EMBEDDED OPTICAL SENSORS FOR THERMAL BARRIER COATINGS

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OBJECTIVES

The overall objective of our program has been to develop a class of prototype optical sensing systems for monitoring thermal barrier coatings based on the luminescence properties of dopants incorporated into the crystal structure of the coating materials themselves. The approach is fundamentally different from the conventional thermographic phosphor approach in which a phosphor material is applied to a coating or surface. A further objective has been the testing and demonstration of different types of thermal barrier coating sensors for assessing damage, wear and temperature. Integral to the overall objective is the demonstration of a combined optical and electronic system incorporating the embedded sensors.

ACCOMPLISHMENTS TO DATE

During the course of this grant, we have identified a number of rare-earth dopant ions that can substitute into the crystal structure of yttria-stabilized zirconia (YSZ), the current material of choice for thermal barrier coatings, and the pyrochlore zirconates, an alternative coating material, without destabilizing these materials. Each of the rare-earth ions produces strong luminescence when excited with a laser beam of the appropriate wavelength. For *in-situ* sensing of temperature, the preferred rare-earth dopant has proven to be the Eu^{3+} ion. We have demonstrated that measurements of the luminescence lifetime of the 606 nm Eu-luminescence are a viable method of measuring temperatures of thermal barrier coatings and the gadolinium zirconate materials. Systematic studies have been carried out on the effect of dopant concentration on luminescence intensity and luminescence lifetime. Furthermore, we have shown that by proper choice of the dopant concentration and of the bandwidth of the luminescence detector system, temperatures of upto 1200°C can be measured, far in excess of previous measurement capabilities using Eu-luminescence.

We have also shown that prolonged high-temperature exposure of Eu-doped YSZ coatings prepared by electron beam deposition, one of the standard means of producing thermal barrier coatings, does not affect either the luminescence characteristics or the life of the coatings. Even after exposing the coatings to 1425°C, a much higher temperature than current turbine blades are exposed to, for 200 hours, and also converting more than

half the coatings to the monoclinic phase, there is no change in the luminescence spectra except in the fine structure, and it doesn't affect the use of the lifetime method to measure temperature. Although a statistically significant number of coatings containing dopants have not yet been thermally cycled to failure, those that do have exceeded the average life on cycling to 1150°C, suggesting that the incorporation of the dopants have not adversely affected the coating life.

Paralleling the materials development and testing aspects, we have also assembled a sensor system that includes solid-state laser excitation, a sapphire fiber optic light pick-up, a fiber-optic signal communication and spectral filtering system, and photomultiplier detector, all under computer control through USB connectors. The components are portable and have been used in luminescence-temperature evaluation tests at NASA Glenn.

Wear and damage sensing using the multiple luminescence dopants in zirconia coatings have also been demonstrated as part of the research performed under this grant. Publications describing the work are presently in preparation.

FUTURE WORK

Now that we have demonstrated that the luminescence spectra are unchanged after prolonged high temperature exposure and even conversion to half of the coatings to the monoclinic phase (both far more extreme than current coatings are subject to) the focus of the research in the remaining months of the contract will be on (i) the demonstration of an LED based optic-fiber luminescence detector system, and (ii) the investigation of plasma-sprayed coatings under combustor-type environments.

LIST OF PAPERS and CONFERENCE PRESENTATIONS

1. "Luminescence Sensing of Temperature in Pyrochlore Zirconate Materials for Thermal Barrier Coatings", M. M. Gentleman and D. R. Clarke, Surface and Coatings technology, submitted. (Also, presented at the International Conference on Metallurgical Coatings and Thin Films, San Diego)
2. "Effect of Long Term, High Temperature Aging on Luminescence from Eu-doped YSZ Thermal Barrier Coatings", M. D. Chambers and D. R. Clarke, Surface and Coatings technology, submitted. (Also, presented at the International Conference on Metallurgical Coatings and Thin Films, San Diego)

PATENTS and AWARDS --- None

STUDENTS PARTIALLY SUPPORTED BY GRANT

Ms. Molly Gentleman, graduate student in Materials, due to obtain her PhD in 2006.
Mr. Matt Chambers, graduate student in Materials.