Luminescence-Based Temperature Mapping at Turbine Engine Temperatures Using Breakthrough Cr-Doped $GdAlO_3$ Broadband Luminescence

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Progress is presented on the implementation of a NASA-developed breakthrough thermographic phosphor, Cr-doped $GdAlO_3$ (Cr:$GdAlO_3$), for making temperature measurements that exhibit important advantages over currently employed turbine engine temperature measurement technologies such as thermocouples and pyrometry. The novel use of the spin-allowed luminescence from Cr:$GdAlO_3$ offers the benefit of high luminescence emission intensity typical of a transition metal dopant, but with temperature measurement capabilities extending into the range typically associated with much weaker rare-earth dopant luminescence. It is shown that this combination of attributes extends the practical implementation of luminescence-based temperature measurements in highly radiant environments such as turbine engines from 600° to 1200°C, an unprecedented improvement of 600°C in upper temperature capability. Modeling is presented that shows that the exceptional persistence of the spin-allowed broadband luminescence can be attributed to the strong crystal field that the Cr^{3+} dopant ion experiences where it substitutes for the Al^{3+} ions in the orthorhombic perovskite structure of $GdAlO_3$. Two implementation efforts have made considerable progress: (1) development of an optical thermometer for probing combustion gas environments and (2) producing specimens for 2D temperature mapping of temperature gradients around cooling holes. Optical thermometers were developed consisting of Cr:$GdAlO_3$ at the tip of a high-temperature lightpipe. Impurities in the lightpipe materials were found to sometimes interfere with the luminescence emission used for temperature indication. Results using different diameters and purities of quartz and sapphire rod lightpipes are compared, including successful measurements to 1100°C. Recommendations are given for achieving a maximum upper temperature limit of 1200°C. Progress was also made on the development of a Cr:$GdAlO_3$ coating for 2D temperature mapping of component surfaces. Deposition of this coating composition by electron beam physical vapor deposition proved challenging, but the difficulties encountered were overcome to produce temperature-sensing coatings with the desired performance. Coatings are being deposited onto specimens with arrays of cooling holes for 2D temperature mapping in the vicinity of the cooling holes during active cooling in the presence of a high heat flux. The status of these measurements will be reported.