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Thermal Conductivity and Water Vapor Stability of HfO_2-BASED Ceramic Coating Materials

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HfO_2-Y_2O_3 and $La_2Zr_2O_7$ are candidate thermal/environmental barrier coating materials for gas turbine ceramic matrix composite (CMC) combustor liner applications because of their relatively low thermal conductivity and high temperature capability. In this paper, thermal conductivity and high temperature phase stability of plasma-sprayed coatings and/or hot-pressed HfO_2-5mol%Y_2O_3, HfO_2-15mol%Y_2O_3 and $La_2Zr_2O_7$ were evaluated at temperatures up to 1700°C using a steady-state laser heat-flux technique. Sintering behavior of the plasma-sprayed coatings was determined by monitoring the thermal conductivity increases during a 20-hour test period at various temperatures. Durability and failure mechanisms of the HfO_2-Y_2O_3 and $La_2Zr_2O_7$ coatings on mullite/SiC Hexoloy or CMC substrates were investigated at 1650°C under thermal gradient cyclic conditions. Coating design and testing issues for the 1650°C thermal/environmental barrier coating applications will also be discussed.

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Advanced copy has been sent to Diane Chapman
Thanks Dongming

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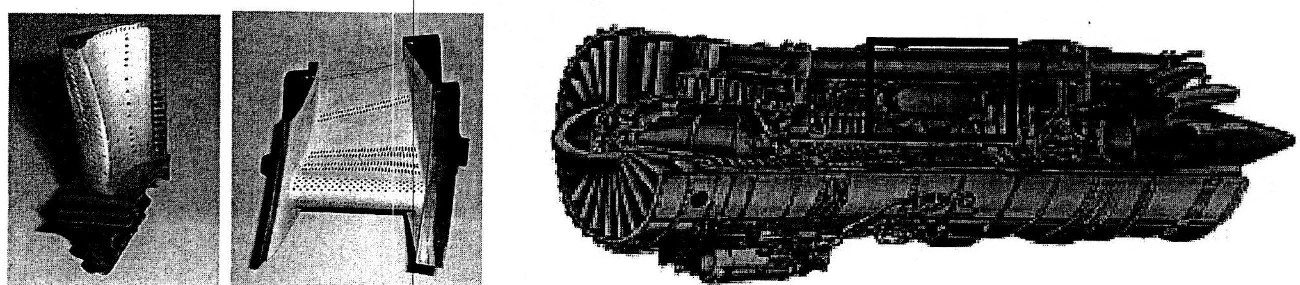
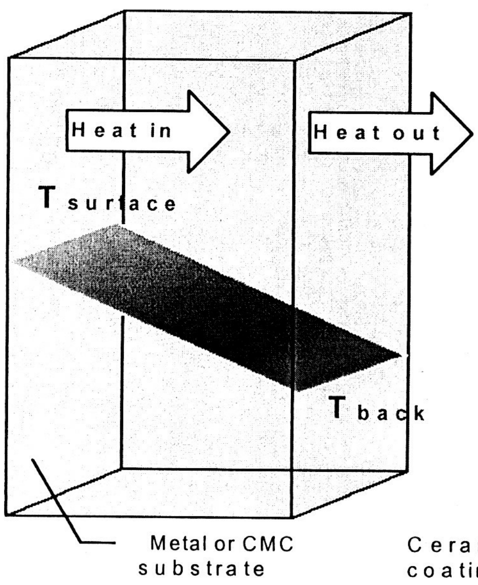
Abstract

HfO_2-based oxides are important thermal/environmental barrier coating materials for 3000°F ceramic matrix composite (CMC) applications. In this paper, thermal conductivity and high temperature stability of hot-pressed HfO_2-based disk specimens and plasma-sprayed coatings were evaluated at temperatures up to 1700°C using a steady-state laser heat-flux technique. Sintering behavior of the plasma-sprayed coatings was determined by monitoring the thermal conductivity changes under steady-state heat flux testing. Durability and failure mechanisms of the HfO_2-Y_2O_3 coatings on mullite/SiC hexoloy or CMC substrates were investigated at 1650°C under thermal gradient cyclic conditions.

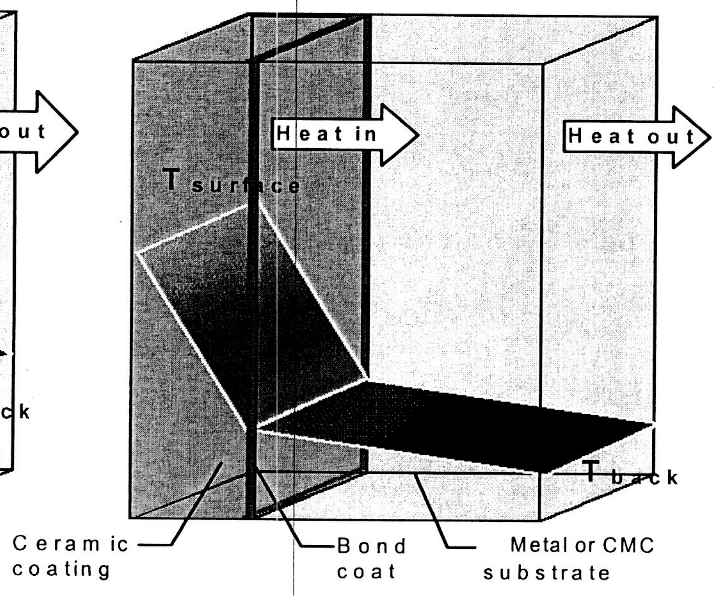
Thermal and Environmental Barrier Coatings (T/EBCs) are Critical to Future Advanced Gas Turbine Engine Systems

