Topical Symposia
Room California - Session TS2-2
Thermal, Cold, and Kinetic Sprayed Surface Coatings

Moderators: Pylin Sarobol, Sandia National Laboratories, USA, Charles Kay, ASB Industries, Inc., USA

1:30pm **TS2-2-1 Influence of Bondcoat and Substrate Chemistry on Lifetime in Suspension Plasma Sprayed Thermal Barrier Coatings***, **Mohit Gupta**, N Markocsan,* University West, Sweden*; X Li,* Siemens Industrial Turbomachinery AB, Sweden

A Thermal Barrier Coating (TBC) system is designed to protect gas turbines from high temperatures and harsh environments. Development of TBCs allowing higher combustion temperatures is of high interest since it results in higher fuel efficiency and lower emissions. It is well known that nano-structured TBCs produced by Suspension Plasma Spraying (SPS) have significantly lower thermal conductivity as compared to conventional systems due to their very fine porous microstructure. However they have not yet been commercialised due to low reliability and life expectancy of the coatings.

Lifetime of a TBC system is highly dependent on bondcoat and substrate chemistry as it influences the interdiffusion characteristics and growth rate of Thermally Grown Oxide (TGO) layer. To enhance the lifetime of TBCs, fundamental understanding of relationships between bondcoat-substrate chemistry, TGO growth rate, and lifetime is essential. The objective of this work was to study the effect of TGO growth rate on lifetime in SPS TBC systems by changing bondcoat and substrate materials. Experimental NiCoCrAlY bondcoat powders with different aluminium activity were investigated. High velocity air fuel spraying was used for bondcoat deposition while axial-SPS was used for yttria stabilised zirconia topcoat deposition. Lifetime was examined by thermal cyclic fatigue and thermal shock testing. The failure mechanism in each case will be discussed.

1:50pm **TS2-2-2 *a*-Oxide-Induced Grain Growth in Ligand-Free CZTS Nanoparticle Coatings***, **Stephen Exarhos**, E Palmes, R Xu, L Mangolini,* University of California, Riverside, USA

Cu_2ZnSnS_4 (CZTS) is a material of interest for application as the photo-absorber layer in polycrystalline thin film photovoltaic (PV) devices due to its earth abundant, inexpensive, and nontoxic constituents. We have developed a highly scalable synthesis technique for the controllable formation of surface-ligand-free CZTS nanoparticles using aerosol spray pyrolysis. Further, we have developed scalable techniques to generate uniform large-grained polycrystalline thin films from nanoparticle coatings. High quality PV absorber layers are unattainable by sintering our ligand-free particles using traditional methods. We have found that a simple annealing step at moderate temperature (200-300 ºC) in air results in the formation of a thin oxide layer at the particle surface. Powder processed in this manner shows significantly enhanced grain growth kinetics after high-temperature annealing in a low-pressure sulfur atmosphere in concert with alkali incorporation. Most importantly, using these particles and the oxidizing technique, we avoid the introduction of carbon to the system which invariably facilitates the formation of a fine-grain carbon-rich layer between the substrate and the large-grained absorber layer in previously reported nanoparticle-derived films. We also observe structural and compositional inhomogeneity from grain-to-grain in these annealed films, a result previously reported by our group to be found in alternatively processed CZTS films, which allows us to infer possible unknown mechanics of grain growth in the material system. We present extensive characterization of these particles and films in order to understand the role an amorphous oxide layer and phase evolution may play in enhancing grain growth in CZTS nanoparticle coatings.

2:10pm **TS2-2-3 CaviTec HVOF Coatings for Protection against Cavitation Erosion***, **Sébastien Lavigne**,* Polytechnique Montreal, Canada

CaviTec® is an alloy known for its high resistance to cavitation. Under cavitation conditions, this material exhibits a long incubation period before erosion sets-of, and a low erosion rate is observed afterwards. During the incubation period, the material absorbs energy, and a structural transition takes place. In the present work, Cavitec powders were prepared by water atomization followed by HVOF thermal spray. Compared to the bulk alloy, the coatings exhibit a relatively poor cavitation resistance and no incubation period. The defects present in the coatings (intersplat boundaries, pores etc) initiate cracks during erosion, leading to the removal of dense CaviTec particles. However, by ball milling the powder at high energy prior to deposition, the cavitation resistance can be improved by a factor of 2. Moreover, deposition at high velocity leads to a much higher cavitation resistance comparable to that of other well-known cavitation resistant HVOF coatings: For instance, a lower erosion rate than that of WC-CoCr HVOF coatings was achieved, and a longer incubation period than that of Stellite-6 was observed.

