. Magnetostriction of the as-deposited coating at ambient temperature is -73×10^{-6} with an applied magnetic field of 4530 Oe.

Keywords: cobalt compounds, cobalt ferrite, cobalt ferrite powder, hysteresis loops, magnetostriction, magnetostrictive devices, plasma spraying, powders, sensors, wustite phase, x-ray diffraction analysis

S. Liang, B.G. Ravi, S. Sampath, and R.J. Gambino, Materials Science and Engineering Department, Stony Brook University, Stony Brook, NY 11794-2275. Cited: *IEEE Trans. Magn.*, 2007, June, **43**(6), p 2391-2393. ISSN 0018-9464.

Fabrication of MOSFET capacitive sensor using spray coating method. A capacitive MOSFET sensor using a SOI wafers for detecting vertical force applied to its floating gate is herein proposed. A MOSFET is fabricated on a SOI wafer, and the box oxide under the gate is removed to release the gate structure. This sensor detects the displacement of the movable gate electrode from changes in drain current, and this current can be amplified electrically by adding voltage to the gate; that is, the MOSFET itself serves as a mechanical sensor structure. By using a SOI wafer having a thick active silicon layer, a thick gate structure is made possible, which increases the mechanical stiffness and durability and increases the sensitivity in accelerometer application by weighting a proof mass. During the fabrication process of this sensor, it is necessary that photoresist be coated on the top surface and sidewall of the vertical pillar structure with a high aspect ratio. To address this problem, photoresist is applied using spray coating. The uniform coating is successfully realized by adjusting the moving speed of the substrate and the substrate temperature. A practical test device is under development using this method, and aluminum electrodes for drain, source, and gate areas are successfully patterned.

Keywords: accelerometers, electric currents, electrodes, gate dielectrics, high aspect ratio pillar, MOSFET devices, sensors, silicon on insulator technology, spray coating of photoresist, spray drying, vertical sidewall

S. Aoyagi, Y. Matsui, K. Makihira, H. Tokunaga, M. Sasaki, and K. Hane, Kansai University, Suita, Osaka 564-8680, Japan. Cited: *IEEJ Trans. Sensors Micromach.*, 2007, **127**(3), p 153-159. ISSN 1341-8939.

Shape memory effect and superelastic behavior of TiNi shape memory alloy processed by vacuum plasma spray method. Machining of TiNi shape memory alloy into a complicated three-dimensional (3D) shape is quite difficult; thus a near-net-shape forming of 3D-shaped TiNi alloy is attractive and cost effective. Vacuum plasma spray (VPS) process is one of such near-net-shape forming processes. In this paper, two kinds of thick TiNi layer, Ni-rich and Ti-rich compositions, were fabricated by VPS process and their shape memory effect (SME) and superelastic (SE) behaviors were characterized. As-VPS processed Ni-rich TiNi, which was subjected to homogenization at 1163 K for 7.2 ks and subsequent aging at 773 K for 18 ks exhibited good martensitic transformation behavior. The recoverable strain of the TiNi alloys due to SME and SE behavior were measured to be 2.4 and 5.0%, respectively. The Ti-rich TiNi alloy also exhibited good martensitic transformation behavior and SME in the as-homogenized state.

Keywords: elasticity, martensitic transformations, near-net-shape forming, shape memory effect, stress-strain curves, superelastic behavior, titanium alloys, vacuum applications, vacuum plasma spray

H. Nakayama, M. Taya, R.W. Smith, T. Nelson, M. Yu, and E. Rosenzweig, Center for Intelligent Materials and Systems, Department of Mechanical Engineering, University of Washington, Seattle, WA 98195-2600. Cited: *Mater. Sci. Eng. A*, 2007, June 25, **459**(1-2), p 52-59. ISSN 0921-5093.

Photocatalytic Applications

Effect of silver addition on the formation and deposition of titania nanoparticles produced by liquid flame spray. In this study, liquid flame spray (LFS) was used to produce titania, silver, and silver-titania deposits of nanoparticles. Titanium (IV) ethoxide (TEOT) and silver nitrate in ethanol solutions were used as precursors and sprayed into turbulent hydrogen-oxygen flame. Production rates of 1.5 to 40 mg/min of titania were used with silver additions of 1, 2, 4, and 8 wt% compared with titania. Nanoparticle deposits were collected by thermophoretic sampling at six different axial distances from the flame torch head: 3, 5, 10, 12, 15, and 20 cm, of which the all but the last one occurred inside the flame. The deposit samples were analyzed by TEM and SAED analysis. The powder samples of the particles were also collected by electric precipitator to XPS and specific surface area analysis. Particle size and effective density after the flame in the aerosol were analyzed with SMPS and ELPI. The results from the previous studies, that is, controlling the particle size by setting the production rates of the particles were seen to apply also for this binary system. Characterization of the deposits showed that when the substrate is inserted into the flame, in the beginning of the flame the deposit is formed by gas-phase deposition whereas further down the flame the particles are first formed in the gas phase and then deposited. The location of the transition from gas-phase deposition to gas-phase nucleation prior to deposition depends on chemical/physical properties (e.g., thermodynamics and gas-phase interactions) of the precursor, precursor concentration in the flame and also flame temperature profile. Therefore, the deposit collection distance from the burner also affected the collected particle size and degree of agglomeration. The two component deposits were produced in two different ways: one-step method mixing both precursors in the same solute, and two-step method spraying each precursor separately. The particle morphology differs between these two cases. In one-step method the primary (d_{TEM}) and agglomerate particle size (d_{SMPS}) decreased with the amount of silver addition, verifying the fact that when present, the silver has a clear effect on the titania nanoparticle formation and growth.

Keywords: aerosols, ethanol, flame spraying, gas-phase interactions, hydrogen, nanoparticles, particle size analysis, precursor concentration, silver, silver addition, thermophoresis, titania nanoparticle formation, titanium oxides

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Photocatalytic performance of plasma sprayed Pt-modified TiO_2 coatings under visible light irradiation. Plasma sprayed Pt/TiO_2 coatings were prepared by Atmospheric Plasma Spraying process. As-sprayed coatings were characterized by TEM, XRD and XPS. The photocatalytic performance was evaluated through the photo mineralization of methylene blue. All the Pt modified titanium dioxide coatings show significant absorption in the visible light range, while the pure titania coating reflects almost all the visible light. The photocatalytic efficiencies of as-sprayed pure TiO_2 coating and Pt/TiO_2 coatings are almost same under the irradiation of visible light. However, the efficiencies of all Pt/TiO_2 coating are greatly improved compared with that of pure TiO_2 coating by applying 15 V external bias under the irradiation of visible light.

Keywords: light absorption, photo mineralization, photocatalysis, photocatalytic performance, plasma spraying, Pt-modified TiO_2 coating, titanium dioxide, transmission electron microscopy, visible light, x-ray diffraction

Y. Zeng, W. Wu, S. Lee, and J. Gao, Shanghai Institute of Ceramics, Chinese Academy of Science, Shanghai, 200050, China. Cited: *Catal. Commun.*, 2007, June, **8**(6), p 906-912. ISSN 1566-7367.

Synthesis of titania films by combustion flame spray pyrolysis technique and its characterization for photocatalysis. The phase composition, texture, and roughness of titania films deposited using combustion flame pyrolysis technique are studied as a function of substrate temperature, deposition time, and precursor concentration. In this process, a liquid precursor feedstock that results in TiO_2 film is injected into a combustion flame and the film is deposited onto a silica substrate. The resulting film has anatase at low substrate temperature, rutile at high substrate temperature, and a mixture of these two phases at intermediate temperatures. A large decrease in the average size of the primary particles that constitute the film is observed with low precursor concentration. The band gap energy of titania films with different phase compositions is measured using UV spectrophotometer. ZnO films are deposited from sprayed droplets of an aqueous zinc acetate solution by using this process and comparison of TiO_2 and ZnO films on the photocatalytic degradation of remazol brilliant blue is investigated.

Keywords: combustion, combustion flame, deposition time, energy gap, feedstocks, flame spray pyrolysis, flame spraying, photocatalysis, rutile, substrate temperature, textures, thin films, titanium oxides, ultraviolet spectrophotometers

R. Kavitha, S. Meghani, and V. Jayaram, Department of Metallurgy, Indian Institute of Science, Bangalore, India. Cited: *Mater. Sci. Eng. B: Solid-State Mater. Adv. Technol.*, 2007, May 15, **139**(2-3), p 134-140. ISSN 0921-5107.

Solid Oxide Fuel Cells

Suspension and solution plasma spraying of finely structured layers: Potential application to SOFCs. Suspension direct current plasma spraying allows achieving finely structured coatings whose thickness is between few tens and few hundreds of micrometers. Drops (200-300 μm in diameter) or liquid jets are mechanically injected in the plasma jet. With radial injection they are rapidly (a few μs) fragmented into droplets (a few μm in diameter). The latter are vaporized (in a few μs), and the solid particles contained in suspension droplets are accelerated and melted by the plasma jet. As in conventional plasma spraying (CPS), much smaller splats (with diameters between 0.2 and 3 μm and thicknesses between 30 and 200 nm) are arranged in layers up to form the coating. The low inertia of particles requires spray distances between 40 and 60 mm, which induces plasma heat fluxes up to 22 MW/m^2 participating in coating densification. Even more than in CPS, the plasma jet fluctuations, particularly for plasmas containing diatomic gases, perturb drops penetration and fragmentation. It has been chosen to illustrate difficulties and possibilities of this new method, through the spraying of the three layers of an element of solid oxide fuel cells. Indeed, it requires a dense stabilized zirconia electrolyte, if possible thin (15-20 μm) with two porous electrodes: cathode made of perovskite prone to decomposing upon spraying and anode made of two materials (nickel and zirconia) with very different melting points. These components were obtained by spraying ethanol suspensions, with, first, $LaMnO_3$ perovskite particles doped with 10 mol% of MnO_2 and 3 μm in mean diameter sprayed with pure argon to limit their decomposition and achieve porous coatings, second, yttria-stabilized (13 wt%) zirconia (YSZ) with two different particle size distributions and morphologies for which plasma compositions were adapted, producing in both cases 15 μm thick and fully dense coatings, third, porous Raneigh nickel by cospraying the YSZ suspension and solution of nickel nitrate.

Keywords: coating densification, densification, perovskite, plasma jet fluctuations, plasma jets, plasma spraying, porous coatings, solid oxide fuel cells, solid particles, suspensions (fluids), yttria-stabilized zirconia

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Thermal Barrier Coatings

Application of rare earths in thermal barrier coating materials. Rare earths are a series of minerals with special properties that make them essential for applications including miniaturized electronics, computer hard disks, display panels, missile guidance, and pollution controlling catalysts, H_2-storage, and other advanced materials. The use of thermal barrier coatings (TBCs) has the potential to extend the working temperature and the life of a gas turbine by providing a layer of thermal insulation between the metallic substrate and the hot gas. Yttria (Y_2O_3), as one of the most important rare earth oxides, has already been used in the typical TBC material YSZ (yttria-stabilized zirconia). In the development of the TBC materials, especially in the latest 10 years, rare earths have been found to be more and more important. All the new candidates of TBC materials contain a large quantity of rare earths, such as $R_2Zr_2O_7$ (R = La, Ce, Nd, Gd), CeO_2-YSZ, $RMeAl_{11}O_{19}$ (R = La, Nd; Me = Mg, Ca, Sr) and $LaPO_4$. The concept of double-ceramic-layer coatings based on the rare earth materials and YSZ is effective for the improvement of the thermal shock life of TBCs at high temperature.

