

MATERIALS ENGINEERING

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“Optimization of First Cycle Heat Treatments for Ytterbium Disilicate-Based Environmental Barrier Coatings”

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Purdue MSE M.S. Final Exam

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ABSTRACT

Environmental Barrier Coatings (EBCs) protect ceramic gas turbine engine components from corrosion by high temperature water vapor, but the coatings often form complex metastable microstructures upon plasma spray deposition. In ytterbium disilicate (YbDS) and its yttrium-doped counterpart (Y/YbDS), two coatings compatible with SiC/SiC parts, plasma spray forms an amorphous phase with poor mechanical integrity that constitutes ~80% of the coating. The amorphous phase must be crystallized with a pre-service heat treatment. During the treatment, interplay between thermal expansion and crystallization contraction can cause vertical cracks which expose the component to the corrosive atmosphere. Remedial treatments with long, high temperature holds (~1300 °C) can both crystallize the coating and heal existing cracks. However, these temperatures cause unnecessary grain growth that reduces the structural integrity of the coating over its lifetime.

Here we propose an alternate heat treatment informed by experiments and modelling that removes metastable phases, heals cracks, and reduces time at temperature to prevent significant grain growth. First, we determine crystallization and phase change kinetics by applying the Ozawa-Flynn-Wall and Vyazovkin kinetic methods to differential scanning calorimetry (DSC) data. Next, we track locations and microstructural effects of phase evolution using correlative Raman spectroscopic mapping, scanning electron microscopy (SEM), and X-Ray diffraction (XRD). We interpret the formation of three distinct phases – a major phase of stable β -YbDS, and minor phases of stable χ_2 -YbMS and metastable α -YbDS – within the existing framework of kinetic theory and quantify differences in their transformations between YbDS and Y/YbDS. We find that cracks in the coating heal through the crystallization of the amorphous phase and the transformation of the metastable phase although the mechanisms remain unclear. Each phase transformation causes a bulk volumetric change which we measure using dilatometry and use to calculate delamination stresses during a simulated heat treatment. Lastly, we determine the viability of our heat treatment compared to the industry standard using ablation torch testing.

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