- Advanced T/EBCs can increase engine temperatures, reduce cooling, lower emission, and improve engine efficiency and reliability
- Low thermal conductivity and long-term high temperature stability are important issues for developing advanced coating systems

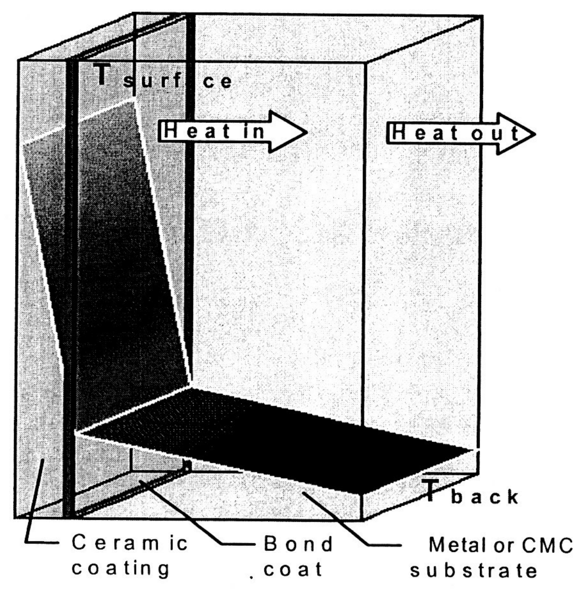




(a) without T/EBC



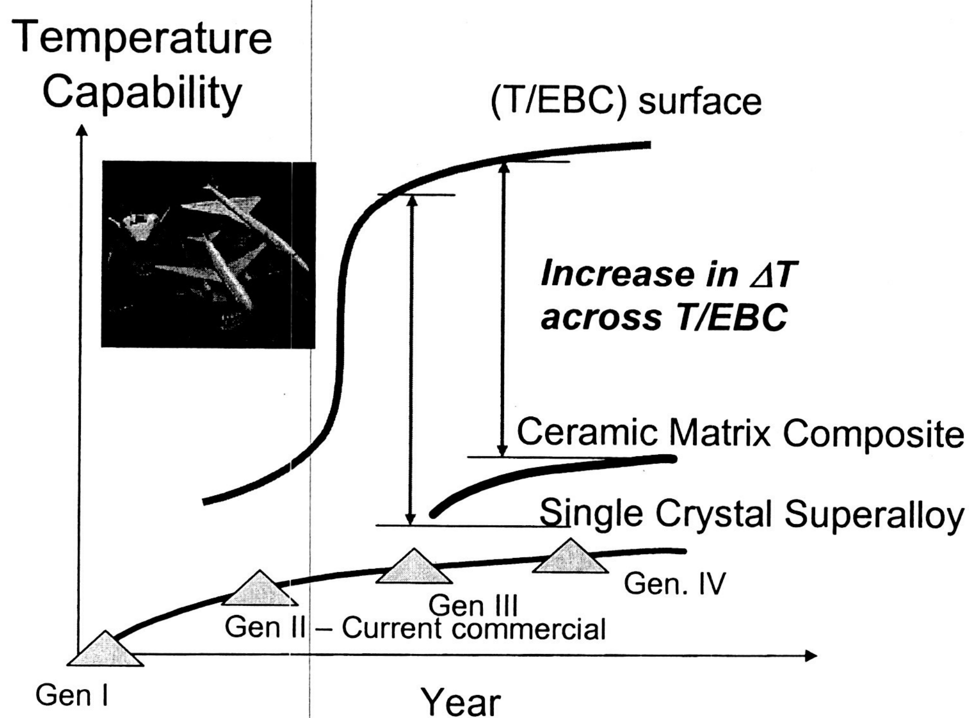
(b) with a T/EBC system

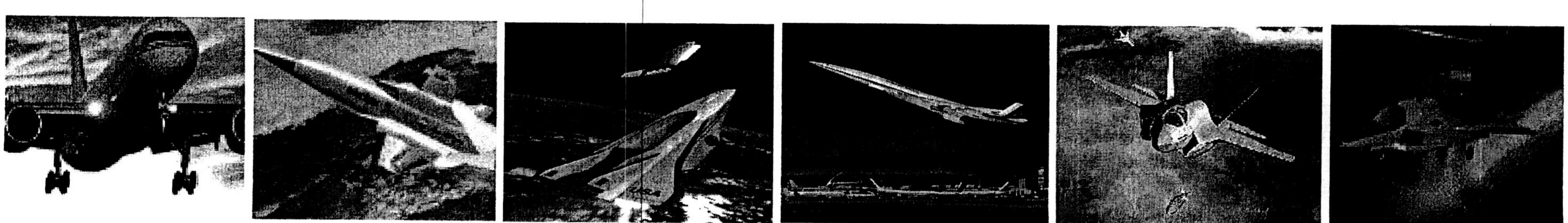


(c) with an advanced T/EBC

Temperature Reductions by Ceramic Coatings will Increase for Future Advanced Low Emission and High Performance Engine Applications