Keywords: cerium compounds, double ceramic layer coatings, gadolinium compounds, gas turbines, lanthanum compounds, neodymium compounds, rare earth oxides, rare earths, thermal barrier coatings, thermal insulation, thermal shock, working life, working temperature, yttria-stabilized zirconia

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Effect of interface roughness and coating thickness on interfacial shear mechanical properties of EB-PVD yttria partially stabilized zirconia thermal barrier coating systems. The effect of interface roughness and thickness of thermal barrier coating (TBC) on the interfacial shear mechanical properties of electron beam physical vapor deposited (EB-PVD) TBC was examined using as-sprayed and polished bond coats (BC) 200 and 500 μm TBC thickness systems, by using a barb test method. The residual compressive stress in the TBC layer from the interface to the top surface was measured, by using Raman spectroscopy. The interface toughness related to the interface roughness and the thickness of the TBC. The interface toughness was larger for the BC as-sprayed TBC system than for the BC polished TBC system. The delamination of the TBC propagated within the TBC layer adjacent to the interface for the BC as-sprayed TBC; for the BC polished TBC, this occurred at the interface between the TGO and the BC. Moreover, the interface toughness was larger in the 500 μm thickness TBC than in the 200 μm thickness TBC. The relation of interface toughness to interface roughness and thickness of the TBC was associated with the interface residual compressive stress and with the interface sliding friction during the delamination of TBC.

Keywords: compressive stress, delamination, electron beams, interface sliding friction, interface toughness, physical vapor deposition, residual stresses, surface roughness, thermal barrier coatings, yttria-stabilized zirconia

S. Guo, Y. Tanaka, and Y. Kagawa, Composites and Coatings Center, National Institute for Materials Science, Tsukuba, Ibaraki, 305-0047, Japan. Cited: *J. Eur. Ceram. Soc.*, 2007, **27**(12), p 3425-3431. ISSN 0955-2219.

Effects of segregating elements on the adhesive strength and structure of the α-Al_2O_3/β-NiAl interface. We investigate with first-principles density functional theory (DFT) the adhesion of the $Al_2O_3(0001)$/NiAl(110) interface as a model for the thermally grown oxide/bond coat alloy interface in thermal barrier coatings. We find that the clean interface has an ideal work of adhesion of 0.66 J/m^2. We predict that S impurities reduce interfacial adhesion significantly, due to a reduction in cross-interface bonds. The presence of Pt alters the interface adhesion only slightly, while Hf dopants dramatically increase adhesion via formation of strong Hf-O bonds, as expected from the open-shell character of Hf. We discuss the implications of these predictions, which are consistent with experimental observations of the effects of S, Pt, and Hf on the lifetime of thermal barrier coatings.

Keywords: adhesives, crystalline oxides, interface segregation, interface structure, nickel aluminides, nickel compounds, probability density function, segregation (metallography), thermal barrier coatings

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High-pressure turbine deposition in land-based gas turbines from various synfuels. Ash deposits from four candidate power turbine synfuels were studied in an accelerated deposition test facility. The facility matches the gas temperature and velocity of modern first-stage high-pressure turbine vanes. A natural gas combustor was seeded with finely ground fuel ash particulate from four different fuels: straw, sawdust, coal, and petroleum coke. The entrained ash particles were accelerated to a combustor exit flow Mach number of 0.31 before impinging on a thermal barrier coating (TBC) target coupon at 1150 °C. Postexposure analyses included surface topography, scanning electron microscopy, and x-ray spectroscopy. Due to significant

differences in the chemical composition of the various fuel-ash samples, deposit thickness and structure vary considerably for each fuel. Biomass products (e.g., sawdust and straw) are significantly less prone to deposition than coal and petcoke for the same particle loading conditions. In a test simulating one turbine operating year at a moderate particulate loading of 0.02 ppm by weight, deposit thickness from coal and petcoke ash exceeded 1 and 2 mm, respectively. These large deposits from coal and petcoke were found to detach readily from the turbine material with thermal cycling and handling. The smaller biomass deposit samples showed greater tenacity in adhering to the TBC surface. In all cases, corrosive elements (e.g., Na, K, V, Cl, S) were found to penetrate the TBC layer during the accelerated deposition test. Implications for the power-generation goal of fuel flexibility are discussed.

Keywords: chemical analysis, coal ash, combustors, deposition, fuel ash, gas fuels, gas turbines, high-pressure turbine deposition, land-based gas turbines, scanning electron microscopy, surface topography, synfuels, thermal barrier coatings, x-ray spectroscopy

J.P. Bons, J. Crosby, J.E. Wammack, B.I. Bentley, and T.H. Fletcher, Department of Mechanical Engineering, Brigham Young University, Provo, UT 84602. Cited: *J. Eng. Gas Turbines Power*, 2007, Jan, **129**(1), p 135-143. ISSN 0742-4795.

Low thermal conductivity ceramics for thermal barrier coatings. This paper summarizes the basic properties of a series of rare earth zirconate ceramics ($Gd_2Zr_2O_7$, $Sm_2Zr_2O_7$, $Dy_2Zr_2O_7$, $Er_2Zr_2O_7$, and $Yb_2Zr_2O_7$). The phases and microstructures were characterized by x-ray diffraction (XRD) and scanning electron microscopy (SEM). Thermal properties of these materials were determined. The results indicated that $Sm_2Zr_2O_7$ rare earth zirconate ceramics have the lower thermal conductivity and the highest thermal expansion coefficient than other rare earth zirconate ceramics. The dielectric constant decreases with the increase of atomic number.

Keywords: atomic number, ceramic materials, microstructure, rare earth compounds, scanning electron microscopy, thermal barrier coatings, thermal conductivity, thermal conductivity ceramics, thermal expansion, thermal expansion coefficients, x-ray diffraction, zirconate ceramics

Y. Qin, J. Wang, W. Pan, C. Wan, and Z. Qu, State Key Laboratory of New Ceramics and Fine Processing, Department of Materials Science and Engineering, Tsinghua University, Beijing, 100084, China. Cited: *Key Eng. Mater.*, 2007, **336-338**(II), p 1764-1766. ISSN 1013-9826.

Preparation and thermophysical properties of CeO_2 doped $La_2Zr_2O_7$ ceramic for thermal barrier coatings. Lanthanum zirconate ($La_2Zr_2O_7$, LZ) and CeO_2 doped $La_2Zr_2O_7$ (LCZ) ceramic were synthesized by the coprecipitation-calcination method. The chemical compositions, phase compositions, and thermophysical properties of these materials were investigated. Inductively coupled plasma-atomic emission spectrometry (ICP-AES) and XRD results revealed that the compositions of all prepared ceramic materials were in the range of the synthesis of single $La_2Zr_2O_7$ with pyrochlore structure. After the prepared ceramic powders were mechanically ball milled, vacuum dried, molded by cold pressure, and densified by sinter at 1650 °C for 10 h, the bulk density of the sample was measured by the Archimedes method with an immersion medium of deionized water, a high-temperature dilatometer, differential scanning calorimetry (DSC), and laser thermal diffusivity method were used to analyze its thermal expansion coefficient, specific heat, and thermal diffusivity. The results showed that, with the temperature increasing, the thermal expansion coefficient (TEC) of these ceramics increased, while the thermal conductivity decreased. The thermal expansion coefficient of $La_2Zr_2O_7$ was enhanced clearly by adding CeO_2, and its thermal diffusivity and specific heat were all changed slightly. The thermophysical results also indicated that TEC of LCZ was slightly higher than that of conventional Y_2O_3-8 wt%ZrO_2 (8YSZ), but its thermal conductivity was lower than that of 8YSZ. The lower thermal conductivity of LCZ was mainly attributed to more oxygen vacancies and larger atomic weight of substitutional atom (La, Ce). These results imply that LCZ can be explored as the candidate material for the ceramic layer in TBCs system.

Keywords: atomic emission spectroscopy, CeO_2, ceramic materials, cerium compounds, coprecipitation calcination method, doping (additives), inductively coupled plasma, inductively coupled plasma-atomic emission spectrometry, lanthanum compounds, lanthanum zirconate, synthesis (chemical), thermal barrier coatings, thermodynamic properties

H. Zhou, D. Yi, Z. Yu, and L. Xiao, School of Materials Science and Engineering, Central South University, Changsha, Hunan 410083, China. Cited: *J. Alloys Compd.*, 2007, July 12, **438**(1-2), p 217-221. ISSN 0925-8388.

A promising $Sm_{1.9}Ca_{0.1}Zr_2O_{6.95}$ ceramic for thermal barrier coatings. $Sm_{1.9}Ca_{0.1}Zr_2O_{6.95}$ ceramic was sintered at 1600 °C for 10 h in air by solid-state reaction method. The phase structure and thermal expansion coefficient were measured by x-ray diffraction and a high-temperature dilatometry, respectively. The results show that the crystal structure of $Sm_{1.9}Ca_{0.1}Zr_2O_{6.95}$ ceramic is still pyrochlore. The doping with calcium cation leads to a shift of the x-ray spectrum of $Sm_{1.9}Ca_{0.1}Zr_2O_{6.95}$ ceramic to lower 2θ values. The experiments also show that the thermal expansion coefficients of $Sm_{1.9}Ca_{0.1}Zr_2O_{6.95}$ ceramic are higher than those of $Sm_2Zr_2O_7$ ceramic. These results are related to the vacancy induced by doped calcium cation in the samarium lattice.

Keywords: calcium cations, ceramic materials, high-temperature dilatometry, pyrochlores, samarium alloys, samarium lattices, sintered alumina, solid-state reactions, thermal barrier coatings, thermal expansion, x-ray diffraction

X. Qiang, P. Wei, W. Chunlei, Q. Longhao, and M. Hezhuo, State Key Laboratory of New Ceramics and Fine Processing, Department of Materials Science and Engineering, Tsinghua University, Beijing, 100084, China. Cited: *Key Eng. Mater.*, 2007, **336-338**(II), p 1762-1763. ISSN 1013-9826.

Stresses and microstructural development of thermal barrier coatings using AIP/D-gun two-step processing. After depositing a Ni-32Co-20Cr-8Al-0.5Y-1Si-0.03B (wt%) bond coat on a Ni-base superalloy using arc ion plating (AIP), a ceramic topcoat with hollow spherical powder of ZrO_2-8 wt%Y_2O_3 (HSP-YSZ) was deposited using detonation gun (D-gun) spraying. Thermal exposure behaviors of thermal barrier coatings (TBCs) were investigated at 1100 °C. The thermal growth oxides (TGO) layer thickened and became more undulated during thermal exposure. Yttrium aluminum garnet (YAG) was observed within TGO, which produced thickness imperfections and thus aided to build up out-of-plane stresses. As a result, radial cracks initiated at the defects around TGO imperfections and separation developed through crack nucleation, propagation, and coalescence at the weaker TGO/bond coat interface. With further thermal exposure, coalescence of interfacial separations created a connected crack. The TBC detached and final failure occurred at the TGO/bond coat interface, leading to spallation of TBC when cooling to ambient. The stress distributions in the TGO layer with different thermal exposure times were also measured using luminescence spectroscopy. The stresses were independent of time after a transient period from θ-Al_2O_3 to α-Al_2O_3 scale. It is suggested that the lifetime of AIP/D-gun TBCs with an HSP-YSZ coat is controlled by the initiation and linking of a subcritical interfacial crack.

Keywords: coalescence, detonation, interfacial cracks, luminescence spectroscopy, microstructure, nucleation, powders, spallation, thermal barrier coatings, thermal growth oxides

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Temperature dependence of the yttria-stabilized zirconia Raman spectrum. The Raman spectrum of 5 wt% yttria-stabilized tetragonal zirconia from 25 to 1250 °C is reported. All six Raman bands broaden and shift toward lower energy with increasing temperature. The shift associated with thermally induced volume changes is shown to be the main contribution for all bands, but does not explain the unexpected negative value of the thermospectroscopic coefficient found for the mode at 260 cm^{-1} (at room temperature). For all bands, the shift is found to be quasi-linear in the range of temperatures considered. As the thermospectroscopic coefficients are large, Raman spectroscopy is well suited as a noncontact, in situ method for monitoring temperature in applications of yttria-stabilized zirconia such as thermal barrier coatings and fuel cells.

