Microstructural Effects in the Fracture Toughness of Thermal Barrier Coatings

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The cyclic durability of thermal barrier coatings (TBCs) based on yttria-stabilized zirconia (YSZ) is greatest for compositions in the metastable tetragonal (t') phase field, with the maximum occurring at ~7-8mol%$YO_{1.5}$ (7-8YSZ). This trend in durability has been ascribed to a relationship between toughness and tetragonality, enabled by ferroelastic domain switching. The baseline toughness of dense t'-YSZ measured by microindentation is ~40±5Jm^{-2}. However, the Mode I toughness of free-standing Atmospheric Plasma Spray (APS) Dense, Vertically Cracked (DVC) TBCs measured by a double cantilever beam (DCB) test configuration is found to be about an order of magnitude higher, $\Gamma \approx 450 Jm^{-2}$. The test geometry has been properly analyzed using FEM analysis and validated with tests on materials with well-known toughness, e.g. poly-methyl-methacrylate (Plexiglas) providing confidence on the methodology. The unexpectedly high toughness reveals important effects of microstructure on the fracture behavior. The proposed mechanisms involve crack bridging by the DVC "columns" and frictional dissipation upon their eventual fracture and pull-out. Evidence suggestive of ferroelastic switching has also been observed; the potential interplay with the bridging/pull-out mechanism is discussed.