NON-DESTRUCTIVELY CAPTURING CMAS DEGRADATION OF EB-PVD THERMAL BARRIER COATINGS THROUGH 3D CONFOCAL RAMAN RENDERINGS

Zachary Stein, University of Central Florida (UCF), Orlando, Florida, USA
steinzj@knights.ucf.edu
Ravisankar Naraparaju, German Aerospace Center (DLR), Cologne, Germany
Uwe Schulz, DLR, Cologne, Germany
Laurene Tetard, UCF, Orlando, Florida, USA
Seetha Raghavan, UCF; Orlando, Florida, USA

Key Words: 3D Confocal Raman spectroscopy, CMAS, TBCs, degradation, thermochemical, and thermomechanical

Calcium-magnesium-aluminosilicate (CMAS) compositions of sediment and dust particles become molten during their flight through the combustor section of the engine and deposit on thermal-barrier coatings (TBCs). CMAS then is able to infiltrate into the columnar microstructure of electron-beam physical vapor deposition (EB-PVD) based TBCs through capillary forces. The CMAS melts have been shown to induce both thermochemical and thermomechanical changes as they interact with 7 wt% yttria-stabilized zirconia (7YSZ) coatings. E.g., yttrium is leached out of the coating and into the CMAS, destabilizing the remaining zirconia coating from its tetragonal phase. Detrimental volumetric expansion takes place to occur as the remaining yttrium-lean zirconia can freely transform into a monoclinic zirconia phase upon cooling. Concurrently, additional stresses are generated within the infiltrated coating region as the CMAS solidifies due to the thermal gradient. The summation of the chemically as well as the mechanically-induced stresses onto the overall residual stress state of the coating increases the risk of micro-crack formation, leading to premature coating failure. As such, it is vital to evaluate the residual stresses in order to better elucidate the overall effects of CMAS-related coating degradation. In addition, a separation between the thermochemical and thermomechanical mechanisms influencing CMAS degradation would help to better understand the driving mechanisms dictating failure as CMAS infiltrates and interacts with the coating over time.

This work presents the development of 3D confocal Raman spectroscopy to non-destructively evaluate localized, microscale resolved, coating degradation of standard EB-PVD 7YSZ TBCs due to CMAS attack. The extent of thermochemical degradation was tracked through mapping and quantifying the development of the monoclinic phase, evaluated from a calculation of the monoclinic phase volume fraction (mPVF) base on the representative Raman bands. Thermomechanical degradation was evaluated by mapping residual stresses within the coating, using shifts from of stress-sensitive Raman peaks of the zirconia polymorphs. Both the mPVF and residual stresses were characterized as a function of coating depth and CMAS infiltration time. The dynamic roles and influences over the infiltration time between the chemically-dominated and the mechanically-dominated degradation mechanisms were quantitatively captured throughout the probed depth. The ability to non-destructively characterize these changes within the TBC on a localized coating microstructure level as a result of CMAS infiltration is expected to benefit the development and implementation of CMAS mitigation strategies as well as towards the development of more degradation-resistant coatings.