



ENERGY

CORROSION PROTECTION COATINGS FOR CERAMIC FIBER COMPOSITE MATERIALS

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Intensive R&D activities in recent years have brought about several high-temperature-stable ceramic fiber composite materials (ceramic matrix composites, CMC), which offer a high potential for structural applications in advanced gas turbines. Besides high-level mechanical properties (strength, damage tolerance), they boast a high oxidation stability thanks to the formation of a protecting layer on the surface of the CMC. The hot gas path of gas turbines, however, involves corrosion processes which destroy the layer that is meant to act as an oxygen diffusion barrier. Consequently, oxidation processes were observed, caused by the free admission of O_2 and H_2O , leading to material degradation inside the CMC.

Environmental barrier coatings (EBC) may be helpful in slowing these processes down significantly. Typical current EBC systems with good functionality consist of a bond coat from silicon, and a corrosion-resistant topcoat, such as BSAS, rare-earth silicates, YAG or ZrO_2 and HfO_2 compounds. Si bond coats are particularly suitable since their thermal coefficient of expansion is comparable to that of the CMC. The Si layer additionally acts as an effective diffusion barrier against O_2 and H_2O penetrating into the ceramic fiber composite material. Nevertheless, the diffusion of O_2 and H_2O into the CMC down into the Si bond coat was found to be a major reason for failure in long-term application. As the result of this diffusion, oxidation processes were observed at the Si layer/topcoat interface. A SiO_2 layer was formed (thermal-grown oxide, TGO), which corroded in hot-gas environments. The associated material loss led to the formation of a gap, which resulted in the flaking of the EBC system with continued use. In order to prevent the formation of the TGO layer and thus improve the lifetime of the EBC sys-

tem, modifications were made to the layer structure. An Al_2O_3 bond coat was used instead of a Si layer. The diffusion processes took place up to the CMC surface. Part of the SiO_2 formed by oxidation at the CMC/ Al_2O_3 interface reacted with the Al_2O_3 in the volume of the bond coat, producing phases similar to mullite ($Al_2O_3-SiO_2$). As a result, this mullite-bound SiO_2 was no longer available for TGO formation. A complete shift of the oxidation process into the Al_2O_3 volume, and thus the suppression of the TGO formation, was achieved through the additional incorporation of non-oxidic particles into the bond coat layer. In the case of stored Si and SiC particles, however, corrosion processes were observed in the hot gas. An SiO_2 margin was formed through oxidation around the Si and SiC particles, which corroded in the hot gas and made the bond coat porous at these points. In contrast to this, TiCN particles and their oxidation products TiO_2 and SE titanates were found to be significantly more stable in hot gas. As a result of the layer modifications described above, it was possible to specifically influence the degradation processes taking place in the hot gas and thus to improve markedly the service life behavior of the entire EBC system.

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- 1 *Typical damage mechanism of an EBC in a hot gas environment due to gap formation.*
- 2 *Layer composition of Al_2O_3 bond coat with TiCN particles after oxidation (1200 °C, 100 h).*