Keywords: fuel cells, in situ processing, monitoring temperature, Raman scattering, stabilization, thermal barrier coatings, thermal effects, thermospectroscopic coefficients, yttria-stabilized zirconia

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Theoretical predictions of hydrogen recombination on zirconia. A model of catalytic recombination of hydrogen over zirconia is reported. Zirconia is the main thermal barrier coating in many propulsion systems and has been proposed also for nozzle facility to test Rubbia's nuclear engine using hydrogen propellant. Because hydrogen temperature may reach 6000 K, part of the heat load may be due to catalytic recombination of H atoms over zirconia. The structural features of zirconia lend themselves to derive a kinetic model similar to that already proposed by Bruno for O and N recombination over silica. This model is applied to conditions representative of high temperature hydrogen expanding in a zirconia-coated nozzle. The range of recombination probability is calculated as a function of model parameters. The heat load is calculated accounting for chemical energy accommodation that is chosen by estimating the most efficient recombination mechanism. The results show that the chemical energy accommodation $\sim 8 \times 10^{-5}$ and that the heat flux at the nozzle throat due to heterogeneous recombination of hydrogen is of order $O(10^{-1})$ MW/m^2 for surface temperature of the order of 1000 K. The kinetic model proposed is therefore capable of preliminary predictions of heterogeneous recombination, if the surface crystal structure is known, narrowing experimental matrices and reducing testing cost.

Keywords: catalyst activity, catalytic recombination, chemical energy accommodation, crystal structure, heat flux, kinetic model, nozzles, zirconia, zirconia-coated nozzle

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Thermal barrier coating of a turbine blade in the GTE transient operating conditions. We present a theoretical analysis of the thermostressed state of the thermal barrier coating on the perforated turbine blade in the transient and steady-state conditions of the GTE operation during flight and justify the technique for solving a nonstationary problem of heat conduction as applied to a blade.

Keywords: flight dynamics, gas turbines, heat conduction, steady-state condition, thermal barrier coatings, thermostressed state, transient-state condition, turbomachine blades

V.A. Trushin and O.V. Trushin. Cited: *Russ. Aeronaut.*, 2006, **49**(4), p 80-85. ISSN 1068-7998.

Thermal cycling behavior of lanthanum-cerium oxide thermal barrier coatings prepared by air plasma spraying. Lanthanum-cerium oxide ($La_2Ce_2O_7$, LC) is considered as a new candidate material for thermal barrier coatings (TBCs) because of its low thermal conductivity and high-phase stability between room temperature and 1673 K. The LC coatings with different La_2O_3 contents were prepared by air plasma spraying (APS), and their lifetime was evaluated by thermal cyclic testing from room temperature to 1373 K. The structures of the coatings were characterized by x-ray diffraction and scanning electron microscopy and the deviation of the composition from the powder was determined by energy-dispersive spectroscopy analysis. Long-time annealing for the freestanding coating at 1673 K reveals that the near-stoichiometric LC coating is stable up to 240 h, and the stability decreases with increasing the deviation from stoichiometric LC composition. During thermal cyclic testing, spallation was observed within the topcoat near the bond coat. It is considered that the effect of intrinsic stress caused by the coefficient of thermal expansion (CTE) mismatch between topcoat and bond coat is larger than that of thermally grown oxide (TGO) and the bond adherence of topcoat with TGO.

Keywords: air plasma spraying, freestanding coatings, lanthanum cerium oxide, lanthanum compounds, plasma spraying, thermal barrier coatings, thermal conductivity, thermal cyclic oxidation, thermal cycling, thermodynamic stability, x-ray diffraction

W. Ma, Y. Ma, S. Gong, H. Xu, and X. Cao, Department of Materials Science and Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100083, China. Cited: *Key Eng. Mater.*, 2007, **336-338**(II), p 1759-1761. ISSN 1013-9826.

Thermal shock behavior of nanostructured functionally graded thermal barrier coatings deposited by supersonic plasma spray. The nanostructured functionally graded 8YSZ/NiCoCrAlY thermal barrier coatings (FG-TBCs) were prepared using a recently developed supersonic plasma spraying (S-PS) system with dual powder feed ports. The alloy powders were fed into the lower-temperature regions of the plasma plume through one of them to prevent it over molten and oxidation. The ceramic powders were fed into high-temperature regions through another for fully melted. The thermal shock behavior of the FG-TBCs were investigated. It was found the totally 1 mm thick FG-TBCs layer still maintained nanostructure form by transmission electron microscopy and also exhibited a finely lamellate microstructure mixed by alloy and ceramic with gradient along the thickness direction by scanning electron microscopy. The FG-TBCs exhibit excellent thermal shock resistance due to it was still perfect without any spallation after thermal shock test over 200 cycles under heating by oxygen-acetylene flam to 1250 °C in 30 s and then quenching into ambient water.

Keywords: acetylene, functionally graded materials, microstructure, plasma spraying, powders, shock resistance, spallation, supersonic plasma spray, thermal barrier coatings, thermal shock, thermal shock resistance, transmission electron microscopy

Z. Han, H. Wang, S. Zhou, and B. Xu, State Key Laboratory of Remanufacture Technology, Armored Force Engineering Institute, Beijing 100072, China. Cited: *Key Eng. Mater.*, 2007, **336-338**(III), p 2624-2627. ISSN 1013-9826.

Thermophysical properties of BaY_2O_4: A new candidate material for thermal barrier coatings. Thermophysical properties of BaY_2O_4 that have a potential to be a new candidate material for thermal barrier coatings (TBCs) were studied. Polycrystalline bulk samples were prepared by solid-state reactions followed by a spark plasma sintering (SPS). The sample density was 88% of the theoretical one. The elastic moduli, Debye temperature, and micro Vickers hardness were investigated at room temperature. The linear thermal expansion coefficient and thermal conductivity were investigated in the temperature range from 300 to 1300 K.

Keywords: barium compounds, ceramic materials, elastic moduli, expansion coefficients, polycrystalline bulks, polycrystalline materials, sintering, thermal barrier coatings, thermal conductivity, thermal expansion

T. Maekawa, K. Kurosaki, and S. Yamanaka, Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Suita, Osaka, 565-0871, Japan. Cited: *Mater. Lett.*, 2007, May, **61**(11-13), p 2303-2306. ISSN 0167-577X.

Diagnostics and Control

Design of a fuzzy logic approach based on genetic algorithms for robust plasma sprayed zirconia depositions. This paper proposes a design for an adaptive system by modeling the relationship between coating surface roughnesses and the controlling factors in plasma spray coating processes. A statistical design was used to obtain sufficient experimental information with the least number of experiments. Analysis of variance was then used to select significant control factors for reinforced coatings, and these identified factors used to construct an adaptive fuzzy logic control model. To model the process, a fuzzy logic controller (FLC) was used. A genetic algorithm (GA) was applied as a tool to optimize rule bases from traditional FLCs. Therefore, with the use of a GA-optimized FLC, robust reinforced deposition for coatings in the plasma spraying process can be obtained. The experimental results show that the obtained optimal rule base for FLC is capable of achieving the desired results. That is to say, the proposed design, which combines a statistical method and a GA-optimized FLC, is efficient and robust for the investigation of reinforced coatings in a plasma spraying process.

Keywords: analysis of variance, fuzzy logic control, fuzzy sets, genetic algorithms, plasma spraying, robustness (control systems), spray coating, statistical design, statistical methods, surface roughness, zirconia

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High-speed thermal imaging of yttria-stabilized zirconia droplet impinging on substrate in plasma spraying. The authors have developed an in situ monitoring system that captures the impacting phenomena of plasma sprayed particles at 1×10^6 frames/s. The system clearly captured deformation and cooling processes of an yttria-stabilized zirconia droplet of 50 μm in diameter impinging at 170 ms on a smooth quartz glass substrate kept at room temperature. The images show that the liquid sheet jetting out sideways from the droplet detached from the substrate and kept on spreading without disintegration until its maximum extent. While the sheet was spreading, the center region of the flattened droplet cooled down much more rapidly.

Keywords: cooling, drops, impacting phenomena, infrared imaging, monitoring systems, plasma spraying, substrates, yttrium oxide, zirconia, zirconia droplet impinging

K. Shinoda, H. Murakami, S. Kuroda, S. Oki, K. Takehara, and T.G. Etoh, Composites and Coatings Center, National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0047, Japan. Cited: *Appl. Phys. Lett.*, 2007, **90**(19), p 194103. ISSN 0003-6951.

Thermal contact resistance between plasma sprayed particles and flat surfaces. Plasma sprayed molybdenum and yttria-stabilized zirconia particles (38-63 μm diameters) were sprayed onto glass and Inconel 625 held at either room temperature or 400 °C. Samples of Inconel 625 were also preheated for 3 h, and then air cooled to room temperature before spraying. Photographs of the splats were captured by using a fast charge-coupled device (CCD) camera. A rapid two-color pyrometer was used to collect thermal radiation from the particles during flight and spreading to follow the evolution of their temperature. The temperature evolution was used to determine the cooling rate of spreading particles. An analytical heat conduction model was developed to calculate the thermal contact resistance at the interface of the plasma sprayed particles and the surfaces from splat cooling rates. The analysis showed that thermal contact resistance between the heated or preheated surfaces, and the splats was more than an order of magnitude smaller than that on nonheated surfaces held at room temperature. Particles impacting on the heated or preheated surfaces had cooling rates that were significantly larger than those on surfaces held at room temperature, which was attributed to smaller thermal contact resistance.

Keywords: charge-coupled devices, heat conduction, heat radiation, heat resistance, mathematical models, nondimensional temperature, pyrometry, splat substrate interface, thermal spray coatings, two-color pyrometry

A. McDonald, C. Moreau, and S. Chandra, Center for Advanced Coatings Technology, Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Ont. M5S 1A4, Canada. Cited: *Int. J. Heat Mass Transfer*, 2007, May, **50**(9-10), p 1737-1749. ISSN 0017-9310.

Manufacturing

Luminescence and crystallinity of flame-made Y_2O_3:Eu^{3+} nanoparticles. Cubic and/or monoclinic Y_2O3:Eu^{3+} nanoparticles (10-50 nm) were made continuously without postprocessing by single-step, flame spray pyrolysis (FSP). These particles were characterized by x-ray diffraction, nitrogen adsorption, and transmission electron microscopy. Photoluminescence (PL) emission and time-resolved PL intensity decay were measured from these powders. The influence of particle size on PL was examined by annealing (at 700-1300 °C for 10 h) as-prepared, initially monoclinic $Y_2O_3Eu^{3+}$ nanoparticles resulting in larger 0.025-1 μm, cubic Y_2O_3:Eu^{3+}. The influence of europium (Eu^{3+}) content (1-10 wt%) on sintering dynamics as well as optical properties of the resulting powders was investigated. Longer high-temperature particle residence time during FSP resulted in cubic nanoparticles with lower maximum PL intensity than measured by commercial micron-sized bulk Y_2O_3:Eu^{3+} phosphor powder. After annealing as-prepared 5 wt% Eu-doped Y_2O_3 particles at 900, 1100, and 1300 °C for 10 h, the PL intensity increased as particle size increased and finally (at 1300 °C) showed similar PL intensity as that of commercially available, bulk Y_2O_3:Eu^{3+} (5 μm particle size). Eu doping stabilized the monoclinic Y_2O_3 and shifted the monoclinic to cubic transition toward higher temperatures.

