COMPARING ENVIRONMENTAL BARRIER SURFACE TEMPERATURE MAPPING WITH EITHER A Y_2SiO_5:Er OR Sc_2SiO_5:Er TEMPERATURE SENSING LAYER

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Phosphor thermometry offers significant advantages for gas turbine engine environments such as insensitivity to emissivity uncertainties, rejection of reflected radiation, and limited interference from fluctuating flame chemiluminescence. However, the background thermal radiation and materials compatibility make the implementation of phosphor thermometry much more challenging with the ongoing transition to higher gas turbine engine temperatures. Currently, the lower-weight, higher temperature capability SiC/SiC ceramic matrix composite (CMC) components that can support these temperatures are protected by environmental barrier coatings (EBCs) that prevent the unacceptable CMC recession that would otherwise occur in the water vapor-containing turbine engine environment [1-2]. Therefore, the surface phosphor temperature sensing layer must not only exhibit good temperature sensing performance in the presence of intense background radiation up to surface temperatures above 1500 °C, but must also be compatible with the EBC rare earth disilicate ($RE_2Si_2O_7$) topcoat and account for the likely slow transition of the EBC topcoat surface to the rare earth monosilicate (RE_2SiO_5).

Y_2SiO_5:Er has previously been shown to exhibit enhanced relative temperature sensitivity above 1300 °C and strong suppression of interference by background thermal radiation in the 1300 to 1560 °C range [3]. Based on this potential, a 10 μm thick Y_2SiO_5:Er(0.8%) sensor layer was deposited using a slurry process [4] via spin coating onto an EBC-coated SiC disk that had a current generation EBC top coat composition of the rare earth disilicate $Sc_2Si_2O_7$. The slurry contained a minor mullite sintering aid addition to promote coating densification. For potentially needed improved materials sensor layer/EBC compatibility, a second specimen was prepared by depositing a 22 μm thick Sc_2SiO_5:Er(0.8%) sensing layer using the same coating process but without any sintering aid addition. Testing was also performed on standalone sintered disks of both the Y_2SiO_5:Er(0.8%) and Sc_2SiO_5:Er(0.8%) compositions prepared without sintering aids.

Luminescence decay curves over a range of temperatures were acquired by mounting the specimen inside a furnace with an optical window through which a pulsed 522 nm excitation could be transmitted and luminescence emission collected and detected by a PMT after bandpass filtering centered at 542 nm. Decay times were determined by fitting a single exponential to the data with intensity threshold crossings at 60% and 2% of the initial intensity selected as the start and end of the fitting window, respectively. The decay times determined in this manner are plotted as a function of temperature in Figure 1. The temperature dependence of decay times is fit to a dual effective phonon energy multiphonon emission model [3] based on a transition from nonradiative multiphonon emission of a small number of large energy phonons to emission of a large number of small energy phonons at high temperatures.

Luminescence lifetime imaging-based temperature maps were obtained using an intensified CCD camera to generate an image stack where each image in the stack was acquired at an incremental increase in delay after a beam-expanded 522 nm excitation pulse. Decay times were determined from the decay curve generated by each pixel in the stack using the same procedure as for the PMT-acquired spot temperature measurements. Furnace calibration measurements were used to convert decay times to temperature at each pixel. Temperature maps acquired in this manner are displayed in Figure 2 along with maps of deviation of pixel temperature from the area-averaged mean temperature. The standard deviation of the pixel temperature values over each temperature map area are shown below the temperature maps.

Despite better relative temperature sensitivity above 1200 °C exhibited by Y_2SiO_5:Er compared to Sc_2SiO_5:Er standalone disks, the better compatibility of the Sc_2SiO_5:Er sensing layer with the underlying EBC enabled surface temperature measurements up to 1535 °C compared to only up to 1382 °C for the Y_2SiO_5:Er sensing layer. Furthermore, because of its more uniform temperature sensing response, the Sc_2SiO_5:Er sensing layer produced without sintering aids showed better relative temperature precision (0.04% at 1535 °C) than could be obtained by the Y_2SiO_5:Er sensing layers produced with sintering aids.

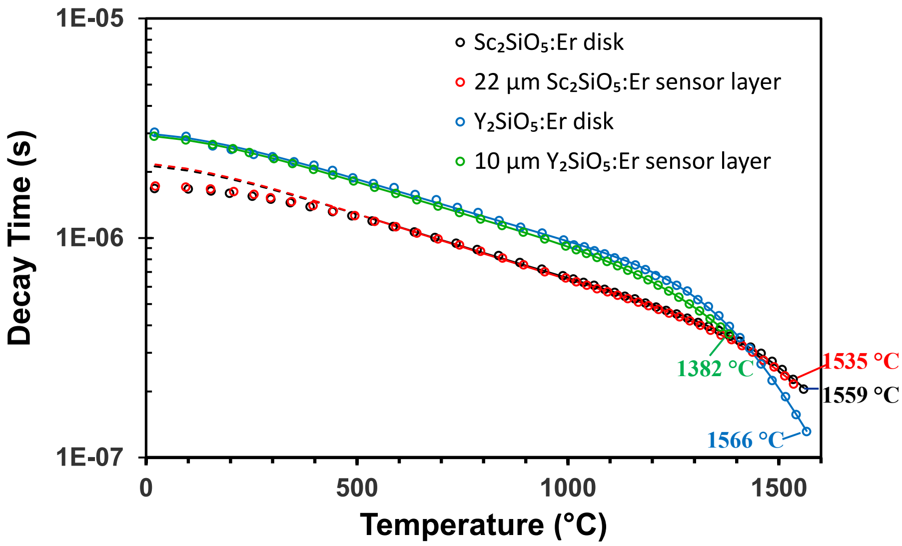

Figure 1. Temperature dependence of luminescence emission decay times for (1) 2.4 mm thick Sc_2SiO_5:Er disk, (2) 22 µm thick Sc_2SiO_5:Er sensor layer on EBC, (3) 2.4 mm thick Y_2SiO_5:Er disk, and (4) 10 µm thick Y_2SiO_5:Er sensor layer on EBC. Upper measurement limit noted for each.

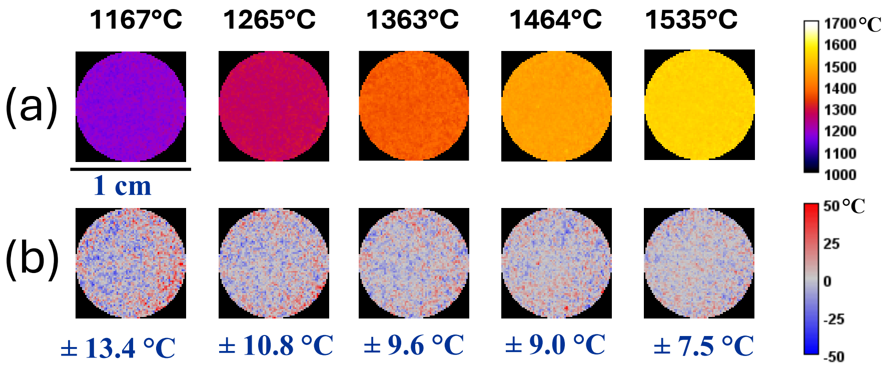

Figure 2. (a) Luminescence lifetime imaging-based temperature maps of 22 µm thick Sc_2SiO_5:Er sensor layer on EBC inside furnace at various specimen thermocouple temperatures. (b) Maps of deviation of pixel temperature from temperature mean ($T-T_m$).

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