- Advances in coatings technology will increase blade, vane and combustor temperature capability, help to achieve engine emission, efficiency and performance goals





Objectives

- **Thermal conductivity and sintering behavior of HfO_2-Y_2O_3 based coating materials as compared to other baseline materials**
  - Hot-pressed specimens and plasma-sprayed coatings
- **Water vapor stability of HfO_2-Y_2O_3 oxides at temperatures up to 1650°C (3000°F)**
- **The cyclic durability of HfO_2-Y_2O_3 coating systems at 1650°C (3000°F)**

Experimental

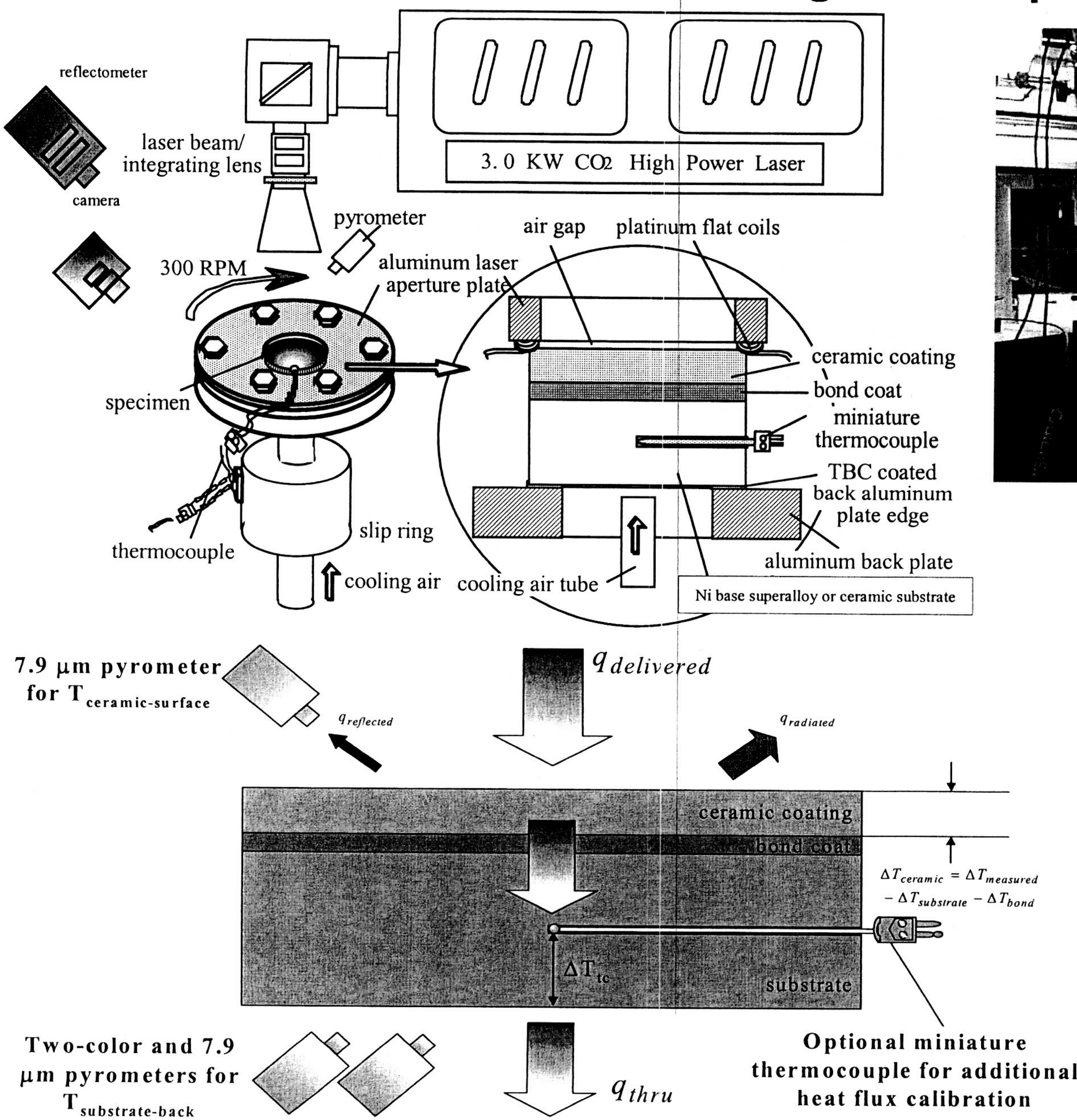
— **The coating systems include:**
- HfO_2-Y_2O_3 with 5, 10, 15, 20, or 25 mol% Yttria
- advanced multi-component HfO_2 also investigated

