Coatings for Use at High Temperatures
Room California - Session A1-3

Coatings to Resist High Temperature Oxidation, Corrosion, and Fouling

Moderators: Vladislav Kolarik, Fraunhofer Institute for Chemical Technology ICT, Shigenari Hayashi, Hokkaido University, Sebastien Dryepondt, Oak Ridge National Laboratory, USA

8:00am **A1-3-1 A Framework for Modelling the Nanomechanical and Nanotribological Properties of High Temperature HfB_xC_y Coatings**, ***Mohammad Humood***, *T Ozkan,* Texas A&M University, USA*; E Mohimi, J Abelson,* University of Illinois at Urbana-Champaign, USA*; A Polycarpou,* Texas A&M University, USA

High aspect ratio conformal HfB_xC_y coatings were synthesized using low-temperature chemical vapor deposition (CVD). The carbon content was varied in the aggregates, which resulted in thin films with different compositions and mechanical properties. A framework was developed based on mixing of different aggregates to predict the nanomechanical properties of these films. Under this framework, we assumed the growth to be either diffusion or nucleation controlled. Different volume fractions of aggregates were considered. Certain mixing rations agreed well with the instrumented nanoindentation and provided further insights to better understand the results of and nanoscratch experiments. Nanoscratch experiments revealed the coefficient of friction (COF) to diminish to a superlubricity level of 0.05 when the carbon content increases in HfB_xC_y thin films. This value is comparable to DLC, and underlines the immense potential of HfB_xC_y hard thin film coatings for tribological applications. However, due to the shortcomings of C-based coatings such as a-C and DLC, which all experience graphitization and degradation under tribological contact conditions at elevated temperatures above 350 °C, there is a potential need for using ultra-high temperature ceramic coatings such as HfB_xC_y as an alternative for tribological applications.

8:20am **A1-3-2 Characterization of Thermal Properties of Different Pyrochlore Ceramic Materials Dedicated for Application as an Insulation Layers in Thermal Barrier Systems**, *M Mikuskiewicz,* ***Damian Migas***, *G Moskal,* Silesian University of Technology, Poland

The basic direction of thermal barrier coatings (TBC) systems development is related to new materials solutions dedicated for bond-coats and ceramic insulating layers. From technological point of view this development consists mainly new conceptions in internal architecture of ceramic sublayer in the form e.g. of segmented, composite or multilayered morphology. In the case of new materials concepts the most interesting areas of investigations are related to strongly defected systems such as pyrochlore ceramic with overall formula RE2(Zr,Hf,Ce)2O7, perovskites or hexaaluminates materials of REZrO3 and (A,B)Al11O19 type respectively, or defected cluster zirconia based materials with two rare earth elements (with high cations ionic size differences) and formula ZrO2-Y2O3-RE12O3-RE22O3.

In presented article thermal properties of different types of pyrochlore material based on zirconia, hafnia and ceria of samarium are presented. Analyzed materials were synthesized by solid state reaction method form mixture of feedstock nano-sized powders of zirconia, hafnia, ceria and samaria. Synthesized materials were analyzed from its chemical and phase constituent point of view. The crystallite size was determined as well by X-ray diffraction method. Additionally the crystallite size and theirs orientations were analyzed by EBSD method. The morphological characterization of used feedstock powders was showed as well. The basic range of investigations was related to thermal parameters such as thermal diffusivity, specific heat and coefficient of thermal expansion analysis. Those data were obtained by laser flash analysis, calorimetric and dilatometric investigations respectively. On the base of those data the thermal conductivity was calculated in temperature range 25 to 1500°C. Obtained value of thermal parameters were compared to analogous data for usually used zirconia based ceramic of 8YSZ type.

The research has been supported by National Science Centre within Sonata scheme, under contract UMO-2016/21/D/ST8/01687.

