THERMAL BARRIER COATINGS ON POLYMER MATERIALS

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Polyimide matrix composite (PIMC) has been widely used to replace metallic parts due to its low density and high strength. It is considered as an effective approach to improve thermal oxidation resistance, operation temperature and lifetime of PIMC by depositing a protection coating. The objective of the research was to fabricate a series of thermal barrier coatings (TBCs) on PIMC by a combined sol-gel/sealing treatment process and air plasma spraying (APS). By optimizing the experimental parameters, thermal shock resistance, thermal oxidation resistance and thermal ablation resistance of PIMC could be improved significantly.

The ZrO_2 sol was prepared by sol-gel process and the effects of the different organic additions on phase structure, crystallite size and crystal growth behavior of the ZrO_2 nanocrystallite were investigated. The addition of HAc and DMF were beneficial to decrease the crystallite size and alter the activation energy for crystal growth, further inducing the crystallization of ZrO_2 nanocrystallite at low temperature (300ºC) and the stability of tetragonal ZrO_2 at 600ºC. Based on the optimized parameters of the sol preparation, the ZrO_2/phosphates duplex coating was fabricated on PIMC via a combined sol-gel and sealing treatment process. The sealing mechanism of the phosphates in the duplex coating was primarily attributed to the adhesive binding of the phosphates and the chemical bonding between the sealant and the coating. It was demonstrated that the duplex coating exhibited excellent thermal shock resistance and no apparent delamination or spallation occurred. Relatively, the duplex coating with the thickness of 150 μm provided excellent thermal oxidation and thermal ablation resistance for the polymer substrate. However, the presence of cracks and delamination in the coatings provided the channels for oxygen diffusion, causing the final failure of the protection coating.

The Zn/YSZ and Al/YSZ coating systems were successfully deposited on PIMC by APS. Metals with comparatively low melting point as the bond coats (Cu, Al, Zn) were beneficial to increase thermal shock resistance of the coating systems. In comparison with the Al/YSZ coating system, the Zn/YSZ coating exhibited the better thermal shock resistance, which was ascribable to the lower residual stress in the Zn layer after deposition and the lower thermal stress induced during thermal shock test. For these coatings, the increase in surface toughness of the substrate as well as the decrease in thickness of metal layer favored the improvement of thermal shock resistance of the coatings. With the temperature increases, thermal shock lifetime of the coatings decreased disastrously. However, the difference was that the slight increase of the thickness of YSZ layer favored the increase in thermal shock resistance of the Al/YSZ coatings, while for the Zn/YSZ coating systems the increase in the thickness of YSZ layer made thermal shock resistance weaken. Owing to the protection of Zn/YSZ and Al/YSZ coating systems, the time for 5 wt% weight loss of the sample was prolonged from 16 h to 50 h when oxidation at 400ºC; as the oxidation temperature increased to 450ºC, the time for 5wt% weight loss was extended from 5 h to 13 h. By depositing different coatings, the anti-ablation property of PIMC was significantly improved. During property testing, the formation of cracks and delamination in the coating and the occurrence of the spallation led to the failure of the coating systems, which was mainly due to the residual stress during the deposition process, thermal stress induced by the mismatch in thermal expansion coefficient and further oxidation of the substrate.

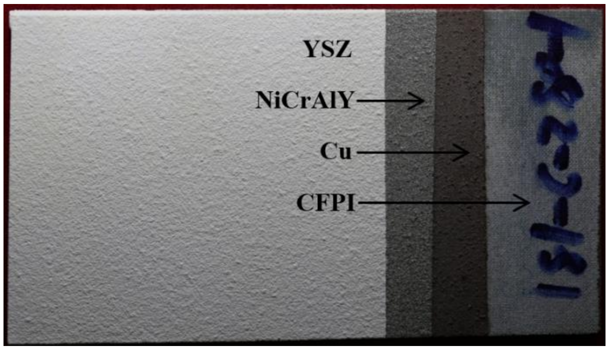

Figure 1 – TBCs on CFPI