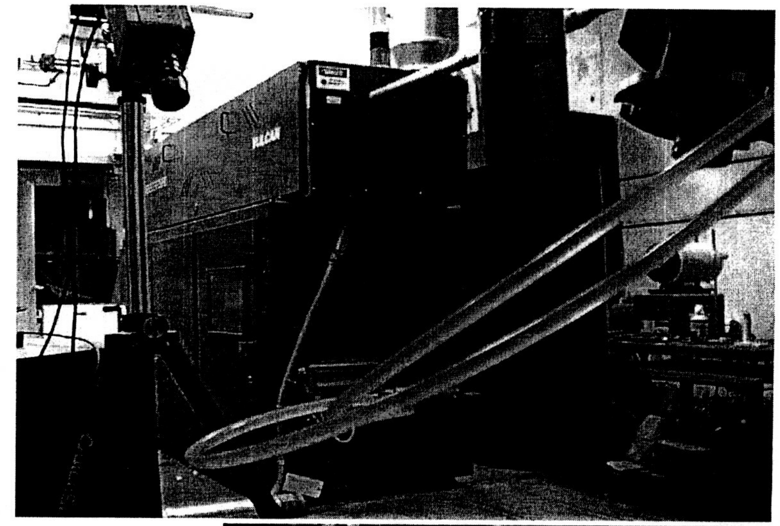
— **Test specimens were either hot-pressed disks (25.4 mm diameter, 3-4 mm thick) , or plasma-sprayed coatings, coated on mullite/Si/SiC hexoloy or MI SiC/SiC ceramic matrix composite**

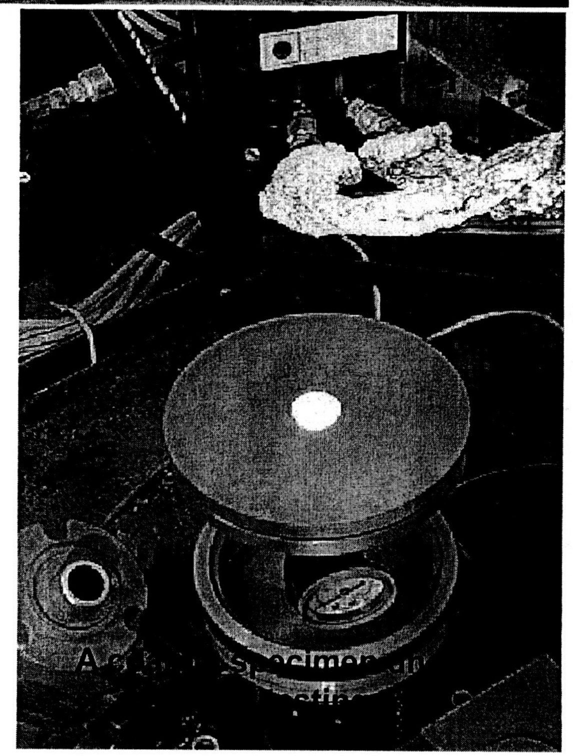
— **Water vapor determined by TGA and laser steam chamber**

— **Thermal conductivity and cyclic durability determined by a laser heat-flux technique for the coating systems on SiC hexoloy and CMCs**

Laser High-Heat-Flux Approach for Advanced Thermal/ Environmental Barrier Coatings Development

