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STABILITY OF OXIDES/ENVIRONMENTAL BARRIER COATING CANDIDATE MATERIALS IN HIGH-TEMPERATURE, HIGH-VELOCITY STEAM

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Stability of oxides/Environmental Barrier Coating (EBC) candidate materials in high-temperature, high-velocity steam has been characterized using a steam-jet furnace modeled after Lucato et al [1]. The objective of this work is to quantify stability of oxides for use as coatings on SiC-based composites in turbine engine environments with the long term goal of developing thermochemical life prediction models for EBCs. SiO_2, TiO_2, Y_2O_3, and rare earth silicates were exposed in one atmosphere steam flowing at approximately 170 m/s at temperatures between 1200 and 1400°C for times up to 375 h. Oxide recession, attributed to formation of volatile metal hydroxides, was measured for SiO_2, TiO_2 and Y_2O_3. The SiO_2 recession rates were consistent with values predicted assuming loss of material was limited by transport of $Si(OH)_4(g)$ through a laminar gas boundary layer. TiO_2 single crystal recession was slightly less than SiO_2 but too rapid for use in a turbine environment. Y_2O_3 recession was not measureable within the sensitivity of techniques used here.

$Y_2Si_2O_7$ exposed in the steam-jet furnace was selectively depleted of SiO_2 by the reaction:

$$Y_2Si_2O_7 + 2H_2O(g) = Y_2SiO_5 + Si(OH)_4(g) \qquad (1)$$

A porous surface layer of Y_2SiO_5 formed after exposure of $Y_2Si_2O_7$ and was confirmed by X-ray Diffraction Analysis (XRD), Scanning Electron Microscopy (SEM), and Energy Dispersive Spectroscopy (EDS). Key microstructural features observed in addition to the porosity include grain refinement, faceting, and grain fall out. The growth rate of the porous layer decreased with time at 1300°C, although the depletion depth varied significantly across the surface, possibly due to preferred crystallographic orientations for the depletion reaction. The silica depletion depth *decreased* with increasing temperature. The depletion depths were uniform at 1200°C as shown in Figure 1. At 1400°C the porous surface layers sintered rapidly, closing off paths for water vapor ingress into the material and thus minimizing SiO_2 depletion by Reaction (1). Y_2SiO_5 was significantly more stable than $Y_2Si_2O_7$. Significant SiO_2 depletion of the monosilicate was not observed within the sensitivity of the techniques used here.

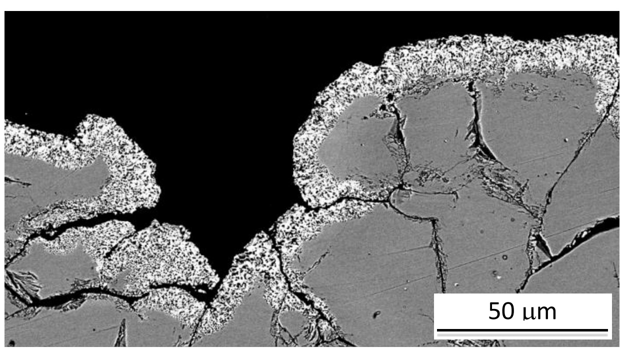

Figure 1 – SEM image of $Y_2Si_2O_7$ cross-section after exposure in the steam-jet furnace at 1200°C with a steam velocity of 170 m/s for 125 h. Note the formation of a porous surface layer of Y_2SiO_5

[1] dos Santos e Lucato, Sergio L., Olivier H. Sudre, and David B. Marshall. "A Method for Assessing Reactions of Water Vapor with Materials in High-Speed, High-Temperature Flow." J. Am. Ceram. Soc. 94 [s1] s186-s195 (2011).