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Investigation of Oxidation properties of YSZ with Al_2O_3/YAG Composite Thermal Barrier Coating

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1- Introduction

Thermal barrier coatings (TBC) have been considered as the most applicable materials in overall design of gas turbines and parts of aero engines. A TBC system consists of a super alloy and a metallic bond coat which is generally deposited on a super alloy. Super alloy is generally based on a nickel and titanium and bond coat is normally made of a MCrAlY (M = Cr or Ni) and the traditional TBCS usually consists of 6-8wt% Y_2O_3 stabilized ZrO_2.YSZ Ceramic top-coat has been used a top-layer material for many years due to high melting point, low thermal conductivity and high thermal expansion of coefficient, but also sintering and various transformation develop drastically decrease its life time up to 1200°C. When the bond coat experiences temperature higher than 1100°C, the useful life time for TBC is decreased drastically and this is related to the thermally grown oxide (TGO) Scales. TGO is formed on the bond coat when aluminum from bond coat and oxygen from porous channels come together in high temperature environment. Firstly alumina and yttrium oxide layers are obtained. Besides by increasing the oxygen diffusion from top coat to bond coat, TGO layer is formed which is consisted of Cr_2O_3, NiO and $Ni(Al,Cr)_2O_4$ spinels (CSN). Besides CSN oxides confront to expansion and this brings about thermal stresses and separation of the bond coat from top coat.

One of the deficiencies of YSZ as a thermal barrier coating is its high oxygen coefficient.Al_2O_3 has the potential in high temperature oxidation protection for the extremely low oxygen diffusivity and dense HCP crystal structure. Besides Al_2O_3 is used as a composite layer due to its high internal stresses and low thermal expansion of coefficients and Al_2O_3/YSZ composite coatings have been widely investigated due to their enhanced strength and fracture toughness. YAG ($Y_3Al_5O_{12}$) is considered as a high temperature material, the same features with Al_2O_3, with an excellent oxidation resistance, but it has higher thermal stresses and lower thermal expansion of coefficient ($3Wm^{-1}K^{-1}$) compared to YSZs.

2- Experimental

The precursor solution for Al_2O_3/20WT%YAG powder was prepared by sol-gel method using $AlCl_3$.6H2O, Al powder, Y_2O_3 and HCL, Y_2O_3 powder was first dissolved in aqueous HCL and stirred in 80 °C for 30 min. Then main solution was prepared by dissolving aluminum chloride hexahydrate, aluminum powder and Yttrium oxide solution in to the deionized water. The precursor solution was then continuously stirred at 100°C for 4h to produce sol and then gel. Then gel is dried at 120°C for 48 h. Then obtained powder was calcined in a muffle furnace at 1400°C for 4h. Phase identifications of calcined powder was performed by X-ray diffractometry.

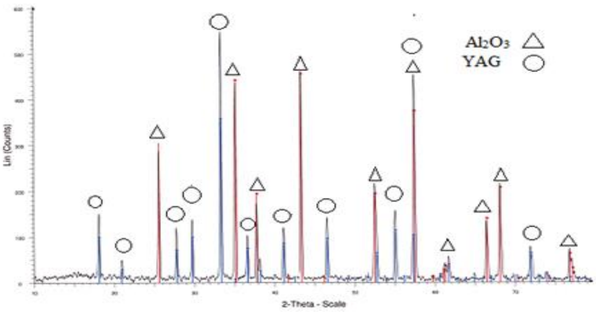

Fig. 1 Al_2O_3/20WT%YAG synthetic powder after calcination

After calcinations particle size analyzer (PSA) test was performed to gain an average particle size. In plasma spray method, particles should be in a particle size between 40-90 µm and agglomeration with water and PVA help attached particles to be in a desired particle size. For preparing the composite thermal barrier coating, 15wt% of Al_2O_3/YAG was mixed with 85wt% of YSZ, 30wt% of Al_2O_3/YAG was mixed with 70wt% of YSZ and 45wt% of Al_2O_3/YAG was mixed with 55wt% of YSZ. Firstly specimens were placed in a ceramic crucible and then crucibles were placed on the alumina bricks Specimens were oxidized at 1050°C for 10 h and cooled to room temperature for 20-30 min. In the combination of Al_2O_3/YAG with YSZ in a composite thermal barrier coating, Al_2O_3 decrease the porosity of YSZ TBC. One can say that YSZ grains are spherical and pungent Al_2O_3 grains are effective in compaction among Al_2O_3/YSZ coating particles. Besides YAG grains effectively slow down alumina grain growth. It is expected that the YS55 has the highest compaction compared to other composite thermal barrier coatings, but thermal stresses after plasma spray, would be increased due to mismatch increase in the thermal coefficient of expansion between Al_2O_3/YAG and YSZ and this cause to increase the voids in YS55 TBC.

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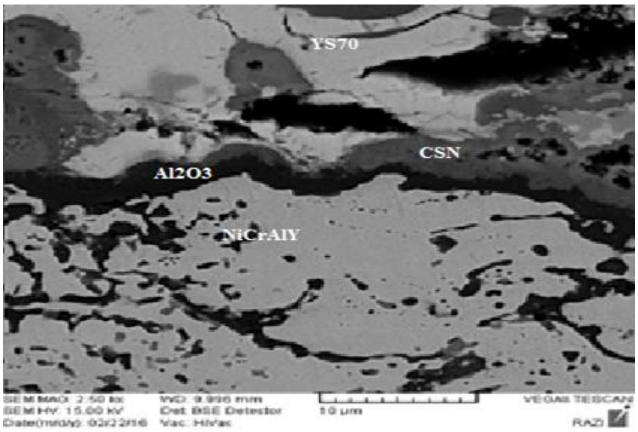

Fig.2 SEM Micrograph of TGO layer in YS70

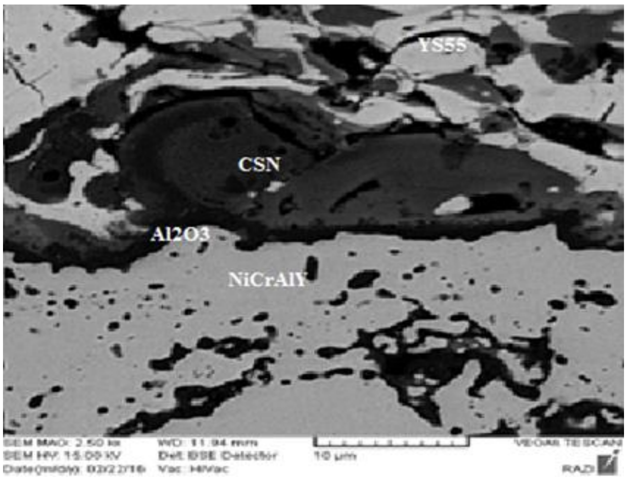

Fig. 3 SEM Micrograph of TGO layer in YS55

3- Conclusions

1) In order to investigate the oxidation properties of YSZ with Al_2O_3/YAG thermal barrier coating, Al_2O_3/YAG powder was synthesized by a sol-gel method.
2) High temperature cyclic oxidation test at 1050°C for 200h and weight changes per unit area of Composite YSZ TBCS revealed that in YS85 and YS70 the oxidation resistance was increased and the thickness of thermally grown oxide was decreased (3/2µm) and in YS55 composite thermal barrier coating, by increasing the thermal stresses the oxidation resistance was decreased and the thickness of thermally grown oxide was gradually increased.