control, this membrane would be pulled down to maintain a gap of the order of nanometers between the tips of the nanowires and the anode.

The bias potential would be applied to the anode and the temperature of the array (the cathode) would be measured by the thermistor. Because of the thermionic reduction of temperature is expected to be small in initial experiments, the sensitivity of measurement of this reduction would be enhanced by use of a lock-in technique in which the bias potential would be modulated and the variation in temperature measured at the modulation frequency.

This work was done by Eui-Hyeok Yang, Daniel Choi, Kirill Shcheglov, and Yoshikazu Hishinuma of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Delamination-Indicating Thermal Barrier Coatings

Luminescent sublayers reveal previously hidden coating damage.

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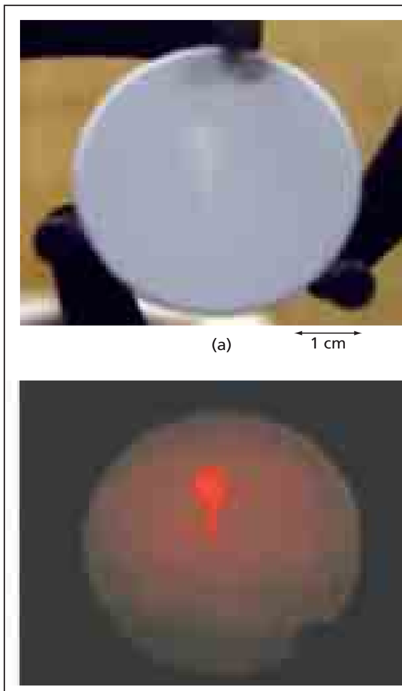
The risk of premature failure of thermal barrier coatings (TBCs), typically composed of yttria-stabilized zirconia (YSZ), compromises the reliability of TBCs used to provide thermal protection for turbine engine components. Unfortunately, TBC delamination proceeds well beneath the TBC surface and cannot be monitored by visible inspection. Nondestructive diagnostic tools that could reliably probe the subsurface damage state of TBCs would alleviate the risk of TBC premature failure by indicating when the TBC needs to be replaced before the level of TBC damage threatens engine performance or safety. To meet this need, a new coating design for thermal barrier coatings (TBCs) that are self-indicating for delamination has been successfully implemented by incorporating a europium-doped luminescent sublayer at the base of a TBC composed of YSZ. The luminescent sublayer has the same YSZ composition as the rest of the TBC except for the addition of low-level europium doping and therefore does not alter TBC performance.

The strategy for producing delamination-indicating TBCs relies on the enhanced luminescence produced by regions of the TBC where subsurface cracks are propagating. This enhanced luminescence is due to a large fraction of the excited luminescence that is incident upon the crack at an angle beyond the angle for total internal reflection. Deposition of 125-μm thick TBCs above a 7-μm thick europium-doped layer was performed in collaboration with Penn State University. These self-indicating TBCs were deposited by multiple-ingot electron-beam physical-vapor deposition without disrupting TBC growth so as not to alter the usual columnar growth that gives these TBCs many of their desirable properties. To demonstrate delamination indication, localized TBC delamination was induced by scratching the coating with a stylus.

While the delaminated region can be faintly discriminated in a standard white-light image [part (a) in the figure], the delaminated region stands out strongly in a luminescence image due to the greatly enhanced red emission originating from that area [part (b) in the figure]. The enhanced luminescence from the europium-doped sublayer was caused by total internal reflection of a large fraction of both the 532-nm excitation and the 606-nm emission wavelengths at the TBC/crack interface. Typically, luminescence is enhanced from delaminated regions by about a factor of three for electron-beam physical vapor deposited TBCs and by an incredible factor of about 100 for plasma-sprayed TBCs. Luminescence imaging was very simple to implement and can be achieved using only light-emitting-diode illumination source and a camera with a band-pass filter. High-resolution luminescence images were obtained within a few seconds that immediately identified regions of TBC delamination that would otherwise be difficult to detect, thereby showing great promise for routine inspection of TBCs.



Delamination-Indicating Thermal Barrier Coating is examined as (a) white-light image and (b) Eu^{3+} luminescence image. Enhanced Eu^{3+} 606 nm (red) luminescence detected from scratched region of TBC readily reveals subsurface delamination.

Future work will concentrate on developing delamination-indicating TBCs with near-infrared-luminescent sublayers. Because TBCs are much more transparent at near-infrared wavelengths than at visible wavelengths, luminescence can then be detected with less attenuation and from much greater coating depths. The prime candidate dopants for near-infrared luminescence are erbium and neodymium, which luminesce at 1.55- and 1.06-μm wavelength, respectively.

This work was done by Jeffrey I. Eldridge of Glenn Research Center. Further information is contained in a TSP (see page 1). Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17929-1/30-1.