Chapter 68
Application of Electrophoretic Deposition for Interfacial Control of High-Performance SiC Fiber-Reinforced SiC Matrix (SiC_f/SiC) Composites

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ABSTRACT

This chapter reviews the novel fabrication process of continuous SiC_f /SiC composites based on electrophoretic deposition (EPD). EPD process is very effective for achieving relatively homogeneous carbon coating with the thickness of several tens to hundreds nanometers on SiC fibers. Carbon interface with the thickness of at least 100 nm formed by EPD acts effectively for inducing interfacial debonding and fiber pullout during fracture, and the SiC_f /SiC composites show excellent mechanical properties. From these results, it is demonstrated that the fabrication process based on EPD method is expected to be an effective way to control the interfaces of SiC_f /SiC composites and to obtain high-performance SiC_f /SiC composites.

INTRODUCTION

Silicon carbide (SiC) is one of the attractive materials for structural applications at high temperatures because it shows high thermal and chemical stability, high stiffness, high hardness, high thermal conductivity, excellent oxidation, corrosion and wear resistance, high mechanical strength at high temperatures, low thermal expansion and good resistance to high-energy neutron irradiation (Harbell & Sanders, 1992; Hopkins & Price, 1985; Rovner & Hopkins, 1976; Whalen, 1986). However, monolithic SiC fractures in a brittle manner, resulting in its low reliability, and the application of monolithic SiC as high temperature structural parts has been limited.

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In the 1970s, Yajima, Hasegawa, Okamura, and Matsuzawa (1978) developed the process for the technical synthesis of SiC-based ceramic fibers based on the thermolysis of polycarbosilane. The fabrication process of SiC-based ceramic fibers is a unique technology in the world, and the fibers with the best quality and high performance have been produced in Japan. To improve its reliability, SiC matrix reinforced with continuous SiC fibers with high elastic modulus and strength, i.e. continuous SiC fiber-reinforced SiC matrix (SiC_f/SiC) composites that show a pseudo-ductile fracture behavior and high fracture energy, have been attracting attention as the ceramic materials with high reliability. Figure 1 shows the typical load-strain curves of monolithic ceramics and ceramic fiber-reinforced ceramic matrix composites (CFCC), and the schematic illustrations of microfracture processes and the mechanism of CFCC. While monolithic ceramics fracture catastrophically after cracking, CFCC fractures in complicated processes with interfacial debonding, fiber bridging, fiber fracture and fiber pullout (Niihara, 1991; Sakai, 1995; Yano & Yoshida, 2009; Zok, Evans, & Mackin, 1995). It is important for the unique fracture behavior in SiC_f/SiC composites to design the optimum fiber/matrix interface and microstructure. The optimum interface plays an important role for the promotion of interfacial debonding and fiber pullout, and for the inhibition of the reaction between fibers and the matrix.

Continuous SiC_f/SiC composites have been expected to be applied as components for high temperature gas turbine (turbine vane, combustion chamber, nozzle), aerospace industries (leading edge, combustion chamber, turbine vane, nozzle, nose cone, thruster) and nuclear power applications (fuel cladding for fission power application, breeding blanket and divertor for fusion power application), and they have been recognized as a key material for these application (Beesley, 1997; Christin, 2002; Giancarli, Aiello, Caso, Gasse,

Figure 1. (a) Typical load-strain curves of monolithic ceramics and ceramic fiber-reinforced ceramic matrix composites (CFCC), and (b) the schematic illustration of micro-fracture processes and the mechanism of CFCC