Keywords: crystallites, europium, flame spray pyrolysis, flame spraying, luminescence, nanoparticles, nitrogen adsorption, particle residence, phosphor powder, phosphors, pyrolysis, x-ray diffraction, yttrium oxide

A. Camenzind, R. Strobel, F. Krumeich, and S.E. Pratsinis, Department of Mechanical and Process Engineering, Particle Technology Laboratory, Institute of Process Engineering, CH-8092 Zurich, Switzerland. Cited: *Adv. Powder Technol.*, 2007, **18**(1), p 5-22. ISSN 0921-8831.

Microstructure and properties of TiC-Fe cermet coatings by reactive flame spraying using asphalt as carbonaceous precursor. A kind of agglomerated Ti-Fe-C compound spraying powder was prepared by heating a mixture of ferrotitanium and asphalt to pyrolyze the asphalt as carbonaceous precursor. The carbon by the pyrolysis of the asphalt acts as a reactive constituent as well as a binder in the compound powders. TiC-Fe cermet coatings were prepared by reactive flame spraying (RFS) of the compound powder. X-ray diffraction, scanning electron microscopy, energy-dispersive spectroscopy, and transmission electron microscopy were employed to analyze the microstructure of the cermet coating. To investigate the forming mechanism of the cermet coating, a quenching test was performed. The results show that the Ti-Fe-C compound powder has a very tight structure, which can avoid the problem that reactive constituent particles are separated during spraying. The TiC-Fe cermet coatings presents a typical morphology of thermal spraying coatings with two different laminated layers: the one is the composite layers in which the round fine TiC particles (≤500 nm) are dispersed within a Fe matrix; the other is the paragentic layers of TiC and Ti_2O_3. The nucleation mechanism of the TiC in the two layers is homogeneous nucleation and heterogeneous nucleation, respectively. The TiC in the composite layers grows in the dissolution-precipitation mode that the smaller particulates dissolve and larger ones grow. The TiC-Fe cermet coating by RFS shows high hardness and wear resistance property: The surface hardness of the TiC-Fe cermet coating is 65 ± 6(HR30N). In the same fretting conditions, the wear area of Ni60 coating is much more than that of the TiC-Fe cermet coating.

Keywords: asphalt, carbonaceous precursor, cermet coating, cermets, coatings, dissolution, flame spraying, homogeneous nucleation, microstructure, morphology, nucleation, precipitation (chemical), pyrolysis, reactive flame spray, wear resistance

H.Y. Liu, J.H. Huang, C.F. Yin, J.G. Zhang, and G.B. Lin, School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing, 100083, China. Cited: *Ceram. Int.*, 2007, July, **33**(5), p 827-835. ISSN 0272-8842.

Processing, microstructure, and property aspects of a spray-cast Al-Mg-Li-Zr alloy. This paper describes a microstructural and property investigation of an Al-5.31Mg-1.15Li-0.28Zr alloy produced by spray casting and downstream processing. Following a dispersoid precipitation treatment of 4 h at 400 °C, samples were hot compressed at strain rates of 2, 1, 0.2, and 0.1×10^{-2} s^{-1} at temperatures between 250 and 475 °C. Electron backscattered diffraction showed a strong dependence of recrystallized grain size on deformation temperature. At 250 °C and faster strain rates at 325 °C, a network of fine recrystallized necklace grains formed by progressive lattice rotation. At 325 °C at slow strain rates and at 400 °C and higher, dynamic recrystallization occurred by discontinuous nucleation and growth at regions of microscopic strain localization such as grain boundaries and triple points. The microstructures from small-scale hot compression experiments were compared with larger forgings under similar conditions and microstructural evolution was broadly similar. Mechanical properties of larger-scale forgings exceeded the targets for mechanically alloyed Al-Mg-Li alloy AA5091.

Keywords: aluminum alloys, backscattering, crystallization, dynamic recrystallization, electron diffraction, microstructure, precipitation (chemical), spray casting, spray forming

S.C. Hogg, I.G. Palmer, L.G. Thomas, and P.S. Grant, University of Oxford, Department of Materials, Oxford, OX1 3PH, United Kingdom. Cited: *Acta Mater.*, 2007, April, **55**(6), p 1885-1894. ISSN 1359-6454.

Solvent nature effect in preparation of perovskites by flame-pyrolysis. 1. Carboxylic acids. The effect of a series of carboxylic acids (C_2-C_8), as solvents for the preparation by flame spray pyrolysis of $LaCoO_3$ catalyst for the flameless combustion of methane, has been investigated. Acetic acid showed to be unsatisfactory from several viewpoints: low-phase purity of the catalyst, higher amount of unburnt carbonaceous residua, lower catalytic activity and low thermal stability. By increasing the carbon chain length of the solvent, the consequent increase of flame temperature led to an increase of crystal phase purity and of particle size and to a decrease of specific surface area of the catalyst. Catalytic activity showed only marginally affected by the last parameter, phase purity seeming more important. Thermal resistance showed directly related to flame temperature, that is, to the combustion enthalpy of the solvent, but a relatively high amount of residual organic matter can negatively affect this property.

Keywords: acetic acid, carbonaceous residua, carboxylic acids, catalyst activity, combustion, enthalpy, flame spray pyrolysis, flame spraying, flameless combustion, heat resistance, methane, methane catalytic flameless combustion, perovskite, pyrolysis, solvents, thermodynamic stability

G.L. Chiarello, I. Rossetti, L. Forni, P. Lopinto, and G. Migliavacca, Dip. Chimica Fisica ed Elettrochimica, Universita degli Studi di Milano, ISTM-CNR, I-20133 Milano, Italy. Cited: *Appl. Catal. B: Environmental*, 2007, March 30, **72**(3-4), p 218-226. ISSN 0926-3373.

Measurement Methods

Acoustic emission characteristics for diagnosis of TBC damaged by high-temperature thermal fatigue. Acoustic emission (AE) technology was adopted to the damage diagnosis of thermal barrier coating (TBC) by plasma spray process. These samples were composed of CoNiCrAlY bond layer made by vacuum plasma spray and ZrO_2-8 wt%Y_2O_3 ceramic layer made by air plasma spray on Inconel 718 substrate. To investigate the thermal fatigue damage by high temperature, the AE signal was measured during four-point bending test followed by cyclic thermal test. The AE monitoring system was composed of PICO-type sensor, a wide-band preamplifier, and a digital signal processing board. The AE events, amplitude, cumulative energy, and count were evaluated according to the cycles of thermal fatigue. By AE test, it is shown that AE source is caused from the stress of thermally grown oxide layer and microcrack.

Keywords: acoustic emissions, bending tests, bond layers, cyclic thermal tests, damage diagnosis, plasma spraying, substrates, thermal barrier coatings, thermal fatigue, thermal spraying, vacuum plasma spray

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Mixed-mode interfacial fracture toughness for thermal barrier coating. A new interfacial fracture test method was developed for measuring the mixed-mode interfacial fracture toughness of thermal barrier coated material over a wide range of loading phase angles. The principle of this developed method is based on peeling the coating from the substrate due to compressive loading to the coating edge, as forming a shear loading to the interface, and slinging loading such as beam bending, as normal loading to the interface. The complete closed form of the energy release rate and associated complex stress-intensity factor for our testing method is shown. An yttria-stabilized zirconia (YSZ) coating, which was sprayed thermally on nickel-base superalloy, was tested using the testing device developed here. The results showed that the energy release rate for the coating-interfacial crack increased with loading phase angle, which is defined by $\tan^{-1}$ for a ratio of stress intensity factor K_2 to K_1. It was noticed that the interfacial energy release rate increasing with mode II loading could be mainly associated with the contact shielding effect due to crack surface roughness rubbing together.

Keywords: compressive loading, cracks, energy release rate, fracture toughness, interfaces (materials), interfacial crack, interfacial fracture, nickel alloys, sprayed coatings, stress-intensity factors, superalloys, surface roughness, thermal barrier coatings, yttria-stabilized zirconia

M. Arai, Y. Okajima, and K. Kishimoto, Material Science Research Laboratory, Central Research Institute of Electric Power Industry, Komae-shi, Tokyo, 201-8511, Japan. Cited: *Eng. Fract. Mech.*, 2007, Sept, **74**(13), p 2055-2069. ISSN 0013-7944.

Standardization and audit-readiness in the metallography lab. Some of the significant factors, such as audits, standards used, and trained laboratory personnel are needed to evaluate the performance of metallography laboratories in the thermal spray coatings industry. Companies using thermal spray coatings are needed to get certifications from OEMs, the National Aerospace and Defense Contractors Accreditation Program (NADCAP), and the American Association for Laboratory Accreditation (A2LA). Associated audits are also conducted to locate deficiencies related to documentation, calibration, and

training. Some other significant factors also need to be considered, while minimizing the number of findings in an audit. Laboratories need to follow standards to have documented procedures, with specific methods of preparation for specific coatings. Internal and external training programs can also be used to evaluate the performance of a metallography laboratory.

Keywords: calibration, coating techniques, coatings industry, metallography, standardization, thermal spray coatings, thermal spraying, training programs

D. Puerto and D. Crossmore, MR Test Labs, Lansing, NY. Cited: *Adv. Mater. Process.*, 2006, Nov, **164**(11), p 104-105. ISSN 0882-7958.

Thermal shock experiment and simulation of ceramic/metal gradient thermal barrier coating. A thermal shock experiment is designed to explore the thermal shock properties of ceramic/metal gradient thermal barrier coating. The specimens are heated up by oxygen-acetylene flame and cooled by water spray. The experiment procedure includes two stages, heating the specimen from the initial temperature 30 °C for 40 s, and then cooling for 20 s. The heat transfer and the associated thermal stresses produced during the thermal shock procedure are simulated by finite element method. Experimental results indicated that the specimen of gradient coating behaves better in thermal shock experiments, which agree with the results of simulation.

Keywords: ceramic materials, finite element method, functionally gradient materials, gradient coatings, heat transfer, initial temperature, thermal barrier coatings, thermal shock, thermal spraying, thermal stress, water spraying

J. Xiao, K. Liu, W. Zhao, and W. Fu, School of Automotive Engineering, Wuhan University of Technology, Hubei 430070, China. Cited: *Key Eng. Mater.*, 2007, **336-338**(II), p 1818-1822. ISSN 1013-9826.

Microstructure

Bulk FeAl nanostructured materials obtained by spray forming and spark plasma sintering. This paper examines the efficiency of two consolidation-processing techniques high-velocity oxyfuel (HVOF) spray forming and spark plasma sintering (SPS), which allow one to obtain bulk dense nanostructured materials. An oxide dispersion strengthened (ODS) Fe-40Al (at.%) based milled powder (with a nanostructure ≤30 nm in size) was used as a precursor. The microstructures of the sintered end products were characterized by transmission electron microscopy (TEM). The results indicated that, under the present processing conditions, the HVOF spray forming is more effective to retain nanograins (30-90 nm in size) within unmelted powder particles. However, the SPS processing shows its potential to fully densify the material while retaining ultrafine grains having sizes in the range 100-400 nm together with larger micrometer grains.

Keywords: high-velocity oxyfuel spray forming, intermetallics, iron aluminides, metal forming, microstructure, nanograins, nanostructured materials, spark plasma sintering, spray forming, transmission electron microscopy

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Combined coating for turbine blades of high-temperature gas turbine engines. A combined coating for protecting turbine blades of high-temperature gas turbine engines is studied. Comparative tests of coatings under laboratory conditions and of coated blades in engine operation are performed. The microstructure of the coating is studied, and the concentration profiles of alloying elements are determined by the method of x-ray diffraction analysis. Tests for high-temperature strength are performed.