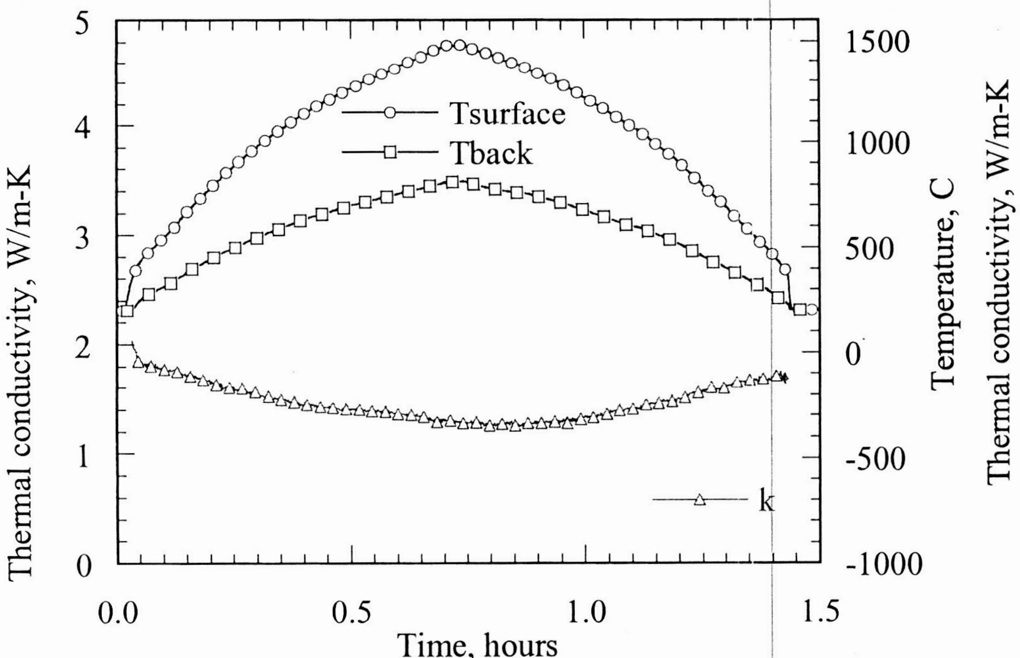


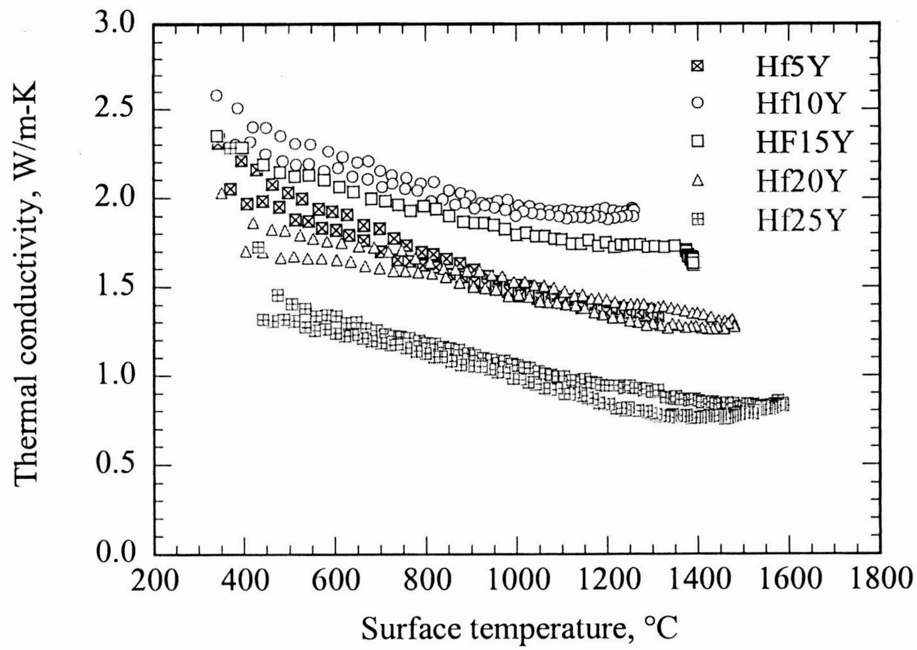




Thermal Conductivity Measurements of Hot-Pressed HfO_2-Y_2O_3 Coatings

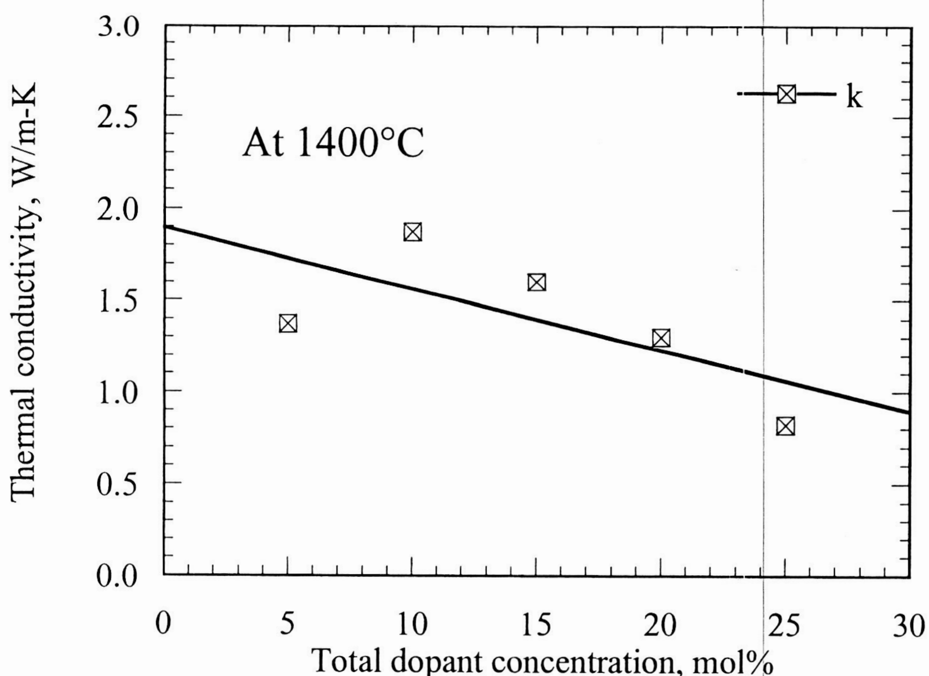
— Temperature dependence can be determined using the laser heat-flux test approach

