Development of advanced Thermal Barrier Coating System Prepared by Electron Beam PVD

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Thermal barrier coatings (TBCs) are widely used to protect the hot section parts of aircraft engines. The current state-of-the-art TBCs consist of thermally insulating top coat of yttria stabilized zirconia (YSZ) prepared by electron beam physical vapor deposition (EB-PVD), and bond coat of MCrAlY overlay coating or Pt modified aluminides. Since the lifetime of TBCs depends on both ceramic top coat and bond coat, improvement of TBCs requires modification of both top coat and bond coat. This study investigates an effect of HfO_2 and La_2O_3 co-doping on properties of YSZ coating prepared by EB-PVD and thermal cycle life of TBCs on EB-PVD CoNiCrAlY bond coat, in order to develop advanced TBCs with superior thermal barrier property and durability.

The effects of HfO_2 and La_2O_3 co-doping on thermal conductivity and thermal cycle life of YSZ coatings produced by EB-PVD are investigated, because co-doping them significantly suppresses the sintering of YSZ. Figure 1 shows thermal conductivity of YSZ layer and HfO_2 and La_2O_3 added YSZ (ZrO_2-HfO_2-Y_2O_3-La_2O_3) layers after heat exposure at 1200 to 1500°C. Thermal conductivity of ZrO_2-HfO_2-Y_2O_3-La_2O_3 was much lower than that of YSZ, even after heat exposure at 1500°C. Thermal cycle life of the TBC system with ZrO_2-HfO_2-Y_2O_3-La_2O_3 top coat was shorter than that of the TBC system with conventional YSZ top coat, because of smaller coefficient of thermal expansion of ZrO_2-HfO_2-Y_2O_3-La_2O_3 than that of YSZ. A double layered top coat consisting of ZrO_2-HfO_2-Y_2O_3-La_2O_3 topmost layer and YSZ bottom layer was synthesized, in order to improve durability of the top coat. The TBC system with double layered top coat showed improved thermal cycle life which was almost the same as that of TBC system with conventional YSZ top coat.

CoNiCrAlY bond coat prepared by EB-PVD was also investigated, since EB-PVD CoNiCrAlY is expected to have less macroscopic defects which are thought to promote the growth of TGO. As shown in Fig.2, CoNiCrAlY layers deposited by EB-PVD were relatively dense columnar structure. Thermal cycle life of the EB-PVD YSZ / EB-PVD CoNiCrAlY TBC system (EB/EB) was evaluated by furnace cycle test, compared with EB-PVD YSZ / vacuum plasma sprayed (VPS) CoNiCrAlY TBC system (EB/VPS). After furnace thermal cycle test, thickness of TGO in the EB/EB system was thinner than that in the EB/VPS system. However, thermal cycle life of the EB/EB system was shorter than that of the EB/VPS system. This difference seems to relate the formation of Ni and Co containing spinels (medium gray area) in TGO in the EB/EB system, as shown in Fig. 3.

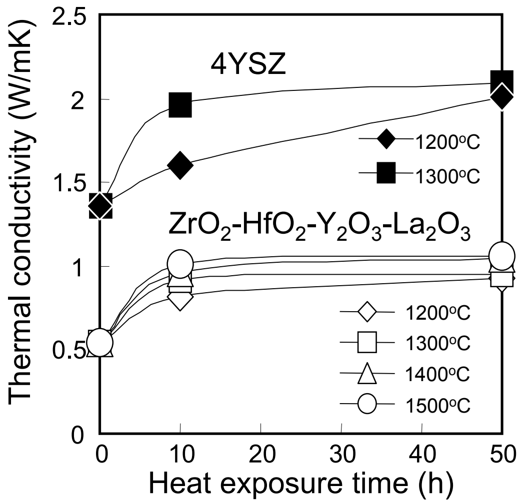

FIG. 1. Thermal conductivity of 4YSZ layer and ZrO_2-HfO_2-Y_2O_3-La_2O_3 layer after heat exposure.

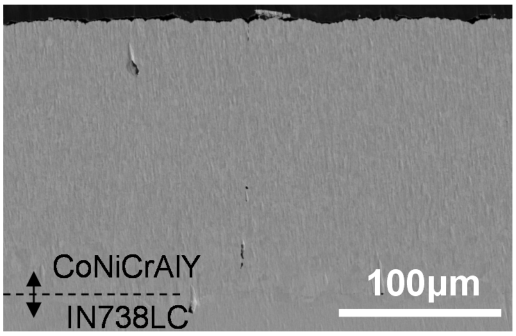

FIG. 2. CoNiCrAlY layer deposited by EB-PVD.

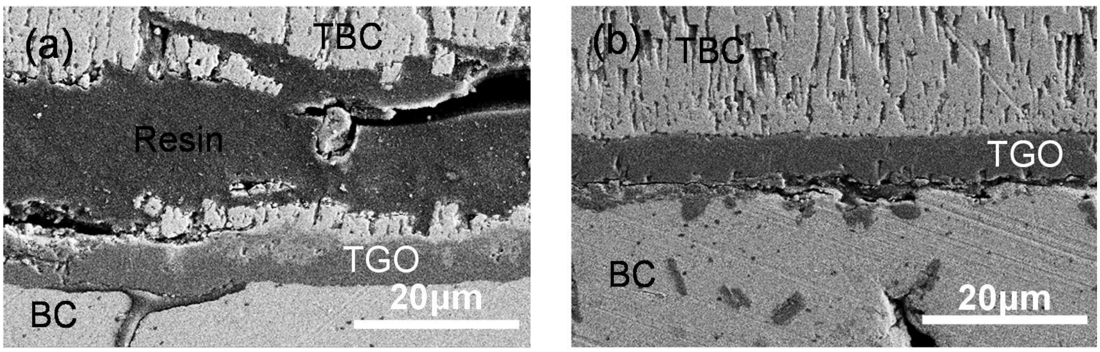

FIG. 3. Cross-sectional SEM images of specimens after furnace cycle test at 1120°C.
(a) EB-PVD YSZ / EB-PVD CoNiCrAlY TBC system after 566 cycles.
(b) EB-PVD YSZ / VPS CoNiCrAlY TBC system after 700 cycles.