Keywords: alloying elements, coated blades, combined coating, gas turbines, high-temperature effects, high-temperature strength, microstructure, protective coatings, turbine blades, turbomachine blades, x-ray diffraction

P.T. Kolomytsev and V.M. Samoilenko, and N.E. Zhukovsky Air-Force Engineering Academy, Moscow, Russian Federation. Cited: *Met. Sci. Heat Treat.*, 2006, Nov, **48**(11-12), p 558-561. ISSN 0026-0673.

Far-from-equilibrium processing of multiphase ceramic nanocomposites. A new far-from-equilibrium processing methodology has been developed to produce multiphase nanocomposite ceramics. The proposed method uses the following steps: (a) spray drying of commercially available powders to make flowable multicomponent feed powder aggregates, (b) plasma melting and quenching to generate dense and homogeneous metastable powders, and (c) pressure-assisted consolidation of these powders to make dense nanocomposite ceramics. By controlling of process parameters, inherent superplasticity of these powders can be used to aid in densification process. In this article, results on multiphase zirconia- and alumina-based ceramics are presented.

Keywords: ceramic-matrix composites, hot isostatic pressing, metastable structures, multiphase ceramic nanocomposites, nanocomposite ceramics, nanocomposites, plasma spraying, quenching, rapidly solidifying powders, superplasticity

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Formation of TiAl intermetallics by heat treatment of cold sprayed precursor deposits. Cold spray is a rapidly developing coating and manufacturing technology in which metal particles are deposited at velocities of >700 ms^{-1} without significant melting. The severe plastic deformation of the particles on impact produces a deposit that is very dense, with low oxide content and no thermally induced tensile stresses. In this study, solid shapes of precursor material were made by the cold spray process using titanium and aluminum powder mixtures and then converted to titanium aluminide with suitable heat treatments. Such heat treated material has been characterized using differential scanning calorimetry to trace the kinetics of the phase transformation, x-ray diffraction to determine the phases present and scanning electron microscopy with microprobe analysis to observe the microstructure and measure the chemical composition. It was found that the first intermetallic phase to form with heat treatment was $TiAl_3$. The desirable set of intermetallic phases ($TiAl_3$, r-$TiAl_2$, TiAl, and Ti_3Al) was obtained by varying heat treatment conditions. While the porosity in the as-sprayed precursor deposits was about zero, significant porosity developed during heat treatment and the sources for this are discussed.

Keywords: cold spray, differential scanning calorimetry, intermetallics, phase transitions, powder metallurgy, powder mixtures, precursor deposits, scanning electron microscopy, sintering, tensile stress, titanium alloys, x-ray diffraction analysis

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Suppression of crystallization during high velocity impact quenching of alumina droplets: Observations and characterization. Droplets of alumina were deposited and quenched onto various smooth substrates using the high-velocity oxyfuel (HVOF) thermal spray process. The microstructure of single splats was examined using optical microscopy, atomic force microscopy (AFM), focused ion beam assisted scanning electron microscopy (FIB-SEM), and transmission electron microscopy (TEM). It was found that the high-impact velocity inherent in HVOF formed splats that were in intimate contact with the substrate, leading to a high solidification rate up to 10^{10} K/s. The solidified alumina splats exhibited a smooth surface devoid of "mud-crack" networks of surface microcracking, commonly observed in ceramic plasma sprayed systems. Microstructural examinations of the smooth areas of the splat revealed an amorphous microstructure as confirmed by selected area electron diffraction. In local areas of poor contact between the splat and substrate, a polycrystalline microstructure was discernible and a metastable γ-Al_2O_3 phase was detected. Second-layer splats, that landed on top of a first-layer splat and experienced slower cooling rate, were found to have surface cracking and revealed principally a γ-Al_2O_3 nanocrystalline structure. The observation of amorphous alumina is explained by the suppression of a first-order liquid-to-solid phase transformation, due to a high solidification rate that we estimate.

Keywords: alumina, alumina splats, crystal microstructure, crystallization, drops, high-velocity oxyfuel thermal spray, microcracking, mud crack, phase transitions, polycrystalline materials, quenching, solidification, thermal spraying

L. Li, B. Kharas, H. Zhang, and S. Sampath, Department of Materials Science and Engineering, Center for Thermal Spray Research, State University of New York at Stony Brook, Stony Brook, NY 11794. Cited: *Mater. Sci. Eng. A*, 2007, May 15, **456**(1-2), p 35-42. ISSN 0921-5093.

Modeling

Mechanical Modeling

Evaluation of interfacial stress transfer efficiency by coating fragmentation test. Probabilistic model of coating fragmentation under uniaxial tensile loading is developed. Analytical expressions of the crack spacing evolution are obtained for small-strain and large-strain fragmentation regimes. The model is applied for coating and interface property identification of several thin brittle coating/polymer substrate systems. An estimate of the stress transfer length, derived from the fragmentation data, is found to correlate with the interfacial shear strength, thus suggesting that both parameters reflect an intrinsic property related to the mechanical efficiency of coating/substrate interface.

Keywords: brittle fracture, cohesive strength, cracks, fragmentation test, fragmentation tests, interfacial energy, interfacial shear strength, probabilistic logics, protective coatings, shear strength, stress analysis, tensile testing

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FEM calculation of residual stresses induced by laser shock processing in stainless steels. Laser shock processing, also known as laser shock

peening, generates through a laser-induced plasma, plastic deformation and compressive residual stresses in materials for improved fatigue or stress-corrosion cracking resistances. The calculation of mechanical effects is rather complex, due to the severity of the pressure loading imparted in a very short time period (in the ns regime). This produces very high strain rates (10^6 s^{-1}), which necessitate a precise determination of dynamic properties. Finite element techniques have been applied to predict the residual stress fields induced in two different stainless steels, combining shock wave hydrodynamics and strain-rate-dependent mechanical behavior. The predicted residual stress fields for single or multiple laser processes were correlated with those from experimental data, with a specific focus on the influence of process parameters such as pressure pulse amplitude and duration, laser spot size, or sacrificial overlay. Among other results, simulations confirmed that the affected depths increased with pulse duration, peak pressure, and cyclic deformations, thus reaching much deeper layers (>0.5 mm) than with any other conventional surface processing. To improve simulations, the use of experimental VISAR determinations to determine pressure loadings and elastic limits under shock conditions (revealing different strain-rate dependences for the two stainless steels considered) was shown to be a key point. Finally, the influence of protective coatings and, more precisely, the simulation of a thermomechanical uncoated laser shock processing were addressed and successfully compared with experiments, exhibiting a large tensile surface stress peak affecting a few tenths of micrometers and a compressive subsurface stress field.

Keywords: corrosion resistance, finite element method, laser shock peening, laser shock processing, plastic deformation, pressure loadings, residual stresses, shock conditions, shot peening, stainless steel, stress-corrosion cracking

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First-principles elastic constants of α- and θ-Al_2O_3. Using an efficient strain-stress method, the first-principles elastic constants c_{ij}s of α-Al_2O_3 and θ- Al_2O_3 have been predicted within the local density approximation and the generalized gradient approximation. It is indicated that more accurate calculations of c_{ij}s can be accomplished by the local density approximation. The predicted c_{ij}s of θ-Al_2O_3 provide helpful guidance for future measurements, especially the predicted negative c_{15}. The present results make the stress estimation in thermally grown oxides containing of α- and θ-Al_2O_3 possible, which in turn provides helpful insights for preventing the failure of thermal barrier coatings on components in gas-turbine engines.

Keywords: aluminum compounds, approximation theory, elastic constants, gas turbines, gradient approximation, strain control, stress estimation, thermal barrier coatings, thermally grown oxides

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Impacting behavior of bulk metallic glass powder at an abnormally high strain rate during kinetic spraying. Impacting behavior and deposition formation of Ni-Ti-Zr-Si-Sn bulk metallic glass during kinetic spraying were investigated in this study. Bulk metallic glass particle deposition was primarily dependent on the impacting particle velocity. Secondly, the impacting particle temperature could transfer the deposition mode from fracture-induced local melting to severe viscous flow, especially for the splat on previously deposited splat. It is suggested that the deposition behavior of bulk metallic glass particles is determined by the competition between fracture and deformation. Fracture and deformation are controlled by adiabatic shear instability at the faying interface during impacting, with causal factors including temperature-dependent superplasticity of the bulk metallic glass and an abnormally high strain rate of the individual particle impact during kinetic spraying.

Keywords: bulk metallic glass, coating microstructure, deformation, deposition, fracture, kinetic spraying, metallic glass, nickel alloys, optimization, sprayed coatings, strain rate, superplasticity

S. Yoon, C. Lee, H. Choi, H. Kim, and J. Bae, Kinetic Spray Coating Laboratory (NRL), Division of Materials Science and Engineering, College of Engineering, Seoul, 133-791, South Korea. Cited: *Mater. Sci. Eng. A*, 2007, March 25, **448-451,** p 911-915. ISSN 0921-5093.

Thermal stress analysis of HVOF sprayed WC-Co/NiAl multilayer coatings on stainless steel substrate using finite element methods. The scope of this study is to find out the effects of thermal cycling on the coating-substrate system of WC-Co coatings by finite element modeling. With this regard, WC-Co/NiAl coating layers were successfully deposited on 316 L stainless steel substrates by using a HVOF technique and microstructural observations were carried out using scanning electron microscopy (SEM). The SEM study revealed that the coating was very dense with very low oxide content and had a very good contact with the substrate, indicating a very good bonding to the substrate. Thermal cycling tests were performed at the temperature range of 373 and 873 K without external load. In finite element modeling (FEM), thermal residual stresses, developed during and after thermal cycling, were determined by using ANSYS software package. It was found that the stress distributions were obtained in the WC-Co/NiAl architectured coating systems during heating and cooling steps because of the different thermal and mechanical properties of the coating layers and substrates. According to thermal analysis results, the calculated tensile stresses were higher than the compressive stresses, and also thermal stress components for i-direction were bigger than for *y*-direction.

Keywords: finite element method, microstructural observations, microstructure, multilayers, sprayed coatings, stainless steel, stainless steel substrates, substrate bonding, substrates, tensile stress, thermal stress, thermal stress components

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Particle Impact

Numerical simulation of deformation behavior of Al particles impacting on Al substrate and effect of surface oxide films on interfacial bonding in cold spraying. In this study, a comprehensive examination of the deformation behavior of Al particles impacting on Al substrate was conducted by using the arbitrary Lagrangian Eulerian (ALE) method to clarify the deposition characteristics of Al powder and the effect of surface oxide films in cold spraying. It was found that the deformation behavior of Al particles is different from that of Cu particles under the same impact conditions owing to its lower density and thus less kinetic energy upon impact. The results indicated that a higher velocity was required for Al particles to reach the same compression ratio as that of Cu particles. On the other hand, the numerical results showed that the oxide films at particle surfaces influenced the deformation and bonding condition between the particle and substrate. The inclusions of the crushed oxide films at the interfaces between the deposited particles inhibit the deformation.

Keywords: aluminum, Arbitrary Lagrangian Eulerian, cold spraying, deformation, deformation behavior, interfaces (materials), kinetic energy, Lagrange multipliers, spraying, substrates, surface oxide films, surface phenomena

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Process Modeling

Modeling and analysis of combustion-assisted thermal spray processes. The combustion-assisted thermal spray systems are being used to apply coatings to prevent surface degradation. They offer a highly attractive way to modify the surface properties of the substrate to extend the product life. In addition to the materials being sprayed, the quality of combustion-assisted thermal spray coating depends greatly on the flow behavior of reacting gases and particle dynamics. The present study investigates the effect of gas phase and its interaction with particles through the nozzle of a thermal spray gun by developing a comprehensive mathematical model. The objective is to develop a predictive understanding of various design parameters of combustion-assisted thermal spray systems. The model was developed by considering the conservation of mass, momentum, and energy of reacting gases. The particle dynamics was decoupled from the gas phase dynamics since the particle loading in the spray process is very low. The developed model was employed to investigate the influence of various design parameters on the coating quality of thermal spray process.

