SPATIALLY RESOLVED CHARACTERIZATION OF THERMALLY GROWN OXIDES USING TIME-DOMAIN THERMOREFLECTANCE

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Although the porosity of rare-earth disilicate topcoats is advantageous in reducing the thermal conductivity of a barrier coating, the coatings do not prevent the diffusion of air or water vapor. In the environmental barrier coating system for a SiC turbine blade, a silicon bond coat is often used to adhere the disilicate topcoat to the surface of the blade. Water vapor that diffuses through the disilicate reacts with the bond coat to form silica, forming a barrier between the steam and the turbine blade. As the turbine blade is thermally cycled at high temperatures, the thermally grown oxide layer (TGO) begins to crystalize, forming α-cristobalite. The α-cristobalite expands as it is heated, and then contracts when it is cooled, forming cracks through the TGO and causing the topcoat to spall off. To study the phase evolution from amorphous SiO_2 to cristobalite and its effect on the bondedness of the EBC to the turbine blade, we develop a technique to spatially map thermal conductivity of an EBC system with down to 1um resolution.

Time-domain thermoreflectance is an optical pump-probe technique used to measure thermal properties of nanoscale material systems [1,2]. We use a pulsed “pump” laser beam to provide instantaneous heating to the sample while a lower power “probe” beam simultaneously monitors the resultant heating/cooling curve at the sample surface via temperature dependent changes in reflectivity. We are then able to calculate the thermal conductivity of the sample from the rate of cooling. By adding in a motorized stage to move the sample relative to the beam path, we can scan across the sample to generate 2D maps of thermal conductivity and capture even fine inhomogeneities in the sample, such as grain boundaries. This is technique is then used to characterize crystallization in TGOs as well as to quantify porosity affiliated with delamination. We quantify the extent of devitrification within the TGO over broad length scales (up to 1mm length), as well as in extremely thin TGO layers (~1.5 um thick), and we use the porosity to study bondedness of the topcoat to the turbine blade.

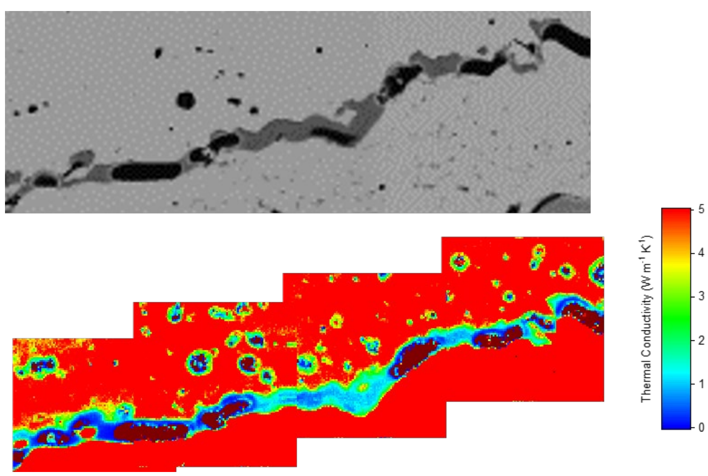

Figure 1. SEM image of a thermally grown oxide layer (above) and its spatially resolved thermal conductivity map (below).

References
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[2] Schmidt, Aaron J., Xiaoyuan Chen, and Gang Chen. "Pulse accumulation, radial heat conduction, and anisotropic thermal conductivity in pump-probe transient thermoreflectance." *Review of Scientific Instruments* 79.11 (2008): 114902.