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An Analytical Model of Oxide Rumpling as the Mechanism Leading to Failure in Thermal Barrier Coatings

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Thermal barrier coatings are deposited on superalloy turbine blades to protect them from engine temperatures in excess of 1000C. Failure of these multi-layer coatings is known to involve undulations that develop in the oxide layer, between the ceramic top-coat and the metallic bond-coat. At temperatures above 600C, the bond-coat creeps readily under stress. Thermal mismatch with the superalloy substrate and, for PtNiAl bond-coats, a reversible phase transformation accompanied by a change in volume, give rise to a large equi-biaxial stress in the bond-coat that dramatically reduces its ability to resist transverse deformation at elevated temperatures. The nonlinear interaction between the stress in the bond-coat and the tractions applied at the surface of the bond-coat by the compressed, undulating oxide film allows an increment of undulation growth to occur each thermal cycle. An analysis of oxide rumpling and the resultant cracking in the top-coat that leads to failure will be presented.

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