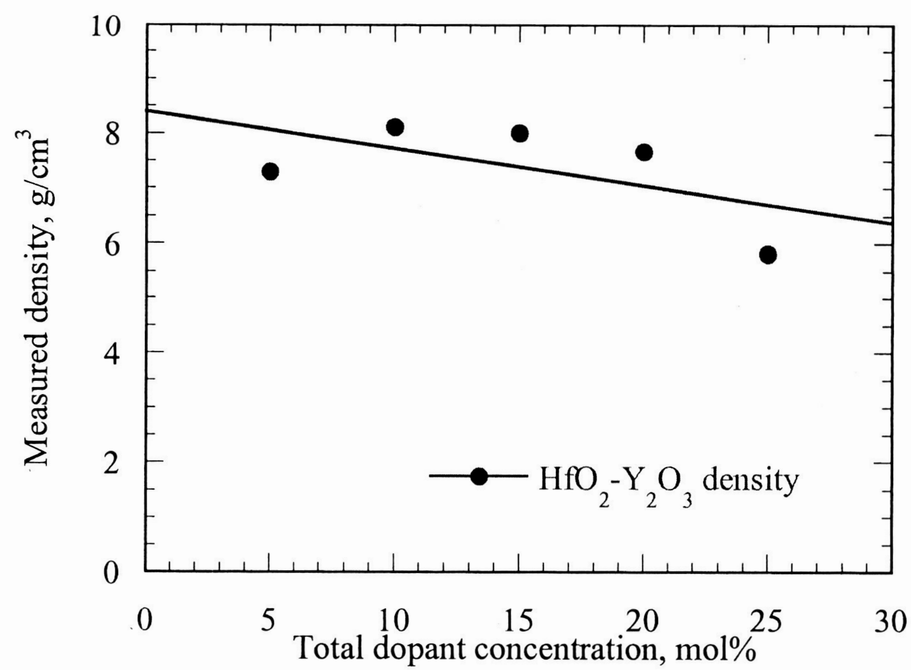




Thermal Conductivity of Hot-Pressed HfO_2-Y_2O_3 Coatings

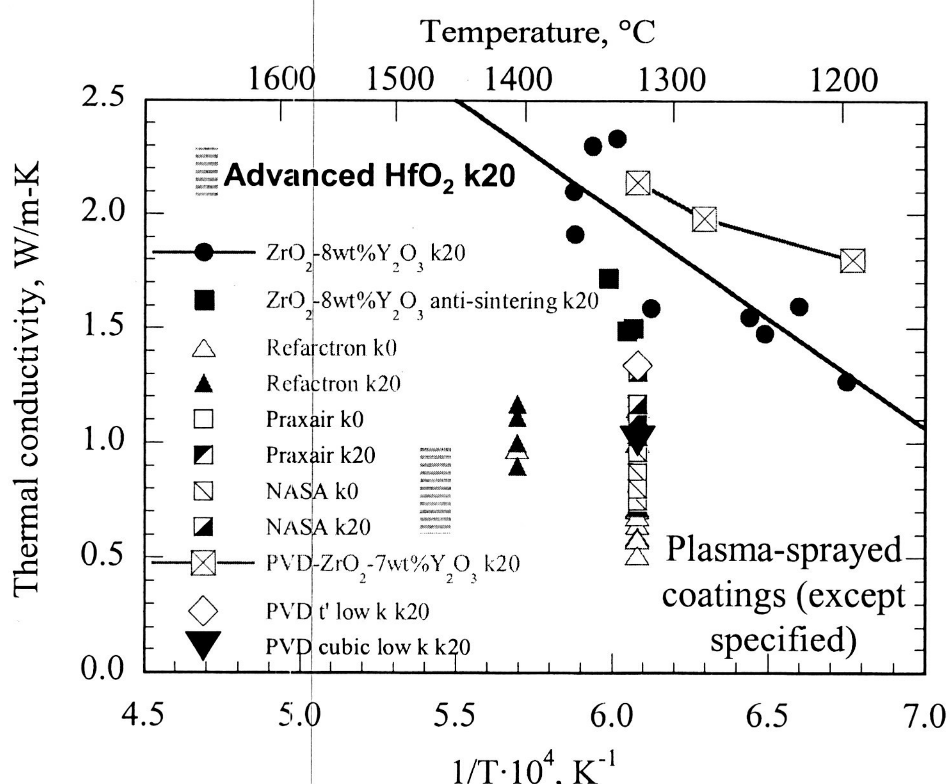
— Thermal conductivity decreases with increasing yttria dopant concentration
— Porosity in the hot-pressed specimens can affect the conductivity measurements





Thermal Conductivity and Sintering Behavior of Plasma-Sprayed HfO_2-Y_2O_3 Coatings Compared with other Coating Materials

— HfO_2 coatings showed low thermal conductivity and excellent high temperature stability