Keywords: combustion, degradation, flow behavior, mathematical models, particle dynamics, surface properties, surface reactions, thermal spray gun, thermal spray systems, thermal spraying

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Modeling of a substrate thermomechanical behavior during plasma spraying. Plasma coating performances and lifetimes may be ruined during service conditions because of uncontrolled residual stress development within the coating. This study presents the results of a CAST3M thermomechanical numerical model the purpose of which is to simulate the different residual stresses development within the duplex coating/substrate during coating build up and its comparison with the experimental results. To achieve the thermal spray process understanding all the thermal fluxes transferred to a metallic beam and surrounding temperatures were measured so as to provide the CAST3M model with precise boundary conditions, corresponding to a specific geometry. The residual stresses were experimentally determined by the in situ curvature measurement and, afterwards, by the hole drilling method. The plasma torch standoff distance, the relative torch/substrate velocity, and the substrate material were considered as the

parameters of this study. The main results concern the substrate temperature and deflection during the preheating stage, the thermal energy transferred by the molten splats to the substrate together with the quenching stress, and the development of thermal stress during the final cooling.

Keywords: boundary conditions, curvature measurement, duplex coating-substrate, energy transfer, heat flux, molten splats, plasma coating, plasma spraying, plasma torches, residual stresses, temperature measurement, thermal stress, thermomechanical treatment

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Postprocessing

Effect of laser remelting on corrosion behavior of plasma sprayed Ni-coated WC coatings. The corrosion properties of plasma sprayed (PS) Ni-coated WC coatings are studied for both before and after laser remelting of the coatings. Optical microscopy (OM), scanning electron microscopy (SEM), and x-ray diffraction (XRD) are applied to investigate the microstructure and phase composition of PS Ni-coated WC coatings. The results indicate that coatings with laser remelting could improve their microstructure, such as lower porosity rate, weaker lamellar structure, and more uniform distribution of phases. XRD shows that the W_2C phase is not identified both in as-sprayed and coatings with laser remelting, which means that the decarburization of WC has not happened because of Ni-coated WC grain. However, the Ni compounds were observed both in the plasma spray and the laser-remelting coatings. The salt-spray corrosion (SSC) shows that the laser remelting coating has better corrosion resistance, which is mainly due to its fully dense top layer, low number of defects, and uniform distribution of the phase and composition.

Keywords: corrosion resistance, decarburization, laser applications, laser remelting, phase composition, phase structure, plasma spraying, remelting, salt-spray corrosion, sprayed coatings, tungsten carbide

X. Guozhi, Z. Jingxian, L. Yijun, W. Keyu, M. Xiangyin, and L. Pinghua, Department of Materials Science and Engineering, Hohai University, Nanjing, 210098, China. Cited: *Mater. Sci. Eng. A*, 2007, July 15, **460-461,** p 351-356. ISSN 0921-5093.

Processing

Chromium-doped forsterite nanoparticle synthesis by flame spray pyrolysis. Synthesis of chromium-doped forsterite (Mg_2SiO_4:Cr) nanoparticles by flame spray pyrolysis (FSP) was investigated. The morphology, crystalline phase, and photoluminescence of the products were evaluated. Crystalline Mg_2SiO_4:Cr nanoparticles of several 10 nm in diameter were obtained, although a small amount of the submicrometer-sized particles and the unreacted MgO phase existed. The product powder showed electron-spin resonance signals from Cr^{4+} and photoluminescence typical for Cr^{4+} in Mg_2SiO_4, suggesting that a part of the Cr^{4+} ions were incorporated into Si^{4+} sites by FSP. On the other hand, the effects of excess SiO_2 addition on the structural and optical characteristics of Mg_2SiO_4:Cr were examined. Addition of excess SiO_2 up to 20 mol% did not influence these characteristics of the products. Further addition of excess SiO_2 (60-100 mol%) enhanced the formation of the amorphous phase and resulted in the emission from Cr^{3+} in the amorphous phase in addition to an emission from Cr^{4+} in Mg_2SiO_4.

Keywords: flame spray pyrolysis, flame spraying, nanoparticles, photoluminescence, pyrolysis, resonance, resonance signals, submicrometer-sized particles, synthesis (chemical)

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Cold spraying of in situ produced TiB_2-Cu nanocomposite powders. The goal of this work was to study the development of microstructure of the coatings cold sprayed from nanocomposite powders TiB_2-43 vol%-Cu containing titanium diboride particles 50-100 nm in size. Titanium diboride phase was in situ produced in a copper matrix using high-energy mechanical milling of Ti, B, and Cu powders and self-propagating high-temperature synthesis. The coatings were fabricated on a copper substrate. The microstructure of the coatings was studied by scanning electron microscopy and energy dispersive spectroscopy. Due to low-temperature conditions of spraying, nanostructured coatings were produced retaining the microstructure of the nanocomposite powder being sprayed. Despite the high content of titanium diboride and the difference in plasticity of the phases, the coatings were fully dense and composed of closely packed powder particles. Considering the results of this study, cold spraying of nanocomposite mechanically milled powders can be recommended as a promising way for fabrication of nanostructured coatings.

Keywords: cold spraying, inorganic coatings, low-temperature phenomena, mechanical milling, metallographic microstructure, nanocomposites, nanostructured coatings, nanostructures, plasticity, powder metals, titanium compounds

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Directly cooled VPS-W/Cu limiter and its preliminary results in HT-7. Tungsten (W) coatings on copper (Cu) substrate have been developed by means of vacuum plasma spraying (VPS) method employing a composition gradient interlayer so as to alleviate mismatch of the physical properties between Cu and W. The gradient interlayer shows dense and lamellar microstructure and the coating surface few microcracks. Directly cooled VPS-W/Cu plasma-facing component (PFC) can withstand e-beam high heat flux (HHF) irradiation of 20 cycles, 100 s/cycle, and heat loads of 9.6 MW/m^2. The PFC joined to a newly modified motion mechanism as a movable limiter was then tested in HT-7 and showed good integrity under the ohmic plasmas. Heat deposition onto the limiter has been investigated and a simplified model proposed to explain qualitatively the surface temperature behavior observed by an IR camera. The model estimates the heat load onto each round edge of the PFC to be about 10 MW/m^2.

Keywords: composition gradient interlayers, heat flux, microcracks, microstructure, ohmic plasmas, plasma spraying, protective coatings, substrates, tungsten, tungsten coatings, vacuum plasma spraying

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High-temperature oxidation behavior of solution precursor plasma sprayed nanoceria coating on martensitic steels. Solution precursor plasma spray (SPPS) is used to deposit nanoceria coating on a 410 martensitic stainless steel. The process of pyrolysis in converting the cerium nitrate solution to cerium oxide, the microstructure and the surface chemistry is confirmed by thermodynamic calculations, x-ray photoelectron spectroscopy, and x-ray diffraction. Subsequent exposure of the coated steel in atmospheric air to cyclic oxidation at 1000 C revealed excellent corrosion resistance of the steel in presence of the SPPS-processed nanoceria coating. The formation of the nanostructured (10-100 nm) ceria coating is studied using transmission electron microscopy. Relative Ce^{4+} and Ce^{3+} concentration in the coating was determined from XPS high-resolution spectrum. Cross-section scanning electron microscopy showed the presence of an impervious nature of the protective layer with reduced scale thickness in the coated oxidized sample. After a preoxidation treatment at 1273 K of the coated specimen, the oxidation kinetics showed a significant decrease compared with the uncoated martensitic steel.

Keywords: coatings, martensitic transformations, nanoceria, oxidation, reaction kinetics, solution precursor plasma spray, surface chemistry, transmission electron microscopy, x-ray diffraction

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Preparation and characterization of plasma sprayed ultrafine chromium oxide coatings. Ultrafine chromium oxide coatings were prepared by plasma spraying with ultrafine feedstock. Processing parameters of plasma spraying were optimized. Optical microscopy (OM) was used to observe the microstructure of the ultrafine chromium oxide coatings. Scanning electron microscopy (SEM) was used to observe the morphology and particle size of ultrafine powder feedstock as well as to examine the microstructure of the chromium oxide coating. In addition, hardness and bonding strength of the ultrafine chromium oxide coatings were measured. The results showed that the optimized plasma spraying parameters were suitable for ultrafine chromium oxide coating, and the properties and microstructure of the optimized ultrafine chromium oxide coating were superior compared with conventional chromium oxide wear-resistant coatings.

Keywords: chromium compounds, coating techniques, microstructure, optical microscopy, plasma spraying, scanning electron microscopy, ultrafine chromium oxide, ultrafine powder feedstock, wear-resistant coating

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Research and development of plasma sprayed tungsten coating on graphite and copper substrates. Vacuum plasma sprayed tungsten coating on graphite and copper substrates have been prepared. VPS-W coated graphite has multilayered silicon and tungsten interface pre-deposited by physical vapor deposition (PVD) and VPS-W coated copper has graded transition interlayer. VPS-W coating was characterized, and then the high heat flux properties of the coating were examined. Experimental results indicated that both VPS-W coated graphite and VPS-W coated copper could endure 1000 cycles without visible failure under a heat flux of approximately

5 MW/m^2 absorbed power density and 5 s pulse duration. A comparison between the present VPS-W coated graphite and VPS-W coated carbon fiber composite (CX-2002U) with Re interface made by Plansee Aktiengesllshaft was carried out. Results show that both Re and Si are suitable as intermediate layer for tungsten coating on carbon substrates.

Keywords: copper substrates, graphite, multilayered silicon, multilayers, plasma facing components, plasma spraying, protective coatings, substrates, thermal load, tungsten, tungsten coatings

X. Liu, F. Zhang, S. Tao, Y. Cao, Z. Xu, Y. Liu, and N. Noda, Southwestern Institute of Physics, Chengdu, 610041 Sichuan, China. Cited: *J. Nucl. Mater.*, 2007, June 15, **363-365**(1-3), p 1299-1303. ISSN 0022-3115.

Stabilizing nanocrystalline materials with dopants. The enhancement of material properties caused by extremely small grain sizes in metals and ceramics is attractive for many technological applications including protective coatings, electronic interconnects, and microelectromechanical systems (MEMS) devices. However, the large driving force for grain growth caused by the abundance of grain boundaries remains a critical complication in the synthesis and functionality of nanocrystalline materials. Here we present atomistic simulations that illuminate the stabilizing effect of interfacially segregated, oversized dopants in face-centered cubic (fcc) copper. Using a bicrystal configuration, the calculated grain-boundary energy is reduced to zero with systematically increasing dopant coverage and atomic radius mismatch. We then extend this result to a nanocrystalline network and determine the critical dopant concentration required to eliminate grain growth in bulk and thin film structures. The results of this investigation are intended to guide future experimental efforts to design appropriately doped, stable nanocrystalline materials.

Keywords: ceramic materials, copper alloys, dopant concentration, doping (additives), face-centered cubic, grain boundaries, grain growth, grain size and shape, grain-boundary segregation, MEMS, molecular dynamics, nanocrystalline materials, nanocrystalline network

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Study of multifunction microplasma spraying technology. A multifunctional micro-arc plasma spraying system was developed according to aerodynamics and plasma spray theory. The soft-switch IGBT (insulated gate bipolar transistor) invert technique, microcomputer-control technique, convergent-divergent nozzle structure, and axial powder feeding techniques have been adopted in the design of the micro-arc plasma spraying system. It is not only characterized by a small volume, a light weight, highly accurate control, high deposition efficiency, and high reliability, but also has multifunctions in plasma spraying, welding, and quenching. The experimental results showed that the system can produce a supersonic flame at a low power, spray Al_2O_3 particles at an average speed up to 430 m/s, and make nanostructured AT13 coatings with an average bonding strength of 42.7 MPa. Compared with conventional 9M plasma spraying with a higher power, the coatings with almost the same properties as those by conventional plasma spray can be deposited by multifunctional micro-arc plasma spraying with a lower power plasma arc due to an improved power supply design, spray gun structure, and powder feeding method. Moreover, this system is suitable for working with thin parts and undertaking on site repairs, and as a result, the application of plasma spraying will be greatly extended.

