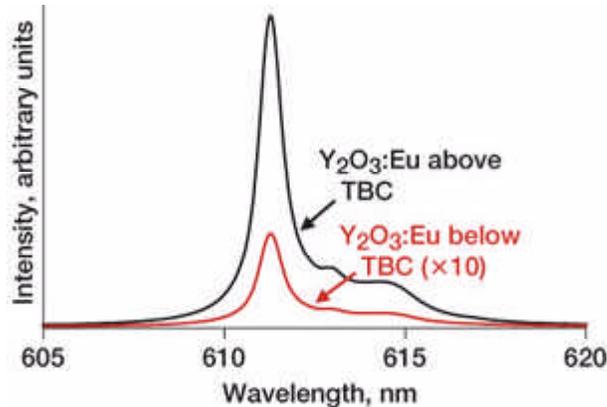


Depth-Penetrating Measurements Developed for Thermal Barrier Coatings Incorporating Thermographic Phosphors

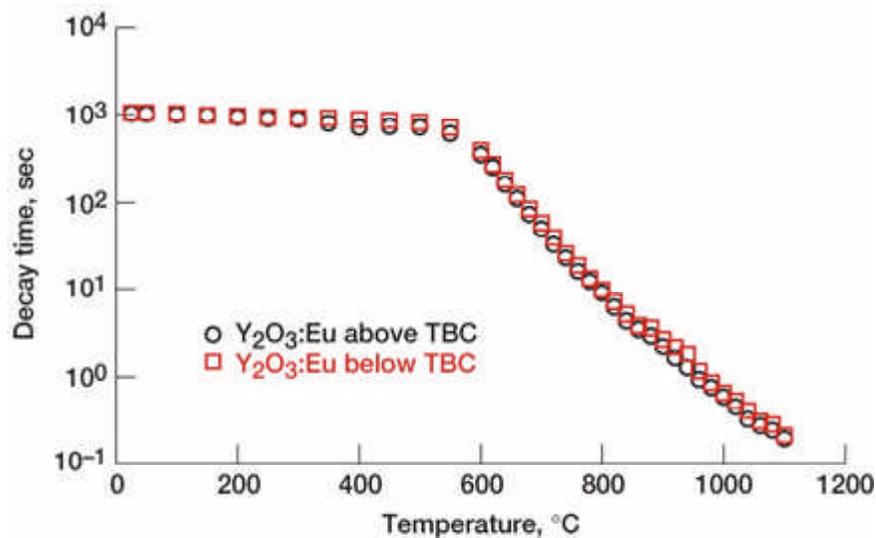
The insulating properties of thermal barrier coatings (TBCs) provide highly beneficial thermal protection to turbine engine components by reducing the temperature sustained by those components. Therefore, measuring the temperature beneath the TBC is critical for determining whether the TBC is performing its insulating function. Currently, noncontact temperature measurements are performed by infrared pyrometry, which unfortunately measures the TBC surface temperature rather than the temperature of the underlying component. To remedy this problem, the NASA Glenn Research Center, under the Information Rich Test Instrumentation Project, developed a technique to measure the temperature beneath the TBC by incorporating a thin phosphor layer beneath the TBC. By performing fluorescence decay-time measurements on light emission from this phosphor layer, Glenn successfully measured temperatures from the phosphor layer up to 1100 °C. This is the first successful demonstration of temperature measurements that penetrate beneath the TBC.

Thermographic phosphors have a history of providing noncontact surface temperature measurements. Conventionally, a thermographic phosphor is applied to the material surface and temperature measurements are performed by exciting the phosphor with ultraviolet light and then measuring the temperature-dependent decay time of the phosphor emission at a longer wavelength. The innovative feature of the new approach is to take advantage of the relative transparency of the TBC (composed of yttria-stabilized zirconia) in order to excite and measure the phosphor emission beneath the TBC. The primary obstacle to achieving depth-penetrating temperature measurements is that the TBCs are completely opaque to the ultraviolet light usually employed to excite the phosphor. The strategy that Glenn pursued was to select a thermographic phosphor that could be excited and emit at wavelengths that could be transmitted through the TBC. The phosphor that was selected was yttria doped with europia ($Y_2O_3:Eu$), which has a minor excitation peak at 532 nm (green) and an emission peak at 611 nm (red)--both are wavelengths that exhibit significant transmission through the TBC.



Comparison of the phosphor emission intensity for the $Y_2O_3:Eu$ phosphor layer above the 100- μm -thick thermal barrier coating (TBC) versus the layer below it. The emission spectrum for the phosphor layer below the TBC has been multiplied by 10 for easier comparison.

The measurements were performed on specimens consisting of a 25- μm -thick phosphor layer beneath a 100- μm -thick TBC. The 532-nm (green) excitation light was provided by a frequency-doubled YAG:Nd (yttrium-aluminum-garnet:neodymium) laser, and the fluorescence decay time measurements were acquired with a modified Raman microscope. The preceding graph compares the intensity of the phosphor emission of the phosphor layer above the TBC versus that of the phosphor layer beneath the TBC. Although there was considerable attenuation of the phosphor signal (a factor of 30), the phosphor emission at the reduced intensity was more than sufficient to perform fluorescence decay time measurements. The following graph shows the fluorescence lifetime temperature dependency for the $Y_2O_3:Eu$ phosphor layers both above and below the TBC. These curves show an excellent match and indicate that, despite the attenuation due to the overlying TBC, the phosphor layer beneath the TBC still functions as an effective temperature indicator.



The fluorescence decay time as a function of temperature for the $Y_2O_3:Eu$ phosphor layer above the TBC versus the layer below it.

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