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Analysis of Dominant Factors Affecting Mechanical Properties of SiC and SiC Fiber-Reinforced Composites

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1. Introduction

The mechanical reliability of ceramics or ceramic matrix composite is very important, because the service conditions of these materials are very severe. In this study, the fracture behavior of ceramic matrix composites with Si-Ti-C-O fibers was analyzed and compared with the fracture behavior of raw materials such as yarn and fabric. The factors controlling the reliability were identified. On the other hand, the factors to increase the mechanical reliability of monolithic SiC ceramics were discussed. The addition of nanometer-sized SiC to submicrometer- sized SiC in the processing was highly effective to enhance the mechanical reliability.

2. Results and Discussion

In the polymer impregnation and pyrolysis method (PIP) using a low viscosity polytitanocarbosilane (PTC) solution, the densification of the laminated composite of the Si-Ti-C-O woven fabric with ceramic filler proceeded with the gradual formation of polymer-derived solid and closed pores with increasing number of PIP sequence. The laminated composite with a relatively strong chemical bond (Si-O-Si bond) between PTC-derived solid and ceramic filler (mullite and SiC) provided a high deformation energy.

The fracture probability of the tensile fracture behavior of Si-Ti-C-O fiber bundle (yarn), woven fabric of yarn and laminated composite of the Si-Ti-C-O fabric / mullite filler / polytitanocarbosilane system was well fitted by the normal distribution function. The tensile strength of the composite could be interpreted by the product of effective fiber content, the Young’s modulus of the fiber and the elongation of the composite. The 800 nm SiC with Al_2O_3 and Yb_2O_3 was hot-pressed to 97-99 % of theoretical density under a pressure of 39 MPa at 1950 ˚C. The strength at a fracture probability 50 % and the Weibull modulus were 622 MPa and 15.0 for the SiC (800 nm)-Al_2O_3-Yb_2O_3 system, 723 MPa and 9.2 for the 75 % 800 nm SiC-25 % 30 nm SiC system with Al_2O_3 - Yb_2O_3 and 575 MPa and 12.7 for the 75 % 800 nm SiC-25 % 30 nm SiC system with Al_2O_3-Yb_2O_3-PTC. Addition of 30 nm SiC improved the strength and Weibull modulus. The infiltrated PTC improved the Weibull modulus but decreased the strength.

3. Conclusions

The deformation mechanism of the densified laminated Si-Ti-C-O fabric with mullite filler was explained by the combination of the following processes: elastic deformation → buckling → delamination along the direction of layered fabric. The laminated composite with a relatively strong chemical bond (Si-O-Si bond) between PTC-derived solid and ceramic filler (mullite and SiC) provided a high deformation energy.

The strength of the yarn (662-765 filament/yarn), fabric and laminated composite decreased in the following order: yarn (752-1714 MPa) > fabric (440-1274 MPa) > composite (72-156 MPa). The fracture probability of the yarn, fabric and composite was well fitted by the normal distribution function. The tensile strength of the composite could be interpreted by the product of effective fiber content, the Young’s modulus of the fiber and the elongation of the composite. The use of Young’s modulus of fabric (64 GPa) in the calculation of the tensile strength of the composite provided a good agreement with the measured strengths lower than 150 MPa.

Addition of 30 nm SiC improved the strength and Weibull modulus. The infiltrated PTC improved the Weibull modulus but decreased the strength.

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