2:30pm **TS2-2-4 Experimental and Numerical Investigation on Fracture Toughness of Plasma-sprayed TBCs using a Modified Three-point Bending Method***, **Jianguo Zhu**,* Jiangsu University, China

Determination of interfacial properties of thermal barrier coatings (TBCs) is very important for designing and evaluating the durability of TBCs. In this work, the adhesion of thermal spraying coatings deposited on a NiCoCrAlY bondcoat by the APS process was investigated experimentally. A modified three-point bending test was adopted to initiate and propagate the topcoat/bondcoat (TC/BC) interfacial crack. The fracture surfaces were examined, and images show that the crack plane was just on the TC/BC interface. Furthermore, the displacement and strain fields of the TC/BC interface were obtained using the digital image correlation (DIC) method, and the crack length was accurately determined. Based on the experimental results, the critical strain energy release rate G_c for crack initiation was calculated with Irwin-Kies formula, and the G_c for crack propagation was inversely determined by a finite element model. Results indicate that the G_c can be reliably obtained theoretically and numerically.

2:50pm **TS2-2-5 Process Induced Real-time Residual Stress Measurement of Thermal Spray Coatings***, W Choi, C Jensen, S Sampath,* ReliaCoat Technologies, LLC, USA*; **Andrew Vackel**,* Sandia National Laboratories, USA

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Thermal spraying (TS) represents a flexible and highly efficient method of materials processing, and applications of protective coatings. Over the last several decades, the thermal spray process has emerged as an innovative and unique means for processing and synthesizing from low melting plastics to complex multi-component alloys and refractory ceramics. TS coatings find extensive applications including, but not limited to aerospace, energy generation, paper and pulp, biomedical implants, earth moving machinery, automotive industries for from thermal barriers for heat shielding to wear/corrosion resistance and reclamation. Despite significant advances in process and materials technology, limitations in coating reliability and repeatability have prevented expanded applicability of thermal spray coatings and, in particular, the use of thermal spray coatings in *prime reliant functions*. One major obstacle to obtaining greater coating performance, repeatability and reliability is the inability to measure relevant coating properties, and to do so in real-time within the production environment.

ReliaCoat Technologies has developed In-situ Coating Property (ICP) sensor, based on bi-layer thermo-elastic beam curvature solutions during and after coating deposition for real time extraction of residual stress evolution, deposition dynamics, and the onset of stress-relief cracking. The sensor distinguishes variation in process condition through resulting residual state of stress and elastic modulus. This real time residual stress analysis can comprehensively be related to both in-flight particle state (temperature and velocity) and booth operational parameters (cooling, spray distance, and deposition rate). Furthermore, monitoring of the residual stress evolution provides a qualitative indication of the stored energy in the layer owing to the intersplat bonding strength (cohesion) and work hardening due to impact (hardness), as well as, energy relief mechanisms including micro/macro cracking, poor cohesion, yielding or creep. Thus, the ICP sensor enables rapid process parametric optimization for design-relevant coating properties within the spray booth.

3:30pm **TS2-2-7 Metallization and Selective Metallization of Silver by Spraying***, **Koen Staelens**,* Jet Metal Technologies, France

Jet Metal Technologies (France) introduces a green alternative for metallization processes like PVD, electroplating or evaporation.

Two chemical solutions, an oxidant containing the metal salt of the metal that the user wants to deposit, the other the reducing agent, are both water based, solvent, Pd ànd CMR free. Using compressed air and a double nozzle spraying paint gun, the reducing and oxidising agent are simultaneously sprayed onto the substrate surface, starting an oxido-reduction reaction and instantly forming a thin metal layer. The end result of this reaction is a dense and high adherent metallic film on the substrate surface.

The technology is applied on many substrate geometries (small or big, easy or complex, 2D or 3 D shape) and basically all substrate material choices, whether it is an electrically conducting or non-conducting surface. The range of substrates goes from metals, metal alloys, over glass, textiles, ceramics, silicon, leather to a long list of plastics and composites to even wax. The only prerequisite is linked with the use of water based solutions: in order realize an evenly well distributed metal layer over the surface, a good substrate wettability is needed which can be achieved via a pre-treatment step (flaming, plasma or corona). Once the required layer thickness is reached, spraying deionized water stops all reactions and the substrate is dried with the help of compressed air, so no for a curing step.

By adding one more step to the above described process, a selective, conductive pattern can be realized: an alkali sensitive organic ink, used as a negative mask, is printed on the substrate with an ink jet printer. As the oxidant and reducing agent have a pH >10, a loss of adhesion of the printed ink is achieved. During the final step of the process (spraying with deionized water) the ink layer is removed, leaving only metallization where there was no ink printed: a selective coating is achieved, and the result is the exact opposite of the pattern designed with the ink.

Today the technology is used on industrial scale in many application areas where Ag is used. In decorative applications like cosmetic bottles & caps, spirit bottles but also in functional applications like anti-bacterial applications, EMI shielding (500 nm Ag gives 65-70 dB between 10 MHz–10 GHz), intermediate conductive layer (150 nm Ag on a non-conductive surface gives enough electrical conductivity to be followed by electroplating, powder coating, electroforming,).

And with the selective metallization technology the manufacturing processes of e.g. antennas, PCB’s, … can be simplified.

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