Chapter 3
Cyclic Oxidation of Combined LTA/YSZ and Alumina Thermal Spray Coatings

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ABSTRACT

Thermal barrier coatings protect the substrate from thermal diffusion, oxidation, phase transformations, elastic deformation, plastic deformation, creep deformation, thermal expansion, thermal radiation. It allows parts and components of gas turbines to withstand high temperature upto1650 °C. Cylic oxidation behavior of alumina incorporated, lanthanum titanium aluminum oxide (LaTi2Al9O19), and yttria stabilized zirconia (YSZ), that is LTA/YSZ top ceramic layer coating, was investigated. Two coating combinations, L 100 having top LTA layer thickness of 100 μm and L 150 having top layer of LTA having thickness 150 μm, were tested for thermal cycles at the temperature of 1100°C. The performances of these coatings were compared with conventional YSZ coatings. Microstructure studies, EDX, and XRD analysis demonstrated the formation of mainly LTA, LaAlO3, Al2TiO5, Al2O3, and TiO2 at 1100°C in both coatings. But in L 150 coating, the rate of oxidation was found slower than L 100 coating. Annealed L 150A and L 100A specimens show cyclic oxidation life of 272th and 250th cycles, respectively.

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INTRODUCTION

The thermal efficiency and power generation of gas turbines and aero engines can be enhanced using different thermal barrier coatings (TBCs). TBCs comprises of ceramic top coat of yttria stabilized zirconia (YSZ) having low thermal conductivity with good insulation capability. The top coat is applied over an oxidation resistant MCrAlY bond coat (Gok, & Goller, 2016). At higher temperatures for longer duration of operation or in case of cyclic thermal loading conditions, the spallation failure of TBC occurs mainly due to sintering and phase transformation of YSZ (Padture et al., 2002). To overcome the challenges associated with higher inlet gas temperature in advanced gas turbine and aero engines, rigorous researches were carried out to find alternative to ceramic materials better than conventional YSZ (Cao, Vassen, Tietz, & Stoever, 2006). Few of them are aluminates, pyrochlores, doped zirconia, perovskites. Excellent high temperature performance and higher thermal stability has been revealed by lanthanum zirconate as a top coat material (Vaben, Cao, Tietz, Basu, & Stover, 2000).

Studies revealed that TGO growth can retards with reduction in the bond coat internal oxidation. It is observed that the NiCrAlY bond coat with incorporated alumina proved better hot corrosion resistant compared to the NiCrAlY bond coat with incorporated YSZ (Wei, Guo, Gong, & Xu, 2008). Oxidation barriers layer of Alumina suppresses the excess bond coat oxidation. The Al_2O_3/YSZ coatings revealed higher oxidation and spallation resistance and increased rate of phase transition and densification (Ma, et al., 2008). The composite coatings with the combination of YSZ/alumina top coat, showed much better resistance to oxidation and thermal cycling (Friedrich, Gadow, & Schirmer, 2001).

La_2Zr_2O7 (LZ) pyrochlore as a top coat material has revealed excellent high-temperature capability and high thermal stability. H. Dong et. al, developed $La_2Ce_2O_7$ (LC) coating using APS by using La2Ce2.5O8 powder. The LC/YSZ coating has thermal cycling life 40% more than YSZ coating at 1320°C. Thermal conductivity of DCL coatings having top layer of 50% $La_2Zr_2O_7$ is reduced and 50% $Gd_2Zr_2O_7$ increased. Pyrochlore LZ is having lower thermal conductivity and good sintering resistance compared to YSZ. But it is having short life due to thermal expansion mismatch and higher thermal stresses generating from it. The LZ coating has low thermal expansion coefficient (TEC) which leads to higher thermal stresses and very short life. Recently co-doping of rare earth material Sc_2O_3 in YSZ was studied. Materials for TBCs are more complex and they were introduced through many studies. $LaTi_2Al_9O_{19}$ (LTA) (Xie, 2011), Lanthanide Tantalate ($RETa_3O_9$), Nd (Neodymium), Sm (Samarium), Eu (Europium), Gd (Gadolinium), Dysprosium-Tantalum Oxide (DTO) (Wu, 2018), Dy (Dysprosium), Er (Erbium)) (Chen L, 2018), Lanthanide Niobate (Ln_3NbO_7) (LNO), Dy (Dysprosium), Er (Erbium), Y (Yttrium), Yb (Ytterbium)) (Yang, 2019), Magnesium-Silicon Oxide (MSO) (Chen S, 2019), Calcium-Magnesium Alumino-Silicate (CMAS) (Gildersleeve, 2019), Zirconium Lanthanate ($Zr_3Ln_4O_{12}$) where, Ln is La (Lanthanum), Gd (Gadolinium), Y (Yttrium), Er (Erbium), and Yb (Ytterbium)) (Zhao M, 2019), Magnetoplumbite ($LnMgAl_{11}O_{19}$), Pr (Praseodymium), and Gadolinium-Zirconium oxide (GZO) (Vaßen, 2020).

LTA/YSZ ceramic layer showed excellent oxidation performance (Xie, Guo, Gong, & Xu, 2011). However, no data on cyclic oxidation study of combined YSZ/alumina TBCs is available in open literature. In present work, the thermal cyclic behavior of the plasma sprayed coatings for oxidation was evaluated at 1100°C. Oxidation kinetics was studied. Phases involved were determined using field emission scanning electron microscopy (FESEM) and x-ray diffraction (XRD).