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(An Autonomous Institution, Aided by Government of Karnataka)

Project Report
on

"STUDIES ON SAMARIUM OXIDE DOPED ZIRCONIA THERMAL BARRIER COATING"

Submitted in the partial fulfillment of the requirements for the award of degree of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING

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2013-14

ABSTRACT

Increasing the maximum operating temperature of a gas turbine engine is central aim to increases in its efficiency. This temperature is limited by the materials available to construct the hot section of the engine (the combustor and high pressure turbine). The blades at the inlet of the high pressure turbine in particular are a challenge, since they must support significant centrifugal loads and are subject to high gas temperatures. Many improvements have been made to turbine blade materials and manufacturing processes to enable their operation at higher temperatures. The blades have evolved from solid wrought nickel-based alloys to single crystal super alloy structures with intricate channels to facilitate internal cooling. The development of these alloys, the casting techniques to produce blades from them, and the design of internal air cooling systems have reached their physical limits and recent increases in engine temperatures instead have relied on the development of Thermal Barrier Coating (TBC) systems. The thermal barrier coating systems applied to substrates consist of three layers.

(i) An aluminum rich metallic bond coat applied to the metal surface.

(ii) A thermally grown oxide layer (TGO) that forms on the bond coat, and

(iii) A thermal insulation(ceramic) topcoat deposited on the TGO by vapor or thermal spray deposition.

Among other requirements, the material for this highly porous top coat must be phase stable from room to operating temperature, have a high melting point (which reduces the rate of sintering) and a low thermal conductivity. Zirconia stabilized with 7 -8 wt % yttria (YSZ) is currently the industry standard for this application. However, its use is limited to temperatures $<1200^{o}C$ due to increased sintering rates and the existence of a phase change at higher temperatures. As a result, alternatives to YSZ are being explored. The pyrochlore rare-earth (RE) zirconates are a promising candidate to replace YSZ, as they possess a low thermal conductivity, have a very high melting point, and are phase stable to the melting point. One of these materials, samarium zirconate (SZO),has been deposited by directed vapor electron beam deposition (DVD) for possible use as a Thermal barrier coating.

However, these coatings had significant compositional fluctuations: both high samarium concentration in initially deposited material and fluctuations in the form of compositional banding, of varying degree, throughout the remainder of the coating. These fluctuations make it difficult to ascertain the suitability of samarium zirconate for thermal barrier coating applications. The compositional variations have been hypothesized to result from the difference in vapor pressure between the Samarium and Zirconia oxides in the single source $Sm_2Zr_2O_7$ melt. In this research the effect of vapor formation, transport, and deposition parameters (beam current, carrier gas flow rate, and rotation of the sample) on these compositional variations has been explored, and the hypothesis critically evaluated. Additional experiments attempted to mitigate the compositional banding by implementing evaporation and deposition from separate samarium oxide and zirconia oxide sources, but failed to alleviate the problem. From these experiments, together with compositional evaluations of source materials and coatings, it was determined that the initial samarium rich region is caused by the difference in component metal oxide vapor pressures. However, the compositional banding problem does not appear to be caused by differences in vapor pressure. Alternative explanations have been evaluated, including the possibility of oscillations in evaporation source temperature, leading to disproportionate changes in the vapor pressures of the constituent oxides, resulting in discrepancies between their evaporation rates