8:40am **A1-3-3 Development of High Performance Corrosion Resistant Coatings using Graphene**, ***Anand Khanna***, *K Aneja,* IIT Bombay, India

Graphene based high performance coatings have been developed using a graphene powder prepared in our lab using a new pressure based exfoliation method. Three kinds of coatings were made: (i) pre-treatment coatings on steel substrates using a new patented method of functionalizing graphene. The thin five micron coating has excellent adherence and very low permeability. (ii) graphene dispersed epoxy primer whose properties appear superior than a epoxy zinc rich coating or inorganic zinc rich coating and (iii) a graphene based polyurethane top coat with superior UV blocking properties. Combining all the individual coatings as conversion coating, primer and top coat, it becomes an excellent high performance coating with very high corrosion resistance, mechanical properties and weathering resistant. Each individual coating has its independent application for example pre-treated graphene can be an excellent replacement for electrolytic coating for automobile bodies and graphene dispersed epoxy can be a good replacement for epoxy based zinc rich coating or inorganic zinc rich primers.

9:00am **A1-3-4 Wide-range and Enhanced Filtration of Polyacrylonitrile Membrane for Water Purification by Coating with Thin Film Metallic Glass**, ***Shewaye Kassa***, *Y Liao, J Chu, J Chen,* National Taiwan University of Science and Technology (NTUST), Taiwan

We have successfully fabricated comprehensive thin-film metallic glass (TFMG) coated polyacrylonitrile (PAN) membrane for wastewater purification. Several PAN-based membranes, synthesized via electrospinning were compacted into a single membrane through Zr-based TFMG coating by a means of magnetron sputtering deposition. TFMG coatings with various thicknesses ranging from 200 nm to 320 nm were grown on the membranes with no external heating. After coating with TFMG, the water purification performance of the membrane for synthetic wastewater, contaminated with toxic heavy metals (Cr and Cd), vegetable oil and microorganisms (E. coli and P. aeruginosa), was found to be higher than 95% with a pure water flux rate of 814 L $m^{-2}h^{-1}$. TFMG-coated PAN membrane exhibited extraordinary selectivity and a remarkable fouling recovery rate in comparison to the bare polyacrylonitrile membrane, which can be as a result of significant enhancement in the strength as well as the thermal and chemical stability of the membrane through the TFMGs coating.

9:20am **A1-3-5 The Effect of Surface Aluminizing to Enhance High-temperature Air-oxidation Resistance of Equimolar FeCoNi and FeCoNiCr Alloy**, ***Wu Kai***, *F Cheng, F Chien, R Huang,* National Taiwan Ocean University, Taiwan*; J Kai,* National Tsing Hua University, Taiwan

The effect of surface aluminizing treatment on air-oxidation behavior of equimolar FeCoNi-based alloys (FeCoNi and FeCoNiCr) was studied at 950°C. The results showed that the oxidation kinetics of the aluminized alloys followed the two-stage parabolic rate law. The optimal aluminized parameters were to heat the alloys at 850°C for 4 h in 63% Al_2O_3-30% (Fe-Al)-7%AlF_3 powders under an Ar-gas flow-rate of 200 cm^3/min. The oxidation rates of the aluminized alloys were significantly lower than those of the untreated alloys by 3 to 5 orders of magnitude. The scales formed on the aluminized alloys consisted of an exclusive thin-layer of a-Al_2O_3 whose formation is responsible for the significant reduction of the oxidation rates with respect to the ternary and quaternary substrates.

9:40am **A1-3-6 TEM Study of Hf-B-Si-C-N Coatings Microstructure at High Temperatures**, ***Yi Shen***, *M Zhang, J Jiang,* University of Texas at Arlington, USA*; J Vlček,* University of West Bohemia, Czech Republic*; E Meletis,* University of Texas at Arlington, USA

Amorphous $Hf_7B_{23}Si_{22}C_6N_{40}$, $Hf_7B_{23}Si_{17}C_4N_{45}$ and $Hf_6B_{21}Si_{19}C_4N_{47}$ coatings were synthesized by reactive pulsed dc magnetron co-sputtering. These coatings possess a hardness of ~ 20 GPa and a Young's modulus of ~170 GPa, and exhibit superior high-temperature oxidation resistance. The microstructures of the coatings annealed up to various temperatures from 1100 °C to 1600 °C in helium and in air were studied by X-ray diffraction (XRD) and transmission electron microscopy (TEM) to understand the effect of slight composition tuning on their microstructure evolution at high temperatures. All annealed films were found to have a two-layered structure composed of the original film followed by a nanocomposite oxidized surface layer involving HfO_2 nanoparticles embedded in a SiO_x-based matrix. Slight changes in the nitrogen content of the coatings were found to result in significant microstructure difference and oxidation resistance at high temperatures.

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