Keywords: aerodynamics, high-current plasmas, high-pressure effects, insulated gate bipolar transistors, microplasma spraying, nanostructured coating, plasma spraying, quenching, soft-switch invert technology, welding

L. Wang, H. Wang, S. Hua, and X. Cao, Xi'an Hi-Tech Research Institute, Xi'an 710025, China. Cited: *Plasma Sci. Technol.*, 2007, Feb 1, **9**(1), p 52-56. ISSN 1009-0630.

Properties

Corrosion

Cyclic hot corrosion of high-velocity oxyfuel sprayed coatings on steel at 900 °C. Chromium carbide nickel chrome (Cr_3C_2-NiCr), nickel chrome (NiCr), tungsten carbide cobalt (WC-Co), and UNS R30006 metallic coatings were sprayed onto ASTM SA213-T22 steel by the high-velocity oxyfuel (HVOF) process using liquid petroleum fuel gas (LPG) for applications in hot corrosion conditions. Microhardness, porosity, and roughness measurements were carried out to assess the coating characteristics. Hot corrosion studies were conducted on the uncoated and HVOF-sprayed specimens by exposure to molten salt at 900 °C under cyclic conditions. The thermogravimetric technique was used to establish the kinetics of corrosion. X-ray diffraction (XRD), scanning electron spectroscopy/energy-dispersive spectroscopy (SEM/EDS), and electron probe microanalysis (EPMA) were used to analyze the corrosion products. All coatings showed better resistance to hot corrosion than the uncoated steel. The NiCr coating was found to be the most protective followed by the Cr_3C_2-NiCr coating. The WC-Co coating was the least effective. The formation of chromium oxide (Cr_2O_3), nickel oxide (NiO), nickel chromate ($NiCr_2O_4$), and cobalt oxide (CoO) may have contributed to the hot corrosion resistance shown by the coatings. The uncoated steel suffered corrosion in the form of intense spalling, cracking, and peeling of the scale.

Keywords: boiler corrosion, corrosion resistance, high-velocity oxyfuel coatings, hot corrosion, microhardness, porosity, protective coatings, sprayed coatings, steel corrosion, surface roughness

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Resistance of zinc thermal sprayed coatings on different corrosive environments. Zinc coatings on ferrous substrates are possible to be applied with thermal spraying. In the present work, the corrosion behavior of zinc thermal sprayed coatings deposited on low carbon steel St-37 was examined in a simulated marine atmosphere (salt-spray chamber-SSC) and in a dry atmosphere at elevated temperature (400 °C). The corrosion progress was examined by means of optical microscopy, scanning electron microscopy, x-ray diffraction, and thermogravimetric analysis. From this investigation it was deduced that in the SSC the coating is uniformly corroded, while the main corrosion products are hydrated zinc oxides and chlorides. By contrast at 400 °C only a thin, compact and continuous film of ZnO is formed on top of the coating, which remains adherent to the ferrous substrate.

Keywords: carbon steel, continuous films, corrosion resistance, electromagnetic waves, protective coatings, thermal sprayed coatings, thermal spraying, thermogravimetric analysis, x-ray diffraction analysis, zinc

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Tribocorrosion behavior of HVOF cermet coatings. The main purpose of this work is to analyze the degradation mechanisms induced on industrial HVOF cermet coatings by tribocorrosion. Tribocorrosion of cermet coatings is a subject that has not been widely analyzed in research studies; in fact, while many works dealing with wear or corrosion of HVOF cermet coatings are published, studies relevant to the combined processes (wear and corrosion) are relatively few. The tribocorrosion mechanisms of the cermet coatings were studied in a sodium chloride solution under sliding wear, trying to combine and integrate differently produced mechanical and electrochemical damage phenomena. Electrochemical techniques such as potentiodynamic polarization curves as well as potentiostatic (I vs. t) or galvanostatic (E vs. t) methods were used in order to stimulate and to interpret tribocorrosion degradation mechanisms. It was shown that coating post grinding, which is a mechanical operation usually performed after the deposition of conventional cermet coatings to obtain a desired roughness, could produce structural damages, which can greatly affect the mechanochemical behavior of the cermet coatings. Mainly abrasive-adhesive wear mechanisms were observed on the coating surface and sometimes, depending on coatings mechanical properties (fracture toughness), cracks developed during wear, causing breakage of the coating continuity. In the latter case, the degradation mechanism is no longer governed only by surface tribocorrosion, but undermining corrosion can occur, greatly affecting sample performances and promoting coating detachment. Cr_3C_2-NiCr coatings, under all the selected experimental conditions, showed good barrier properties and substrate corrosion was never observed. Moreover, when chromium was added to the metal matrix of WC-Co based systems, tribocorrosion behavior was enhanced and the lower tribocorrosion rates were measured. Finally, it was shown that electrochemical techniques can be used to govern the coating corrosion processes and to interpret the main degradation mechanisms, even though they seem not to provide a precise quantitative analysis of tribocorrosion.

Keywords: cermet coatings, coating continuity, erosion, metallic matrix composites, potentiodynamic polarization, protective coatings, surface tribocorrosion, tribology, wear of materials

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Using in situ atomic force microscopy to investigate the kinetics of corrosion of WC-Co-Cr cermet coatings applied by high-velocity oxyfuel. Most of the early applications of thermal spray coatings were focused toward providing a remedy to excessive wear degradation. However, as the introduction of such coatings into wider industrial sections increases there is also exposure to other potential degradation processes—aqueous corrosion is one such process. The complex microstructures in cermet coatings have been shown to translate to complex modes of corrosion attack. In this paper an electrochemical test methodology to probe the local/microaspects of corrosion initiation and propagation are described. A new electrochemical cell has been devised in which the corrosion can be followed "live" and in "real-time." The

surface is subjected to in situ imaging by atomic force microscopy that shows that not only the binder (Co, Cr) corrodes in high-velocity oxyfuel thermal spray coatings, but also the hard phase, with oxidation and dissolution of WC/W_2C taking place. Also potentiostatic tests indicated that the corrosion of WC-based coatings follows an Arrhenius relationship enabling the determination of activation energy (E_a) for the corrosion of WC and demonstrating that the oxidation and dissolution of WC are temperature, particle size, potential, and pH related.

Keywords: activation energy, atomic force microscopy, cermets, corrosion rate, oxidation, pH effects, potentiostatic tests, thermal spray coatings, thermal spraying, WC-Co-Cr cermet coatings, wear degradation, wear of materials

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Electrical

Electrochemical investigations on spray deposited tin oxide thin films. Tin oxide (SnO_2) thin films were prepared by a simple and inexpensive spray pyrolysis technique from an aqueous solution at various substrate temperatures (300, 400 and 500 °C), and their electrochemical studies have been carried out. The thin films have been optically and electrochemically characterized by means of transmittance, cyclic voltammetry, and chronoamperometry. The mechanism of reduction and oxidation reactions that took place during the potential cycling is presented. The samples deposited at 500 °C exhibit better performance in terms of coloration efficiency, reversibility, contrast ratio, and response time.

Keywords: coloration efficiency, contrast ratio, cyclic voltammetry, electrochemistry, pyrolysis, spray pyrolysis technique, thermal spraying, thin films, tin oxides

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Mechanical

Cavitation erosion characteristics of a Fe-Cr-Si-B-Mn coating fabricated by high-velocity oxyfuel (HVOF) thermal spray. A Fe-Cr-Si-B-Mn coating was prepared by high-velocity oxyfuel (HVOF) thermal spray on the surface of 1Cr18Ni9Ti stainless steel. Microstructures of the coating were investigated by x-ray diffraction (XRD), optical microscopy (OM), and scanning election microscopy (SEM), and the cavitation erosion resistance of the coating was evaluated using a GB6383-86 standard method in fresh water and compared with hydromachine material ZG06Cr13Ni5Mo martensite stainless steel. The coating consisted of a Fe-Cr-rich matrix and several kinds of borides, the former comprising both amorphous phase and nanocrystalline grains. The nanocrystalline grains with a size about 10-50 nm further formed into an agglomeratelike structure with an average size of 100-500 nm. The coating had a significantly higher microhardness ($HV_{0.2}1008$) than the comparable material ZG06Cr13Ni5Mo ($HV_{0.2}260$), which resulted in greater weight losses of ZG06Cr13Ni5Mo at the whole cavitation erosion process. It was found that the mass loss began at the edges of the pores or the interface between unmelted or half-melted particles and the matrix in the coating, while the mass loss was initiated at the lath interface of martensite in the ZG06Cr13Ni5Mo. The experimental results indicate that the HVOF thermal spray is a promising method to prepare the cavitation resistance coating.

Keywords: cavitation, cavitation erosion characteristic, chromium, coating techniques, Fe-Cr-Si-B-Mn alloy, high-velocity oxyfuel thermal spray, iron alloys, scanning electron microscopy, silicon, thermal spraying, velocity measurement, x-ray diffraction

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Characterization and modeling of erosion wear of powder composite materials and coatings. In erosion wear of composite materials at solid particle impact against the surface, plastic deformation, brittle fracture, or combined mechanisms are dominating, depending on the properties of target material surface. Soft metal-matrix composite materials require a model of plastic deformation and the ceramic hard phase needs both models: the plastic deformation and the brittle fracture model of wear. In this paper, an attempt is made to model the erosion wear of composite materials, to characterize them using indentation method, and to correlate calculated erosion rates with experimental results and material parameters.

Keywords: brittle fracture, erosion, indentation, modeling of wear, plastic contacts, plastic deformation, powder coatings, powder composites, thermal sprayed coatings, thermal spraying, wear resistance

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Characterization of WC/Co coatings on metal substrates. In the present work, WC/Co coatings were obtained by electrothermal explosion directional spraying technology. The performances including microstructure, elements distribution, hardness, elastic modulus, and wear resistance of the coatings were investigated by means of SEM, EDAX, nanoindentation test, friction, and wear test, respectively. Results show that WC/Co coatings are characterized by compact construction, good bond, high hardness, and elastic modulus. The WC/Co coatings also have outstanding wear resistance.

Keywords: cobalt, electrothermal explosion spraying, energy-dispersive spectroscopy, inorganic coatings, microstructure, nanoindentation, scanning electron microscopy, thermal spraying, tungsten carbide, wear resistance, wear tests

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Fatigue and deformation of HVOF sprayed WC-Co coatings and hard chrome plating. A challenge facing the finishing industry is to replace chrome plating since this technology has negative environmental and health effects. In the case of tungsten carbide and chrome carbide coatings, HVOF and detonation spray technologies have proved to be cleaner and more effective. In this paper, the results of a comparative investigation involve a detailed analysis of fatigue and deformation of two groups of AISI 4340 steel specimens. One group sprayed with HVOF WC-Co coating, and the other group was plated with hard chrome. Rotating beam fatigue tests were performed on the coated and uncoated specimens. Optical and SEM microscopy were used to evaluate the fracture morphology. The fatigue life distributions of coated AISI 4340 steel specimens demonstrated that the HVOF coated specimens exhibited higher fatigue lives compared to the uncoated specimens.

