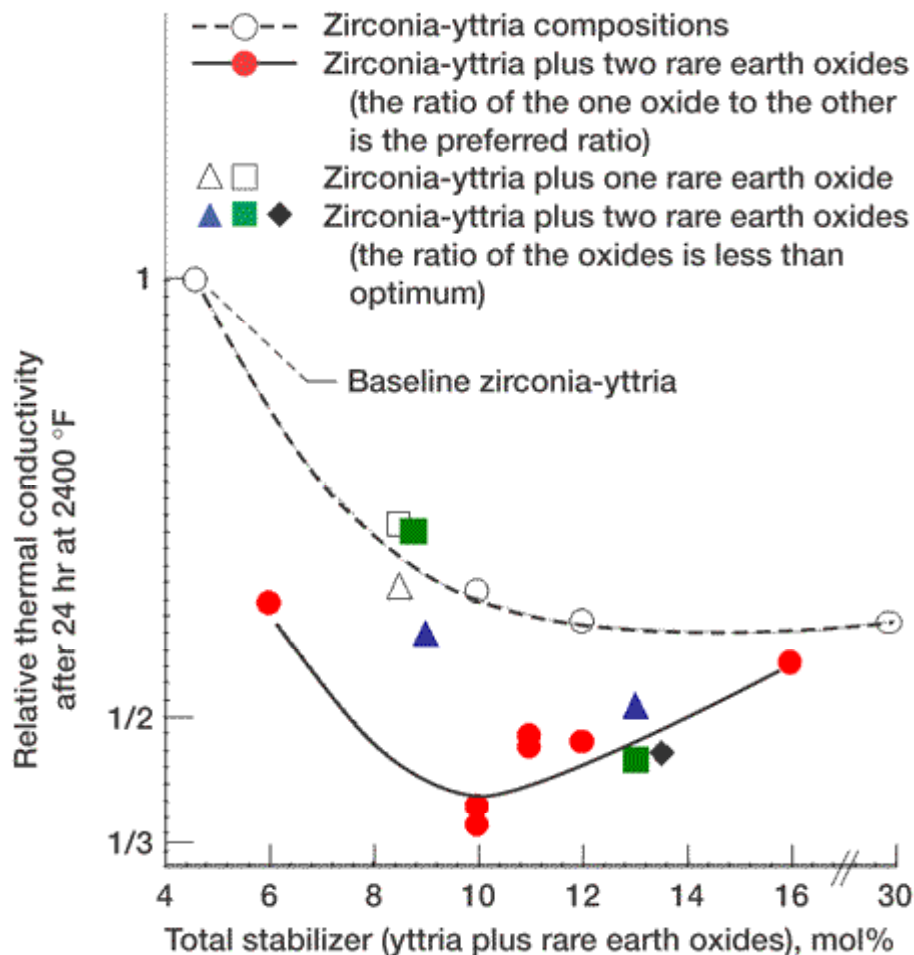


Low Thermal Conductivity Thermal Barrier Coatings Developed



Thermal conductivity, k , after 20 hr of exposure in the laser rig test. The plot shows an approximately 40-percent reduction in the thermal conductivity of the preferred compositions, which are represented by the solid circles.

Long description Data are shown for zirconia-yttria compositions, zirconia-yttria plus two rare earth oxides (the ratio of the one oxide to the other is the preferred ratio), zirconia-yttria plus two rare earth oxides (the ratio of the oxides is less than optimum), and baseline zirconia-yttria.

Thermal barrier coatings (TBCs) are used extensively in modern gas turbine engines to thermally insulate air-cooled metallic components from the hot gases in the engine. These coatings typically consist of a zirconia-yttria ceramic that has been applied by either plasma spraying or physical vapor deposition. Future engines will rely even more heavily on TBCs and will require materials that have even higher temperature capability with

improved insulation (i.e., lower thermal conductivity even after many hours at high temperature). This report discusses new TBCs that have been developed with these future requirements in mind. The Ultra-Efficient Engine Technology Program at the NASA Glenn Research Center is funding this effort, which has been conducted primarily at Glenn with contractor support (GE and Howmet) for physical vapor deposition.

As stated, the new TBC not only had to be more insulating but the insulation had to persist even after many hours of exposure—that is, the new TBC had to have both lower conductivity and improved sintering resistance. A new type of test rig was developed for this task. This new test approach used a laser to deliver a known high heat flux in an essentially uniform pattern to the surface of the coating, thereby establishing a realistic thermal gradient across its thickness. This gradient was determined from surface and backside pyrometry; and since the heat flux and coating thickness are known, this permitted continuous monitoring of thermal conductivity. Thus, this laser rig allowed very efficient screening of candidate low-conductivity, sinter-resistant TBCs.

The coating-design approach selected for these new low-conductivity TBCs was to identify oxide dopants that had the potential to promote the formation of relatively large and stable groupings of defects known as defect clusters. This approach was used because it was felt that such clusters would reduce conductivity while enhancing stability. The approach proved to be successful: low-conductivity TBCs having improved sintering resistance were developed. The figure illustrates the improvement achieved for plasma-sprayed TBCs. In this graph, the mean thermal conductivity of the TBC after 20 hr of exposure in the laser rig at high temperature is plotted versus the mole percent of the oxides that were added to the zirconia. The graph shows an expected result: higher levels of stabilizer lead to lower conductivity even in the binary zirconia-yttria system. The graph also appears to indicate that the conductivity of ternary oxide systems may also more-or-less follow the curve for the binaries.

However, the greatest improvement was observed with certain, somewhat more complex systems—especially those points, indicated by the solid circles, that had been selected according to a certain "recipe." For this particular set of data, the conductivity of the new material after 20 hr at a high surface temperature was about 40 percent of the zirconia-yttria baseline. Furthermore, higher temperatures and longer times have actually increased the relative reduction further.

Thus, these new low-conductivity coatings have successfully met the initial programmatic milestones, and although more work is required, they have demonstrated their potential to improve performance significantly in the demanding applications envisioned for future advanced gas turbine engines.

Bibliography

Zhu, Dongming; and Miller, Robert A.: Thermal Conductivity and Sintering Behavior of Advanced Thermal Barrier Coatings. NASA/TM--2002-211481, 2002.

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