SUCCESSES, CHALLENGES AND OPPORTUNITIES FOR ENVIRONMENTAL BARRIER COATINGS

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SiC-reinforced ceramic-matrix composites offer a superb combination of properties for both flying and power-generating turbines: they're lightweight, refractory, strong and stiff. However, while SiC/SiC composites exhibit excellent oxidation resistance in dry atmospheres, they are susceptible to water-mediated volatilization in combustion environments. Environmental barrier coatings (EBCs) were designed to protect the silicon-based substrates from water vapor as well as from excessive thermal loading, enabling SiC/SiC composites in the hottest sections of gas turbines.

EBC-protected SiC/SiC composites have now entered large-scale commercial service. Whereas much of our early understanding was based on simulative laboratory testing, we are now able to observe the performance of these coatings in their actual service environment. We're confirming what the current-generation EBCs do well while gaining insights into how they need to be improved for future capability growth.

Because EBCs are part of a complex system, many of the performance and durability challenges manifest at the whole-system level. Rather than reflecting the performance of individual coating layers, the system performance encompasses the interaction between individual coating layers, with the substrate and with the engine environment. Examples of such complex interactions include devitrification of the thermally grown oxide, melting point suppression upon long-term inter-diffusion, loss of hermeticity upon thermomechanical cycling, and thermochemical degradation under dust deposits. Solutions to each degradation mode must consider the entirety of the materials system and the operating mission, assuring that improvements made to each individual distress mode yields a net benefit to the overall system.

Looking to the future, EBCs will be challenged in both predictable and yet-to-be-discovered ways. Designs will continue to demand that coating systems operate hotter and thicker, with outstanding reliability. While there are physical constraints on the extent to which these demands can be realized by the materials community, some key opportunities and approaches for improvement are now becoming clear.

Figure 1 – GE Aviation's CMC Shrouds, with the EBC layer (white) on the flowpath surface.

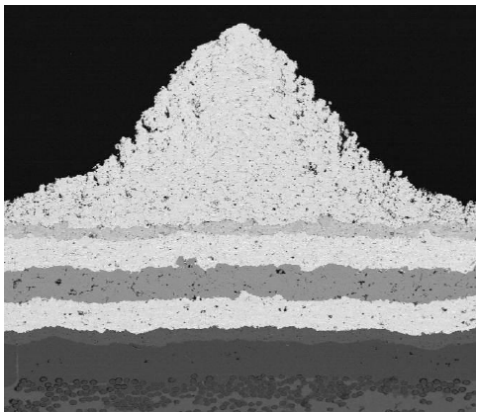

Figure 2 – Cross-section of an EBC-coated, illustrating the complex multilayer architecture of the material system.