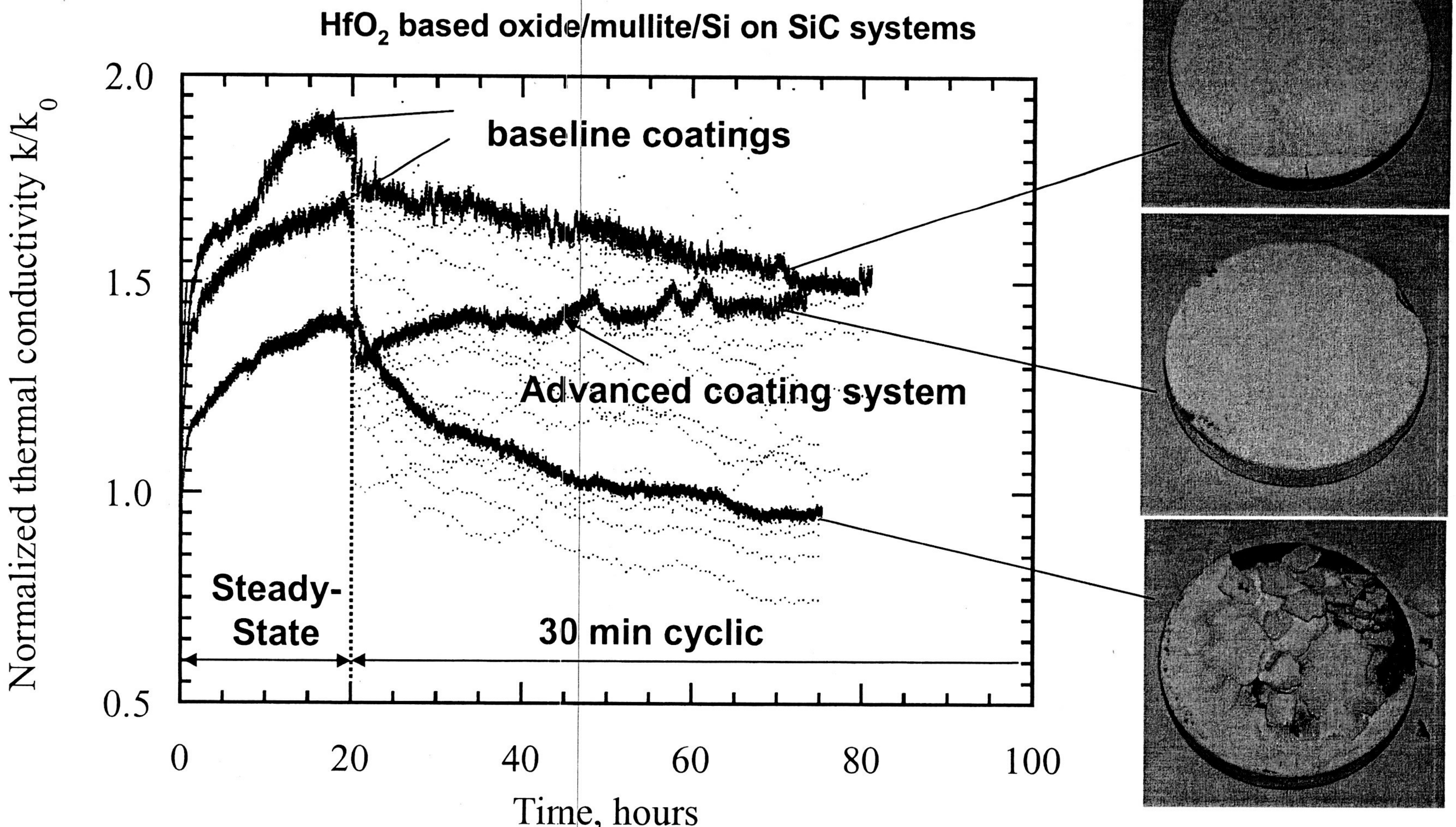


Advanced Coatings Development

Sintering and Cyclic Response of Advanced HfO_2 Coating Systems on SiC Substrate Tested at 3000°F

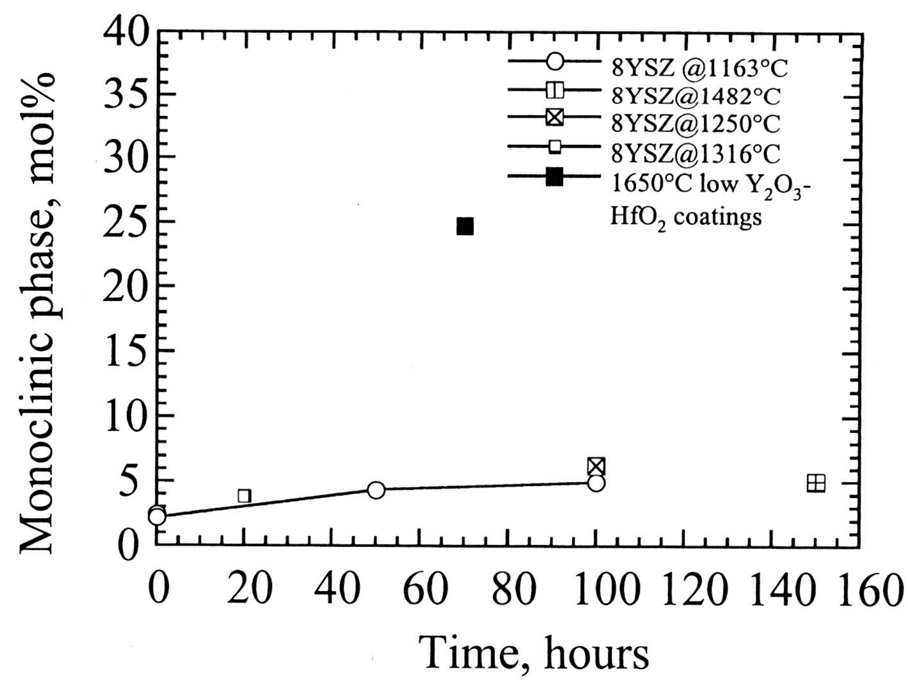
— Initial 20 hr sintering testing and then thermal cyclic testing at 3000°F