Keywords: ceramic coatings, chromium plating, compressive stress, deformation, detonation spray technology, fatigue of materials, fracture morphology, hard chrome plating, morphology, optical microscopy, scanning electron microscopy, spraying, steel, tungsten carbide

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Mechanical properties and oxidation behavior of plasma sprayed functionally graded zirconia-alumina thermal barrier coatings. The microstructures of thermally sprayed coatings usually incorporate process-dependent defects such as globular pores, interlamellar pores, cracks (in case of ceramics), and so forth. Porosity is a prevalent feature in the microstructure and affects various coating properties such as elastic modulus, thermal conductivity, and dielectric behavior. This study is conducted to improve the image analysis (IA) as a reliable method for characterization of porosity in thermally sprayed coatings. The versatility of IA methods for microstructural quantification has been investigated for TBCs deposited with partially stabilized zirconia (PSZ), alumina, and zirconia-alumina composite coatings by gas tunnel type plasma spraying. This study confirms the applicability of image analysis as a straightforward, versatile, reliable, and inexpensive method for porosity analysis agreed with coating qualities and the influences of the Vickers hardness. The paper also discusses the thermal behavior and high-temperature oxidation resistance of the Al_2O_3 coatings as compared to composite coatings at the interface. This interlayer is preferred to minimize the detrimental effect of phase transformation of γ-Al_2O_3 to α-Al_2O_3.

Keywords: alumina, composite coatings, image analysis, interlamellar pores, oxidation, partially stabilized zirconia, plasma deposition, plasma spraying, porosity, surface defects, thermal barrier coatings, thermal conductivity, Vickers hardness, zirconia, zirconia alumina composite coatings

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Superplastic deformation behavior of a spray-deposited eutectic NiAl/Cr(Mo) alloy doped with Dy. The tensile deformation behavior at elevated temperatures and the associated mechanisms are investigated for hot isostatically pressed NiAl-28Cr-5.9Mo-0.1Dy fabricated through spray forming. Superplasticity is observed at above 1323 K under an initial strain rate lower than 10^{-3} s^{-1} with an m value of 0.5. The activation energies for superplastic flow are found to be half of that for self-diffusion in NiAl. Grain-boundary sliding between NiAl and adjacent NiAl or Cr(Mo) grains with local range accommodation; that is, dynamic recovery, is suggested to be responsible for the superplastic deformation of the alloy.

Keywords: activation energy, doping (additives), eutectics, grain-boundary sliding, Ni-28Cr-6Mo (Dy) alloy, nickel alloys, spray forming, strain rate, superplastic deformation, superplasticity, tensile deformation

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Wear behavior of thermal flame sprayed FeCr coatings on plain carbon steel substrate. The principle aim of this study is to investigate the wear behavior of FeCr coatings on Ni-base bond deposited plain carbon steel substrate for several applications in power generation plants. For this purpose, FeCr- and Ni-base powders were sprayed on plain carbon steel substrates using a thermal flame spray technique. Fabricated layers were characterized by using a x-ray diffraction (XRD), scanning electron microscope (SEM), energy-dispersive spectroscopy (EDS), microhardness, and surface roughness testers. FeCr coatings were subjected to sliding wear against AISI 303 stainless steel counter bodies under dry and acidic environments. A pin-on-plate type of apparatus was used with normal loads of 49 and 101 N and sliding speed of 1 Hz. XRD results revealed that FeCr, Fe, Cr, Fe-Cr-Ni, γ-Fe_2O_3, and Fe_3O_4 phases exist in the coating. In addition, some inhomogeneities such as oxides, porosity, cracks, unmelted particles, and inclusions were observed by SEM. The surface morphologies of FeCr samples after wear experiments were examined by SEM and EDS. It was found that friction coefficients of the coatings in dry condition are higher than that in acidic environment.

Keywords: carbon steel, coatings, energy-dispersive spectroscopy, FeCr coating, flame spraying, friction coefficient, iron compounds, scanning electron microscopy, sliding wear, surface roughness, thermal flame spray, thermoelectric power plants, wear of materials, x-ray diffraction

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Oxidation

Cyclic oxidation behavior of thermal barrier coatings in environments containing water vapor. The cyclic oxidation of thermal barrier coating (TBC) specimens consisting of nickel-base superalloy, low-pressure plasma sprayed Ni-24Cr-6Al-0.7Y (wt%) bond coatings and air plasma sprayed 7.5 wt% yttria-stabilized zirconia top coatings was studied at 1050 °C in air, (air + 5% H_2O), O_2, and (O_2 + 5% H_2O), respectively. The oxidation kinetics of the TBC in each test environment accords with parabolic law at the initial stage and obeys almost liner law at the final stage. The cyclic oxidation life of the TBC is 500 h (1 h/cycle) in O_2 and (O_2 + 5% H_2O) and 900 h in air and (air + 5% H_2O). The SEM observations indicated the oxide formed along the bond coat and topcoat interface after failure at 1050 °C in different environments are all consisted of Al_2O_3, $Ni(Al,Cr)_2O_4$, NiO, and Cr_2O_3.

Keywords: cyclic oxidation, cyclic voltammetry, nickel alloys, nickel superalloy, oxidation, plasma spraying, superalloys, thermal barrier coatings, topcoat interfaces, water vapor, yttria-stabilized zirconia

C. Wang, C. Zhou, S. Gong, and H. Xu, Department of Materials Science and Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100083, China. Cited: *Key Eng. Mater.*, 2007, **336-338**(II), p 1750-1752. ISSN 1013-9826.

In situ study of oxidation-induced growth strains in a model NiCrAlY bond-coat alloy. Synchrotron radiation has been used to study in situ the evolution of growth strains in an Al_2O_3 scale (the so-called TGO or thermally grown oxide) on a model bond-coat alloy (Ni-19.7Cr-19.2Al-0.1Y at.%) as oxide growth proceeds in air at 950-1100 °C, and the changes in these strains due to thermal-expansion mismatch as the samples are cooled. Tensile growth stresses develop in the oxide scales during the initial stages of oxidation, a result of initially formed transition aluminas converting to the stable α-Al_2O_3 form, but large residual compressive stresses are present at room temperature due to thermal-expansion mismatch between the scale and the bond coat.

Keywords: alumina, compressive stress, cooling, Debye-Scherrer diffraction rings, elastic moduli, nickel alloys, oxidation, room temperature, spectroscopic analysis, synchrotron radiation, thermal barrier coatings, thermal expansion, thermal-barrier systems

A. Reddy, D.B. Hovis, A.H. Heuer, A.P. Paulikas, and B.W. Veal, Department of Materials Science and Engineering, Case Western Reserve University, Cleveland, OH 44106. Cited: *Oxid. Met.*, 2007, April, **67**(3-4), p 153-177. ISSN 0030-770X.

Recession behavior of a silicon nitride with multilayered environmental barrier coating system. A silicon nitride with multilayered environmental barrier coating (EBC) system was prepared. The multilayered coating consisted of a thin $Lu_2Si_2O_7$ bond coat, $Lu_2Si_2O_7$/mullite eutectic intermediate layer, and a top $Lu_2Si_2O_7$ layer. A glassy phase was observed on the top $Lu_2Si_2O_7$ surface of the as-coated sample. The glassy phase was converted into $Lu_2Si_2O_7$ and Lu_2SiO_5 phases via a heat treatment at 1500 °C in Ar. The recession test was performed at 1300 °C for 500 h using high-speed steam jet equipment, which was employed to simulate the gas turbine engine conditions. Post-test examinations showed that the multilayered EBC system well sustained during the high-temperature steam exposure test. Also, the silicon nitride substrate was protected from the oxidation and corrosion, and thus no material recession was observed. However, some cracks that run through the EBC layer was observed in the sample after the test. The substrate near the cracks oxidized, leading to the formation of a thermally grown oxide phase.

Keywords: barrier coatings, eutectics, glassy phases, mullite, multilayers, oxidation, recession tests, silicates, silicon nitride, steam jet equipments, structural applications, thin films

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Thermal

Effects of doping on thermal conductivity of pyrochlore oxides for advanced thermal barrier coatings. Pyrochlore oxides of general composition, $A_2B_2O_7$, where A is a 3+ cation (La to Lu) and B is a 4+ cation (Zr, Hf, Ti, etc.) have high melting point, relatively high coefficient of thermal expansion, and low thermal conductivity, which make them suitable for applications as high-temperature thermal barrier coatings. The effect of doping at the A site on the thermal conductivity of a pyrochlore oxide $La_2Zr_2O_7$ has been investigated. Oxide powders of various compositions $La_2Zr_2O_7$, $La_{1.7}Gd_{0.3}Zr_2O_7$, $La_{1.7}Yb_{0.3}Zr_2O_7$ and $La_{1.7}Gd_{0.15}Yb_{0.15}Zr_2O_7$ were synthesized by the citric acid sol-gel method. These powders were hot pressed into discs and used for thermal conductivity measurements using a steady-state laser heat flux test technique. The rare earth oxide doped pyrochlores $La_{1.7}Gd_{0.3}Zr_2O_7$, $La_{1.7}Yb_{0.3}Zr_2O_7$ and $La_{1.7}Gd_{0.15}Yb_{0.15}Zr_2O_7$ had lower thermal conductivity than the undoped $La_2Zr_2O_7$. The Gd_2O_3 and Yb_2O_3 co-doped composition showed the lowest thermal conductivity.

Keywords: melting point, pyrochlore oxide, rare earth compounds, sol-gel process, steady-state laser, synthesis (chemical), thermal barrier coatings, thermal conductivity, thermal expansion

N.P. Bansal and D. Zhu, Materials and Structures Division, NASA Glenn Research Center, Cleveland, OH 44135. Cited: *Mater. Sci. Eng. A*, 2007, June 25, **459**(1-2), p 192-195. ISSN 0921-5093.

Thermal properties of VPS-W coatings on CuCrZr alloy with Ti bonding layer. Tungsten coating of 0.2 mm thickness was successfully deposited by vacuum plasma spraying technique on CuCrZr alloy with Ti bonding layer. Microstructure and chemical composition of deposited W were examined. Its thermal response and thermal fatigue properties were studied with active cooling. No cracks and no exfoliation occurred on the W surface after thermal response test with a heat flux from 0 to 8 MW/m^2. It survived up to 200 cycles under 8 MW/m^2. These results indicate that VPS-W coated Ti/CuCrZr is a potential candidate for a high heat resistance armor material on plasma facing components.

Keywords: bonding, bonding layers, copper alloys, heat load experiments, microstructure, plasma spraying, protective coatings, thermal response tests, thermodynamic properties, tungsten, vacuum plasma spraying

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Transport

Integrated, effective, and average interdiffusion coefficients and their applications in multicomponent alloys for energy-production technologies. Solid-state diffusion is a subject of great interest for many intellectual merits and practical applications. It also provides excellent educational studies with cross-fertilization of science and technology. This paper examines the importance of multicomponent-multiphase interdiffusion with specific examples from materials and coatings for components in advanced energy-production systems, including gas turbines and nuclear reactors. Results and analysis from laboratory experiments are presented in terms of interdiffusion fluxes, integrated interdiffusion coefficients, effective interdiffusion coefficients, and average multicomponent interdiffusion coefficients. Applications are highlighted for materials and coatings for components in advanced energy production technologies. Additional consideration is given to the refined approach to assess composition-dependent interdiffusion coefficients in multicomponent alloys.

Keywords: alloying elements, energy production, gas turbines, interdiffusion, interdiffusion (solids), metallic nuclear fuels, microstructure, multicomponent alloys, nickel aluminides, nickel compounds, nuclear fuels, nuclear reactors, superalloys, thermal barrier coatings

Y.H. Sohn, N. Garimella, E. Perez, R. Mohanty, and J. Liu, Advanced Materials Processing and Analysis Center, Department of Mechanical, Materials and Aerospace Engineering, University of Central Florida, Orlando, FL 32816. Cited: *Diffusion and Defect Data. Pt A Defect and Diffusion Forum*, 2006, **258-260,** p 346-359. ISSN 1012-0386.