CYCLIC OXIDATION OF YTTRIUM/YTTERBIUM DISILICATE ENVIRONMENTAL BARRIER COATINGS

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SiC-based ceramic matrix composites (CMCs) are an attractive class of high temperature structural material due to low rates of oxidation and excellent high temperature strength. However, in high pressure and high velocity environments containing water vapor like gas-turbines, SiC oxidizes in a paralinear manner owing to the competing processes of water vapor enhanced silica formation and silica volatilization. To prevent component recession, SiC-based CMCs are coated with environmental barrier coatings (EBCs) which mitigate scale volatilization while simultaneously inhibiting water vapor enhanced rates of oxidation. The current generation of EBCs are typically comprised of a ytterbium disilicate (YbDS) top coating deposited onto a Si bond coating, where both coatings are applied via atmospheric plasma spraying (APS). YbDS is selected as a top coating due to its low coefficient of thermal expansion mismatch, excellent chemical compatibility, seemingly low rate of oxidant permeability, and lower rates of silica activity compared to SiO2 scales [i.e. volatilization]. However, YbDS still experiences minor volatilization rates at lower gas velocities and detrimental volatilization rates at higher velocities. Thus, alternative top coating materials are being evaluated.

From a thermomechanical perspective, most single component rare-earth disilicates (REDS) other than YbDS are viewed as unsuitable due to high coefficient of thermal expansion (CTE) mismatch with SiC-based materials and/or exhibiting phase transformations at gas-turbine relevant temperatures. However, studies have shown that judicious fabrication of multicomponent rare-earth disilicates (REDS) may offer coatings exhibiting a primarily single-solution ß-phase composition and tailorable properties like CTE and thermal conductivity. As a nearer term application, studies have shown that two-component Y/Yb disilicates, or (Y/Yb)DS, have lower thermal conductivities than YbDS, which may lower the bond coating temperature and thereby extend coating lifetimes. This is especially pertinent to industrial gas-turbines, where required component lifetimes are > 25kh and increased turbine inlet temperatures are necessary to increase efficiency.

In the first part of this study, the 1-h 1350°C cyclic dry air oxidation of APS (Y/Yb)DS was compared to APS YbDS/YbMS EBCs to investigate oxygen permeability. Both EBCs were deposited onto APS Si bond coats deposited onto CVD SiC. As a baseline for evaluating EBC oxidant permeability, the dry air cyclic oxidation scale growth rates for bare silica formers (SiC, Si) were also measured and were consistently higher than rates previously measured after isothermal oxidation. The thinner silica scale formed under the thinner and denser (Y/Yb)DS coatings suggested a lower oxidant permeability than the YbDS/YbMS coating. After 500 1-h cycles, the (Y/Yb)DS coating was comprised of a single lattice shifted β-YDS phase with small amounts of yttrium monosilicate, and there was no significant difference in oxidation kinetics for (Y/Yb)DS coatings over the 90 – 240 µm thickness range. In the second part of the study,1-h and 100-h cycling in 90vol%H_2O/10vol%air at 1350°C was conducted on both (Y/Yb)DS and YbDS/YbMS EBCs to investigate the role cycling duration has on silica scale growth rates, and to also compare the effectiveness of both EBCs on reducing steam oxidation rates. Research was sponsored by the U.S. Department of Energy, Office of Fossil Energy, Turbine Program.