A detailed understanding of failure mechanisms in thermal barrier coatings (TBCs) can help develop reliable and durable TBCs for advanced gas turbine engines. One of the characteristics of failure in electron beam physical vapor deposited (EB-PVD) TBCs is the development of instability, named rumpling, at the interface between (Ni, Pt)Al bond coat and thermally grown oxide (TGO). In this study, thermal cycling at 1100°C with 1 hr dwell time was carried out on 25.4mm disc specimens of TBCs that consisted of EB-PVD coated ZrO2-7wt. %Y2O3, (Pt,Ni)Al bond coat, and CMSX-4 Ni-based superalloy. At specific fraction of lifetime, TBCs were examined by electron microscopy and photostimulated luminescence (PL). Changes in the average compressive residual stress of the TGO determined by PL and the magnitude of rumpling, determined by tortuosity from quantitative microstructural analyses, were examined with respect to the furnace thermal cyclic lifetime and microstructural evolution of TBCs. The combination of elastic strain energy within the TGO and interfacial energy at the interface between the TGO and the bond coat was defined as the TGO energy, and its variation with cyclic oxidation time was found to remain approximately constant ~135J/m² during thermal cycling from 10% to 80% thermal cyclic lifetime. Parametric study at ~135J/m² was performed and variation in residual stress with rumpling for different oxide scale thicknesses was examined. This study showed that the contribution of rumpling in residual stress relaxation decreased with an increase in TGO thickness.

High pressure turbine blades serviced for 2843 hours and in the as coated form were also examined using electron microscopy and photostimulated luminescence. The difference in residual stress values obtained using PL on the suction and pressure sides of as-coated turbine blade were discussed. The presence of a thick layer of deposit on the serviced blade gave signals from stress free Al2O3 in the deposit, not from the TGO. The TGO growth constant data from the disc-shape TBCs, thermally cycled at 1100°C, and studies by other authors at different temperatures but on similar EB-PVD coated TBCs with (Pt, Ni)Al bond coat and CMSX-4 Ni-based superalloy were used to determine the temperature profile at the YSZ/bond coat interface. The interfacial temperature profiles of the serviced blade and the YSZ thickness profile were compared to document the variable temperature exposure at the leading edge, trailing edge, suction and the pressure side.