MICROSTRUCTURE CONTROL OF MULTI LAYERED EBC PREPARED BY DUAL ELECTRON BEAM PVD

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Environmental barrier coatings (EBCs) can play important roles in enabling SiC fiber reinforced SiC matrix composites (SiC/SiC) for application to advanced hot-section components in airplane engines. EBCs must exhibit superior environmental shielding durability and excellent volatilization resistance in the combustion environment containing water vapor. Therefore, a multilayered structure is applied when designing EBCs. Yb silicates are promising substances for EBC use. Volatilization resistance of Yb_2SiO_5 is superior to $Yb_2Si_2O_7$. Thermal expansion coefficient of $Yb_2Si_2O_7$ is closer to SiC/SiC composites than Yb_2SiO_5 and it exhibits a single phase up to about 1873 K. Mullite has higher oxygen shielding performance than $Yb_2Si_2O_7$. Thus, we design EBC which is composed of a bond layer, dense mullite oxygen shielding layer, compositional-gradient dense Yb silicate layer showing water vapor shielding function, and Yb_2SiO_5 layer with segmented structure. The function of the Yb_2SiO_5 layer is reduction of thermal stresses during thermal cycling. Such an environmental shielding capability depends greatly on both the compositions and microstructures of the layers. Therefore, the coating processes used to make the EBCs should allow precise control of these factors. While it is difficult to strictly control the compositions of such complex oxides using conventional plasma spray deposition techniques due to incongruent evaporation of raw powders, dual electron beam physical vapor deposition (EB-PVD) is a potential process for constructing the complex oxides layer with controlled compositions as well as microstructures. We recently reported that formation of $Yb_2Si_2O_7$ layer by dual EB-PVD [1]. In the present study, we investigated the in-situ formation of a dense mullite layer, compositional gradient layer from $Yb_2Si_2O_7$ to Yb_2SiO_5 with dense structure, and Yb_2SiO_5 layer with segmented structure via dual EB-PVD, simultaneously heating the substrate.

Yb_2O_3 or Al_2O_3 ingot and SiO_2 ingot were used as vapor sources. They were evaporated by electron beams with appropriate power. Yb silicate and mullite were formed on a substrate. The temperature of the substrate during coating process was maintained at about 1523 K. The obtained coatings were characterized by XRD and SEM.

As-deposited mullite coating prepared by dual EB-PVD was crystalline and it had dense structure. Fig. 1 shows cross-sectional SEM photograph of compositional gradient Yb silicate layer. The coating has dense structure and compositional gradient form $Yb_2Si_2O_7$ to Yb_2SiO_5 in the coating can be confirmed by Raman mapping. Crystalline-oriented Yb_2SiO_5 layer with segmented structure was obtained by increase in coating rate (Fig. 2). Additionally, we successfully obtained multi layered EBC composed of these complex oxides with controlled compositions and microstructures.

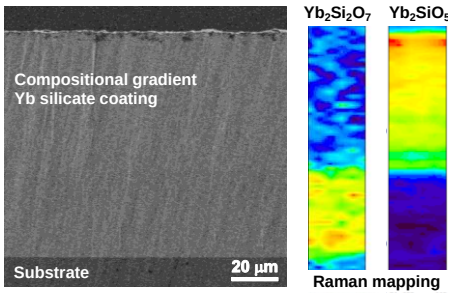

Fig. 1 Cross-sectional SEM photograph of compositional gradient Yb silicate coating and Raman mapping of $Yb_2Si_2O_7$ and Yb_2SiO_5 in the coating.

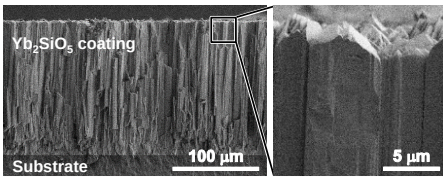

Fig. 2 Cross-sectional SEM photographs of Yb_2SiO_5 coating with segmented structure.

[1] T. Yokoi *et al.*, *Mater. Lette.*, 193, 176–178 (2017).

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