Studies on the Fabrication and Characterization of Porous Ceramic Matrix Composites via Pyrolysis Route

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1. Introduction

In the recent studies different fabrication techniques were applied to fabricate the porous and densified ceramic matrix composites. The main purposes of the present study are listed below:
1. To prepare preforms with unique porous structure for the fabrications of porous ceramic matrix composites,
2. To fabricate the porous ceramic matrix composites with enhanced properties due to the in situ formation of $\beta$-SiC,
3. To develop a new technique that might be implied to convert used polymeric products into SiC/C materials, which can enhance the properties of CMCs,
4. To minimize the environmental problems caused by the gases formed during the combustion of used polymeric products and to suppress the emission of gases by using the closed tubes,
5. To investigate the effect of temperature on the formation of $\beta$-SiC by hot isostatic pressing the pyrolyzed phenol resin-silicon composites,
6. To investigate the effect of preforms on the synthesis of micro $\beta$-SiC from phenol resin and silicon,
7. To investigate the effect of various mass% of ZrO$_2$ on the microstructure and properties of porous CMCs prepared by HIPing the pyrolyzed ZrO$_2$/Si/phenol resin composites, and
8. To fabricate and characterize the densified ceramic matrix composites reinforced by in situ formation of silicon carbide.

2. Results and Discussions

The fabrication of three phase mixture of C/SiC/ZrO$_2$ porous composites was examined by HIPing the pyrolyzed composites of phenolic resin/Si/ZrO$_2$ powders. The results showed that the formation and growth of $\beta$-SiC in addition to the densification of matrix by HIPing led to the increase in hardness at higher temperatures. Pyrolyzed composites which were obtained by heating the novolac-type phenol resin and silicon powders at 850$^\circ$C in vacuum were HIPed at various temperatures. The results showed that $\beta$-SiC was nucleated by the reaction of gaseous SiO and CO molecules. The preforms were prepared from commercially available phenol resin and silicon powders by pyrolysing at 650$^\circ$C and 750$^\circ$C in vacuum, then HIPed at 1400$^\circ$C. The degree of crystallinity in the specimen obtained from the preforms pyrolyzed at 750$^\circ$C was higher than the preforms pyrolyzed at 650$^\circ$C. Porous ceramic matrix composites were fabricated by HIPing the pyrolyzed composites of commercially available yttria partially stabilized zirconia, silicon powders and phenol resin. The formations of $\beta$-SiC in the composite below the melting point of silicon and spherical pores of several $\mu$m in diameter were observed. The fabrication of CMCs with greatly improved hardness and fracture toughness by in situ formation of $\beta$-SiC was examined. As a result, the CMC having Vickers hardness of 29.63 GPa and fracture toughness of 10.60 MPa m$^{1/2}$ was obtained.

3. Conclusions

The fabrications of porous ceramic matrix composites via pyrolysis route were established.