SELECTIVE THERMAL EMISSION COATINGS FOR IMPROVED TURBINE EFFICIENCY

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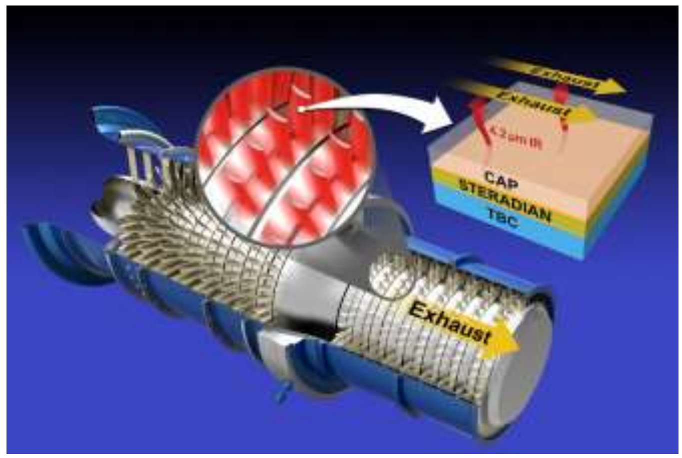

Figure 1. Illustration of selective emitter coating concept in a gas turbine. The SEC (called STERADIAN) is placed on top of a TBC and then capped with an IR transparent protective layer.

Coatings on turbine blades today are principally designed to provide a heat transfer barrier to protect the blade from reaching temperatures higher than the operational capability of the base metal. Hence thermal barrier coating (TBC) design has mainly focused on materials that limit thermal conduction. Over the last decade, major advances have been made in manipulating structures at sub-wavelength of light scale to alter optical properties of coatings. In this paper, we illustrate design of TBC coatings that have enhanced radiative heat transfer properties. Using principles of photonic metamaterial design, we are developing selective emitter coatings (SECs) that shift the normal broad band optical emissions from a hot turbine blade surface to radiate more light between 4 to 4.5 µm corresponding to the infrared absorption band of CO_2. Because mid-IR light in this wavelength region is absorbed in the exhaust within less than 4 cm of the emission source as illustrated in Figure 1, the SEC substantially increases radiative heat transfer to the exhaust stream. Computational fluid dynamics simulations of a turbine blade with this coating show potential for as much as 6% increase in turbine power output. Design of the SEC is being performed using rigorous continuous wave and finite difference time domain computational methods to predict coating emissivity as a function of wavelength. Two SEC structural motifs have shown the most promise. The first is a thin-film stacked layer design called epsilon near zero. This design tunes the dielectric constant to be zero (hence epsilon-near-zero) to enhance emittance at our target wavelength. The second is a photonic crystal design that consists of a periodic array of subwavelength structures that effectively suppresses out-of-target wavelength emissions and induces an excitation at our target wavelength. Samples implementing both coating motifs have been produced and their optical emission properties measured at up to 1200°C using a customized high-temperature FTIR instrument. Both designs show emissivity as high as 0.8 at 4.2 µm. Impacts of deviations from the idealized coating design due to manufacturing tolerances/defects have also been explored. Next steps involve testing thermal cycling stability using furnace cyclic and Jet Engine Thermal Shock (JETS) testing capabilities at Praxair Surface Technologies.