DEVELOPMENT OF CMAS RESISTANT THERMAL BARRIER COATINGS: CHALLENGES AND IMPLICATIONS

Ravisankar Naraparaju, German Aerospace Center (DLR), Cologne, Germany
Ravisankar.naraparaju@dlr.de
C. Mikulla, DLR, Cologne, Germany
L. Steinberg, TUD, Dresden, Germany
Peter Mechnich, DLR, Cologne, Germany
Uwe Schulz, DLR, Cologne, Germany
Z. Stein, UCF, Orlando, USA
S. Raghavan, UCF,Orlando, USA
L. Tetard, UCF, Orlando, USA

Keywords: CMAS, EB-PVD, TBCs, erosion and 3D Raman confocal microscopy.

Thermochemical attack of ingested CaO-MgO-Al_2O_3-SiO_2 (CMAS) particles in thermal-barrier coatings (TBCs) has been an issue of concern for operating aero-engines in dust-laden environments. The degradation by CMAS attack can be lifetime-limiting and will change the properties of the TBCs, such as thermal conductivity and Young's modulus. Novel TBCs such as GZO and 65YZ have been proven to restrict the CMAS infiltration effectively. Even though 7YSZ is vulnerable to the CMAS attack, its superior mechanical properties, such as high toughness and low Young's modulus, make them still the state-of-the-art material, especially in terms of erosion resistance. Hence, it is essential to know the combined influence of erosion and corrosion attack of novel TBCs that form reaction products that restrict CMAS infiltration. The current work focuses on a deeper understanding of the erosion behavior of CMAS-infiltrated EB-PVD $Gd_2Zr_2O_7$ and 65YZ TBCs. The influence of different reaction products such as apatite, garnet, and spinel within the reaction layer on erosion failure was investigated more closely by measuring the hardness and Young's modulus of the individual phases using in situ REM-Nanoindentation. Furthermore, a correlation between the erosion behavior and the factor hardness vs. Young's modulus is drawn and presented. Having understood the weaknesses of GZO and 65YZ in CMAS and Erosion resistance, novel $(Gd_x,Y_{1-x})_2Zr_2O_7$ solid solution TBCs were developed using the EB-PVD jumping beam approach, and its corresponding CMAS infiltration behavior at high temperature is presented.

The second half of this work presents the development of non-destructive evaluation of degraded TBCs due to the CMAS attack. Using 3D confocal Raman spectroscopy, the extent of local thermochemical degradation was identified by mapping the monoclinic phase volume fraction (mPVF) throughout a standard EB-PVD 7YSZ TBC coating. The mPVF was characterized as a function of depth and infiltration time with microscale resolution. Phase transformation from t' into the monoclinic due to the CMAS attack causes a detrimental volumetric expansion which introduces additional residual stresses. The Raman peak shift was used to evaluate the evolution of residual stresses within the infiltrated 7YSZ coating. This ability to quantitatively and non-destructively characterize the local degradation of CMAS infiltrated TBCs in 3D resolution will accelerate the development of degradation-resistant coatings.