Protective and High-temperature Coatings
Room Town & Country A - Session MA2-1-TuA

Thermal and Environmental Barrier Coatings I

Moderators: Sabine Faulhaber, University of California, San Diego, USA, **Fernando Pedraza**, La Rochelle University, Laboratory LaSIE, France, **Francisco Javier Perez Trujillo**, Universidad Complutense de Madrid, Spain, **Gustavo García-Martín**, REP-Energy Solutions, Spain

4:00pm **MA2-1-TuA-8 Multicomponent Rare Earth Oxide Coatings for Refractory Alloys***, Rachel Rosner, Kristyn Ardrey, Will Riffe, Alejandro Salanova, Prasanna Balachandran, Bi-Cheng Zhou, Carolina Tallon, Jonathan Laurer, Jon Ihlefeld, Patrick Hopkins, Sandamal Witharamage,* ***Elizabeth Opila [opila@virginia.edu]****,* University of Virginia, USA **INVITED**

Rare earth oxide (RE_2O_3) exhibit three crystal structures across the lanthanide series:hexagonal, monoclinic, and cubic, with all showing exceptionally high-melting temperatures (>2100°C) and excellent thermochemical stability.The cubic RE_2O_3, dysprosium through lutetium oxides, have isotropic thermal expansion with a reasonable match to Nb, making them suitable high temperature coatings for oxidation-prone refractory alloys.Multicomponent rare-earth oxides (MRO) allow the additional ability to target and optimize thermal expansion, resistance to molten deposits, and especially thermal conductivity, enabling their use as thermal/environmental barrier coatings (T/EBCs) in high-temperature, reactive environments such as turbine engines.Thermal conductivity of MROs has been shown to decrease with mixtures of RE_2O_3 with increasing mass and size variation.The larger, lighter, non-cubic lanthanide oxides, lanthanum through terbium oxides, mixed in a majority MRO cubic phase in non-equimolar proportions will precipitate as second phases once their solubility limit in the cubic RE_2O_3 is exceeded, enabling further reductions in thermal conductivity.In this work, MRO compositions are systematically varied to aid in achieving targeted thermal conductivity, thermal expansion, and resistance to molten deposits.Powder mixtures were combined, ball milled, and sintered via spark plasma sintering.Room temperature thermal conductivity was measured using the laser-based time domain thermoreflectance method.Thermal expansion was determined by dilatometry or lattice parameter measurements as a function of temperature.Resistance to molten CaO-MgO-Al_2O_3-SiO_2 was quantified after exposure at temperatures of 1300-1500°C for times between 1 and 96h.Here we evaluate whether a single layer MRO will meet all design requirements for a (T/EBC) enabling cost efficient coating synthesis or whether additional coating layers are required to achieve adherent, protective properties for hot section turbine engine component applications.

4:40pm **MA2-1-TuA-10 Characterization of the Environmental Barrier Coatings with Al-containing dopants exposed to Steam Environments***,* ***Michael Lance [lancem@ornl.gov]****, Mackenzie Ridley,* Oak Ridge National Laboratory, USA

SiC ceramic matrix composites (CMCs) are desired for use in combustion environments to achieve higher turbine operating temperatures, although CMCs require environmental barrier coatings (EBCs) for protection from the gas environment. EBC systems are known to primarily fail through coating delamination via growth of a thermally grown oxide (TGO) at the EBC – silicon bond coating interface especially when exposed to steam, which accelerates the TGO growth rate. The TGO undergoes a phase transformation during thermal cycling, which results in stresses that encourages EBC spallation. Yb-silicate EBCs with mullite and yttrium aluminum garnet (YAG) dopant additions were deposited on SiC substrates with a Si intermediate bond coating and exposed to thermal cycling in steam at 1350 °C. The impact of Al dopant additions on the TGO growth rate and the SiO_2 phase transformation were assessed. Annealing prior to steam exposure was found to significantly change the course of TGO growth with unannealed samples forming an amorphous Si-Al-Y glassy phase at short cycling durations. The composition of the EBC, TGO and Si bond coating were assessed with wavelength dispersive x-ray spectroscopy (WDS) using an electron probe microanalyzer (EPMA). In addition, photo-stimulated luminescence spectroscopy (PSLS) and Raman spectroscopy was used to characterize the composition and stress in the coating phases.

5:00pm **MA2-1-TuA-11 PVD Ce-Coating to Mitigate Intergranular Oxidation of Additively Manufactured Ni-Base Alloy In625***,* ***Anton Chyrkin [chyrkin@chalmers.se]****, Andrea Fazi, Mohammad Sattari, Mattias Thuvander,* Chalmers University of Technology, Gothenburg, Sweden*; Wojciech J. Nowak,* Rzeszow University of Technology, Rzeszow, Poland*; Dmitry Naumenko,* Forschungszentrum Jülich GmbH, Germany*; Jan Froitzheim,* Chalmers University of Technology, Gothenburg, Sweden

Additively manufactured (AM) Powder Bed Fusion - Laser Beam Ni-base alloy IN625 suffers from intergranular oxidation (IGO) during air exposure at 900 °C in contrast to the conventionally manufactured (CM) forged alloy IN625. A new mechanism of IGO in AM alloys is proposed: IGO is triggered by oxide buckling over the grain boundaries (GBs) in the alloy followed by oxidation of the open intergranular voids. Application of a 10 nm thick PVD coating of Ce promoted a slower inward growth of the Cr_2O_3 scale, better oxide adherence and as a result strongly suppressed IGO. The Cr_2O_3 scales thermally grown on both uncoated and Ce-coated alloys were analysed with SEM/EDX, EBSD, GD-OES, TEM and APT. The main beneficial effect provided by the Ce-coating is improved oxide adherence preventing oxide from buckling and oxidation of intergranular voids.

Author Index

Bold page numbers indicate presenter