Protective and High-temperature Coatings
Room Town & Country A - Session MA2-2-WeM

Thermal and Environmental Barrier Coatings II

Moderators: Fernando Pedraza, La Rochelle University, Laboratory LaSIE, France, **Francisco Javier Pérez Trujillo**, Universidad Complutense de Madrid, Spain

9:00am **MA2-2-WeM-4 Sandphobic Thermal/Environmental Barrier Coatings for Gas Turbine Engines**, ***Andrew Wright***, *Clara Mock,* DEVCOM Army Research Laboratory, USA*; Timothy Sharobem,* Oerlikon Metco, USA*; Luis Bravo, Anindya Ghoshal,* DEVCOM Army Research Laboratory, USA

Previous published work on similar materials, components, and environments has shown that degradation typically is caused by either erosive damage leading to spalling of the coatings or chemical attack from particulates, such as sand, that leads to cracking and delamination. In this work, controlled isothermal furnace tests were conducted to study the chemical compatibility of T/EBCs in the presence of CMAS. The same coatings were also investigated in a hot particulate ingestion rig (HPIR). This rig mimics conditions found in the hot turbine section of a gas-turbine engine and conducts particulate entrainment in a gas-turbine engine relevant combusting test environment. Here, specimens were subjected to thermal cycling and CMAS impingement at high velocity and high temperature to investigate the survivability of the coatings in a more realistic case study. Finally, the wettability characteristics of CMAS were investigated using high temperature contact angle measurements to examine CMAS effects on various T/EBC chemistries. While coating chemistry is certainly a factor affecting CMAS spreading on the surface, results show that surface roughness is also a significant factor. Results were used to develop and validate novel wettability and full-engine scale models.

9:20am **MA2-2-WeM-5 A New Thermal Barrier Coating with Strong Resistance to Molten Silicate Attack and Fracture**, ***Ying Chen***, The University of Manchester, UK

We report a new thermal barrier coating (TBC) with strong resistance to calcia–magnesia–alumina–silicate (CMAS) attack and fracture. The design is based on a core-shell concept in which each microstructural unit of the coating comprises a tough yttria stabilised zirconia (YSZ) core and a thin, CMAS-resistant shell. The core-shell TBC was realised by synthesising core-shell powder and then translating the core-shell structure from powder to coating by thermal spray. The CMAS resistance test shows that the CMAS penetration depth through the core-shell TBC is an order of magnitude lower than that through the industrial benchmark YSZ TBC. The erosion and micromechanical tests show that the core-shell TBC has lower material loss and higher fracture toughness than the benchmark YSZ TBC, suggesting its stronger fracture resistance at both macro and microscales. The strong CMAS and fracture resistance of the core-shell TBC was rationalised by multiscale compositional and microstructural analysis.

9:40am **MA2-2-WeM-6 Enhanced Oxidation Resistance of Ni substrate by Sputtered Nanotwinned $Al_9SiCo_{20}Cr_{20}Ni_{45}NbMo_4$ Medium-Entropy Alloy Thin Films at High Temperatures**, ***Jun-Hui Qiu***, *Yi-Chun Yen, Fan-Yi Ouyang,* Department of Engineering and System Science, National Tsing Hua University, Taiwan

High-entropy alloys exhibit various properties, such as superior thermal stability, oxidation resistance, and corrosion resistance. These characteristics have sparked interest in using HEAs as anti-oxidation protective coatings. The nanotwinned structure within these alloys contributes to their high hardness and thermal stability, while the sluggish diffusion in high entropy alloys helps lower oxidation rates.

In this study, $Al_9SiCo_{20}Cr_{20}Ni_{45}NbMo_4$ medium-entropy alloy thin films with a nanotwinned structure were successfully fabricated using magnetron sputtering system on a nickel-metal substrate. Then, the samples were subjected to high-temperature oxidation tests at 600°C, 700°C, and 800°C for 72 hours in dry air using a thermogravimetric analyzer to investigate the high-temperature oxidation behavior of these films and their protective effects against oxidation on nickel substrates. The results demonstrated that the medium-entropy alloy films exhibited strong oxidation resistance, leading to significantly lower oxidation rates and mass gain than pure nickel. The oxidized films had smoother surfaces than bare nickel substrates, with no pores or cracks. Due to grain growth at high temperatures, the (111) texture and nanotwinned structure in the films partially disappeared at 600°C and 700°C, although some twin structures remained. At 800°C, the twin structures were nearly absent, forming larger grains and a more pronounced (200) diffraction peak. After 24 hours of oxidation at 800°C, chromium oxide particles began to precipitate on the surface, with size and density increasing over time. At 600°C, the oxide layer on the films consisted of an inner aluminum oxide layer and an outer chromium oxide layer, mainly driven by the inward oxygen diffusion. After oxidation at 700°C and 800°C, the oxide layer evolved into a three-layer structure with an inner aluminum oxide layer, a middle chromium oxide layer, and an outer aluminum oxide layer. With prolonged oxidation time, the outer aluminum oxide layer developed an island-like structure with a discontinuous thickness. After extended oxidation at 800°C, form chromium oxide within and on the surface of the aluminum oxide. Additionally, internal oxidation of aluminum occurred inside the film.

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