— The advanced HfO_2 coating system showed excellent performance



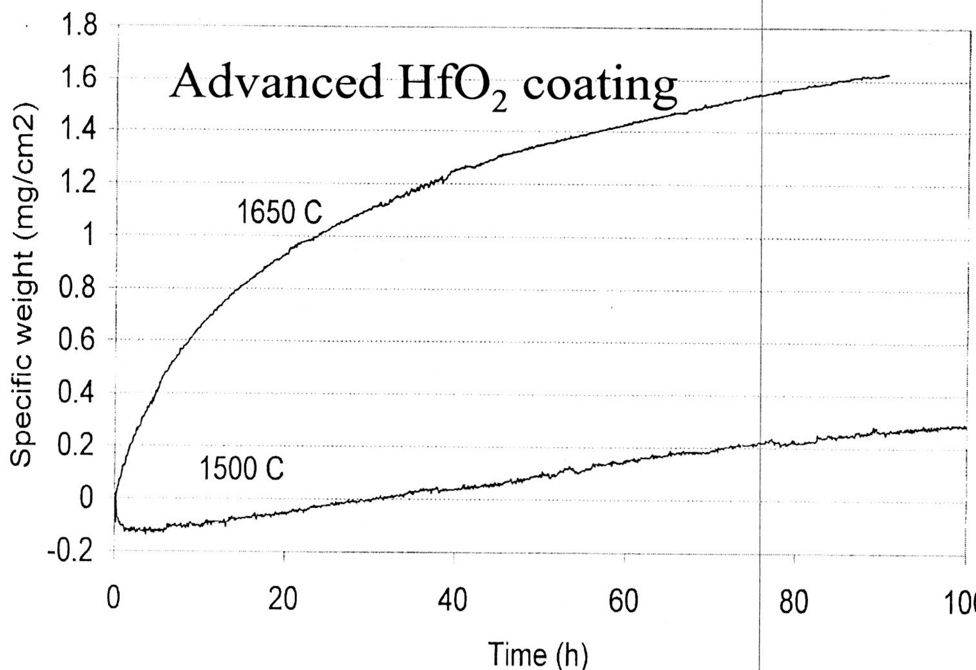
Low Yttria-Hafnia Baseline Showed Severe Cracking and Spalling after Testing at 3000°F

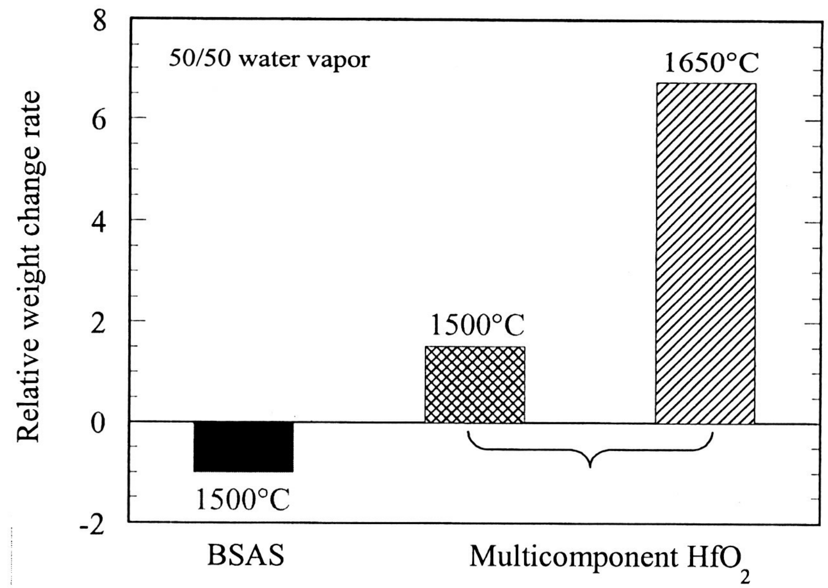
— Sintering, high temperature phase stability along with the CTE mismatch stress are the major causes for the low yttria dopant HfO_2 coating's failure



Water Vapor Stability of Advanced HfO_2 coatings

— **Advanced HfO_2 coatings showed excellent water vapor stability at high temperature**





Concluding Remarks

- Thermal gradient sintering and cyclic durability test approach is demonstrated for advanced 3000F (1650°C) T/EBC coatings development

- Phase stability, and sintering and thermal stress resistance are crucial for coating 3000°F durability

- HfO_2-Y_2O_3 are promising coating materials due to low thermal conductivity, good sintering resistance, and excellent water vapor stability

Acknowledgements

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