In power generation and aero-propulsion applications, thermal barrier coatings (TBCs) are widely used to provide thermal insulation to hot-section metallic components of gas turbine engines. Metallic oxidation-resistant coatings (ORCs) are also widely employed as a protective coating or bond coat for TBCs in many high temperature applications. Among the widely studied durability issues in these high temperature protective coatings, one critical challenge that received greater attention in recent years is their resistance to high-temperature degradation due to corrosive deposits arising from fuel impurities and CMAS (calcium-magnesium-alumino-silicate) sand deposits from air ingestion. Presence of vanadium, sulfur, phosphorus, sodium and calcium impurities in alternative fuels warrants a clear understanding of high-temperature materials degradation for the development of fuel-flexible gas turbine engines.

In this study, high-temperature degradation due to aggressive deposits such as V2O5, P2O5, Na2SO4, NaVO3, CaSO4 and a laboratory-synthesized CMAS sand for free-standing air plasma sprayed (APS) yttria stabilized zirconia (YSZ), the topcoat of TBC system, and APS CoNiCrAlY, the bond coat of TBC system or a stand-alone ORC, is examined. Phase transformations and microstructural development were examined by using x-ray diffraction, scanning electron microscopy, and transmission electron microscopy.

The V2O5 melt degraded the APS YSZ through the formation of ZrV2O7 and YVO4 at temperature below 747°C and above 747°C, respectively. Formation of YVO4 led to the depletion of Y2O3 stabilizer and the deleterious transformation of the YSZ to monoclinic ZrO2 phase. The APS YSZ was found to react with P2O5 melt by forming ZrP2O7 at all temperatures. This interaction led to the depletion of ZrO2 in the YSZ (i.e., enrichment of Y2O3 in t'-YSZ) and promoted the formation of the fluorite-cubic ZrO2 phase. Above 1250°C, CMAS deposits were observed to readily infiltrate and significantly dissolved the YSZ coating via thermochemical interactions. The molten CMAS attack destabilized the YSZ through the detrimental phase transformation (t' -> t -> f + m).

The V2O5 melt degraded the APS CoNiCrAlY through various reactions involving acidic dissolution of protective oxide scale, which yielded substitutional vanadates such as (Co,Ni)3(VO4)2 and (Cr,Al)VO4. Sulfate deposits such as Na2SO4, when tested in encapsulation, damaged the CoNiCrAlY by Type I acidic fluxing hot corrosion mechanisms at 1000°C that resulted in accelerated oxidation and sulfidation. CoNiCrAlY in both as-sprayed and preoxidized condition suffered a significant damage by CaSO4 deposit via basic fluxing mechanism that yielded CaCrO4 and CaAl2O4. The CMAS melt also dissolved the protective Al2O3 oxide scale developed on CoNiCrAlY by forming anorthite platelets and spinel oxides.

Based on detailed investigation on degradation of the APS YSZ and CoNiCrAlY by various corrosive deposits, experimental attempt was carried out to mitigate the melt induced-deposit attack. Experimental results from this study demonstrated, for the first time, that an oxide overlay produced by electrophoretic deposition (EPD) can effectively perform as an environmental barrier overlay for APS TBCs. Furnace thermal cyclic oxidation testing of overlay-modified TBCs on bond-coated superalloy also demonstrated the good adhesive durability of EPD Al2O3 overlay.

Major: Materials Science and Engineering

Educational Career:
Bachelor's of Chemical and Electrochemical Engineering, BS, 2003, Central Electrochemical Research Institute, India
Master's of Materials Science and Engineering, MS, 2007, University of Central Florida

Committee in Charge:
Dr. Yongho Sohn, Chair, AMPAC/MMAE