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FABRICATION OF A C/C-SiC-TiC-TaC COMPOSITE BY HYBRID WET INFILTRATION

ABSTRACT

A novel C_f/C-SiC-TiC-TaC composite was successfully fabricated by performing reactive melt infiltration (RMI) by means of pressureless spark plasma sintering (SPS) at 1700°C to permeate molten 66.7Si-17.9Ti-15.4Ta alloy into a porous C_f/C composite prepared by polymer impregnation and pyrolysis (PIP).

The C_f/C composite preform was of density 1.54g/cm^3 and open porosity 21%, obtained after 3 cycles of PIP with resole phenolic resin. An amorphous carbon matrix was thus obtained and was confirmed by X-Ray Diffraction (XRD) and Raman spectroscopy. The 66.7Si-17.9Ti-15.4Ta alloy prepared by arc melting from $TaSi_2$ and $TiSi_2$ powders formed a solid solution of (Ta,Ti)Si_2 and (Ta,Ti)$_5Si_3$. When the alloy was infiltrated into the C_f/C composite preform cubic face centred carbides of Ta, Ti and Si, and the (Ta,Ti)C solid solution were obtained at 1700°C by SPS for 30 minutes. At 1600°C the UHTC matrix was predominantly unreacted silicides; SiC is the only carbide which was convincingly formed, although (Ta,Ti)C was observed by XRD and SEM to have incipiently precipitated at the C/alloy interface. At 1800°C the carbide formation reactions extended to the reinforcing fibres, thus compromising the fibres' reliability. 1700°C was deemed the excellent trade-off temperature for the formation of the C_f/C-SiC-TiC-TaC composite, wherein an acceptable compromise of the extent of carbide-forming reactions completion and limiting the damage of the melt to the fibres.

Upon exposure to an oxyacetylene flame of at least 3000°C, the C_f/C-SiC-TiC-TaC composite showed thermomechanical degradation first, and thermochemical degradation thereafter. After 7.5s of exposure to the oxyacetylene flame (4 MW/m^2 heat flux) placed 19mm away, the unprotected C_f/C composite showed a mass ablation rate of 0.0402g/s and a linear ablation rate of 0.377 mm/s. The UHTC showed a low mass ablation rate of 0.00388 g/s and a low linear ablation rate of 0.00216 mm/s owing to the scale of the oxides formed adhering to the surface of the composite. The scale, analysed by scanning electron microscopy, X-ray diffraction, electron dispersive spectroscopy and electron probe micro-analysis, showed that the composite constituents had the ability to form glassy self-healing eutectics based on SiO_2 (Ta_5O_2-SiO_2 and $TaTiO_4$-SiO_2). The C_f/C-SiC-TiC-TaC composite is a promising candidate for the sharp nose and leading edges of hypersonic vehicles.