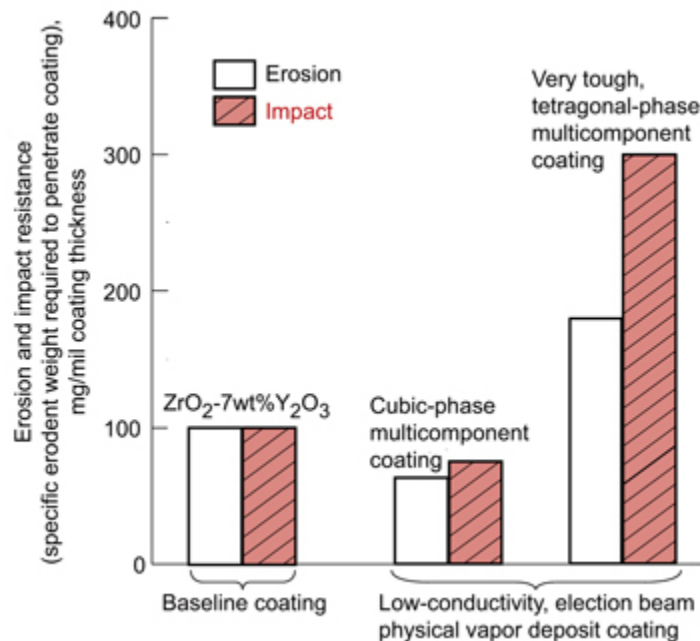


Very Tough, Erosion-Resistant Turbine Airfoil Thermal Barrier Coatings Developed

Ceramic thermal barrier coatings (TBCs) are receiving increased attention for advanced gas turbine engine applications. These coatings are considered to be technologically important because of their ability to further increase engine operating temperatures and reduce cooling requirements, thus achieving higher engine efficiency, lower emissions, and increased performance goals. To take full advantage of the capabilities of these coatings, researchers need to use an aggressive design approach whenever possible--one that allows greater temperature reductions through the coating systems and less cooling air to the components.

Advanced TBCs that have significantly lower thermal conductivity and better thermal stability than current coatings have been developed for future ultra-efficient, low-emission engine systems (refs. 1 and 2). Multicomponent-doped, defect-clustered TBCs have been shown to offer the low conductivity and high stability required for future high-temperature engine applications (refs. 1 and 2).



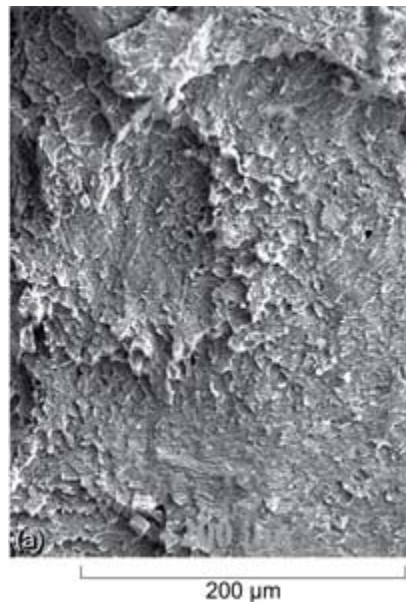
Erosion and impact testing results of a multicomponent, partially stabilized, nontransformable tetragonal t' coating ZrO₂-(Y,Gd,Yb)₂O₃ coating system, showing improved performance in comparison to the baseline ZrO₂-7wt%Y₂O₃ and cubic-phased low-conductivity coatings.

Long description of figure 1. Bar chart of erosion and impact resistance (specific erodent weight required to penetrate coating in milligrams per mil coating thickness for baseline coating (ZrO₂-7wt%Y₂O₃) and low-

conductivity, electron beam physical vapor deposit coatings (cubic-phase multicomponent coating and very tough tetragonal-phase multicomponent coating).

For TBCs designed for turbine airfoil applications, good erosion and impact resistance, in addition to low thermal conductivity and high stability, are crucial in order to effectively protect the components under high heat flux, high velocity flow, and particulate erosion and impact conditions. In this study at the NASA Glenn Research Center, advanced low-conductivity coatings, possessing the partially stabilized nontransformable tetragonal t' structure, were designed and optimized for high erosion and impact performance. The NASA Ultra-Efficient Engine Technology (UEET) Project low-conductivity coating systems were processed by electron-beam physical-vapor-deposit techniques at GE Aircraft Engines (Cincinnati, OH) and Howmet Coatings Corporation (Whitehall, MI) using prefabricated evaporation ingots that were made of the carefully designed compositions.

Considerable thermal conductivity reductions were observed in comparison to the state-of-the-art baseline ZrO_2 -7wt% Y_2O_3 coatings after high-temperature sintering for the multicomponent, partially stabilized nontransformable tetragonal t coating systems (ref. 3). The 2200 °F burner rig erosion and impact testing results indicated that the composition optimizations significantly improved the toughness and erosion/impact resistance of the low-conductivity coating systems.



Thermal barrier coating showing very tough impacting fracture surface after 1200-cycle burner rig impact testing at 2200 °F. (a) Surface morphologies. (b) Cross-section micrograph.

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