Implementation of an Ultra-Bright Thermographic Phosphor for Gas Turbine Engine Temperature Measurements

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Purpose

The overall goal of the Phase II effort is to build on the desirable temperature sensing characteristics of the ultra-bright thermographic phosphor Cr-doped gadolinium aluminum perovskite (Cr:GAP) demonstrated in Phase I by transitioning towards an engine environment implementation. A strategy is adopted to take advantage of the unprecedented retention of ultra-bright luminescence from Cr:GAP at temperatures over 1000ºC to enable fast 2D temperature mapping of actual component surfaces as well as utilization of inexpensive low-power laser-diode excitation suitable for on-wing diagnostics.

Background

Luminescence-based temperature sensing has been shown to offer significant advantages over thermocouples and pyrometry for obtaining surface temperature measurements. In particular, thermographic phosphor based temperature measurements have the potential for overcoming the attachment problem associated with thermocouples and the issues associated with unknown emissivity and interference by stray reflected radiation associated with pyrometry. In the past, however, luminescence intensity at high temperatures has been insufficient for practical temperature measurements using thermographic phosphors in the highly radiant turbine engine environment. The Phase I effort showed that the extraordinary retention of ultra-bright luminescence intensity at temperatures above 1000ºC, several orders of magnitude more intense than state-of-the-art thermographic phosphors, opens a opportunity for the practical implementation of thermographic phosphor based temperature sensing that is uniquely well suited to the turbine engine environment. This desirable performance was shown in Phase I to be primarily due to the very high crystal field experienced by the Cr^{3+} dopant ion in the perovskite structure, resulting in a high energy barrier that suppresses thermal quenching of luminescence, and temperature sensing was demonstrated up to 1200ºC. The ultra-bright luminescence intensity is being exploited in Phase II for 2D temperature mapping and low-power laser diode excitation that would be compatible with on-wing diagnostics.being adopted for temperature measurements from rotating blades on a Pratt & Whitney F117 engine as part of the NASA Vehicle Integrated Propulsion Research (VIPR) project. This rotating blade application will introduce challenges well beyond the scope of the Phase II Seedling effort. However, the turbine blade location will be more favorable for Cr:GAP performance since this location is much more shielded from engine radiation than the leading edge of the first stage vane measured in the Honeywell engine. The Cr:GAP phosphor has been successfully deposited by EB-PVD at Penn State onto a turbine blade, passed a cooling hole air flow inspection test and is being currently installed by Pratt & Whitney into its F117 engine along with two blades with other thermographic phosphor coatings. The actual engine test, where the temperature of the rotating blade will be monitored during volcanic ash ingestion, is scheduled for summer 2014.