Thermal barrier coatings (TBCs) are widely used for thermal protection of hot section components in turbines for propulsion and power generation. Development and applications of TBCs based on a clearer understanding of failure mechanisms can help increase the performance and life-cycle cost of advanced gas turbine engines. Development and refinement of robust non-destructive evaluation techniques can also enhance the reliability, availability and maintainability of hot section components in gas turbines engines.

In this work, degradation of TBCs was non-destructively examined by photostimulated luminescence spectroscopy (PSLS) and electrochemical impedance spectroscopy (EIS) as a function of furnace thermal cycling carried out in air with 10-minute heat-up, 0.67, 9.6 and 49.6 -hour dwell duration at 1121°F (2050°C), and 10-minute forced-air quench. TBCs examined in this study consisted of either electron beam physical vapor deposited and air plasma sprayed yttria-stabilized zirconia (YSZ) on a variety of bond coat / superalloy substrates including bond coats of NiCoCrAlY and (Ni,Pt)Al, and superalloys of CMSX-4, René™ N5, Haynes 230 and MAR-M-509. Detailed microstructural characterization by scanning electron microscopy and energy dispersive spectroscopy was carried out to document the degradation and failure characteristics of TBC failure, and correlate results of PSLS and EIS.

Mechanisms of microstructural damage initiation and progression varied as a function of TBC architecture and thermal cycling dwell time, and included undulation of the interface between the thermally grown oxide (TGO) and bond coats, internal oxidation of the bond coats, and formation of Ni/Co-rich TGO. These microstructural observations were correlated to the evolution in compressive residual stress in the TGO scale determined by PSLS shift. Correlations include stress-relief associated with subcritical cracking of the TGO scale and stress-relaxation associated with the undulation of TGO/bondcoat interface (e.g., rumpling and ratcheting). Microstructural changes in TBCs such as YSZ sintering, TGO growth, and subcritical damages within the YSZ and TGO scale were also correlated to the changes in electrochemical resistance and capacitance of the YSZ and TGO, respectively. Further correlations among the microstructural development, PSLS and EIS are documented and discussed, particularly as a function of dwell time used during furnace thermal cycling test, with due respect for changes in failure characteristics and mechanisms for various types of TBCs.