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Interface Characteristics of Reaction Bonded Silicon Carbide Composites

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Reaction bonding is a proven technology for the fabrication of ceramic composites. The fabrication temperature of this technique is relatively low and is around 1500 °C for SiC/Si composites [1]. Reaction bonded silicon carbide (RBSC) composites have been extensively used in nuclear reactor components [2], heat exchangers [3] and micro electro-mechanical systems [4] because of their outstanding stiffness, excellent thermal conductivity, low thermal expansion, light weight and high environmental stability [5]. The remarkable properties of RBSC are strongly related to its microstructures. For example, Marshall *et al*. [6] reported that the SiC content and minor phases have significant impact on both thermal and mechanical properties. While the SiC/SiC interface in RBSC is an important structural feature associated with the characteristic core-rim structure and material properties, there has been limited investigation on its evolution in literature [7]. Critical characterization of the SiC/SiC interfaces will therefore benefit the understanding of the microstructure in interfacial area including the formation of defects and the optimization of RBSC fabrication.

The microstructure of RBSC was investigated using a FIB/SEM (Zeiss Auriga 60) equipped with an X-ray energy-dispersive spectrometer (EDS, Oxford Instruments X-Max 80) and a transmission electron microscope (TEM, JEOL JEM-2010F) operating at an accelerating voltage of 200 kV. The SEM samples were prepared by standard metallographic procedures, and the TEM specimen was prepared by Ga focused ion beam (FIB) after a SiC/SiC interfacial area of interest was located.

As shown in Fig 1(a), the polished RBSC sample contains pre-existing SiC (dark grey), newly formed SiC (light grey) and residual Si (grey). The distribution of Si and SiC is shown in the EDS maps in Fig 1(b) and 1(c). The dark grey core of SiC is surrounded by a light grey layer of SiC, forming the core-rim structure. TEM was further employed to study this core-rim structure of SiC/SiC.

Fig. 2 (a) shows a TEM image of an interfacial area between "new" SiC and "old" SiC where it is noticed that the structural faults are largely formed in "new" SiC. A sharp interface is identified in Fig. 2(b). Fig. 2(c) and 2(d) are the HRTEM images of "new" SiC and "old" SiC respectively. Both SiC grains have hexagonal structure as the insert selected area electron diffraction (SAED) pattern indicates. The dislocations in "new" SiC are confirmed by the inverse fast Fourier transform (FFT) images. The formation of high density dislocations and micro-twins are primarily due to the rapid growth of "new" SiC during the fabrication. Based on a "carbon dissolution and saturation" mechanism [7], the carbon moves to cold spots ("old" SiC) due to carbon concentration and temperature gradients during infiltration process, and it then becomes saturated out to form "new" SiC. This is an endothermic process, which contributes to the growth of the "new" SiC and generates considerable number of crystal defects inside the grain at the same time.

A core-rim structure was observed in RBSC consisting of preexisting "old" SiC and the surrounding reaction formed "new" SiC, respectively. There are a great number of structural defects including dislocations and micro-twins in the newly formed SiC rim and these defects are probably formed due to the growth strain associated with high speed formation of SiC rim during the fabrication [8].

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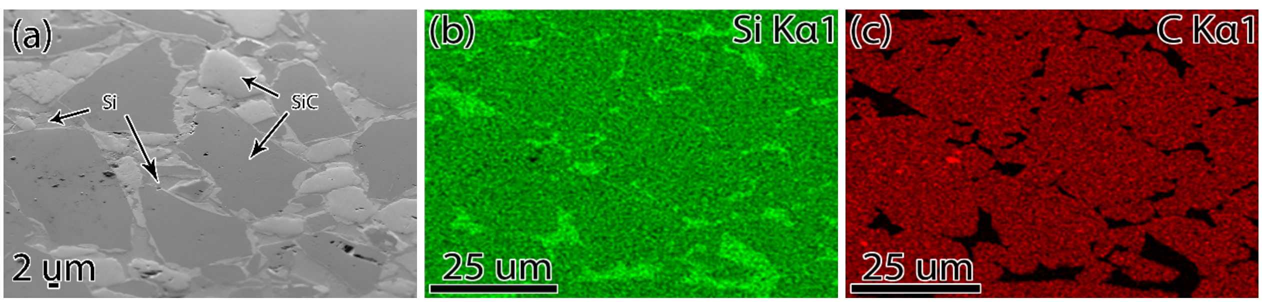

Figure 1. SEM images and EDS maps of RBSC composites: (a) SEM image of a polished RBSC surface, (c) Silicon map, (d) Carbon map.

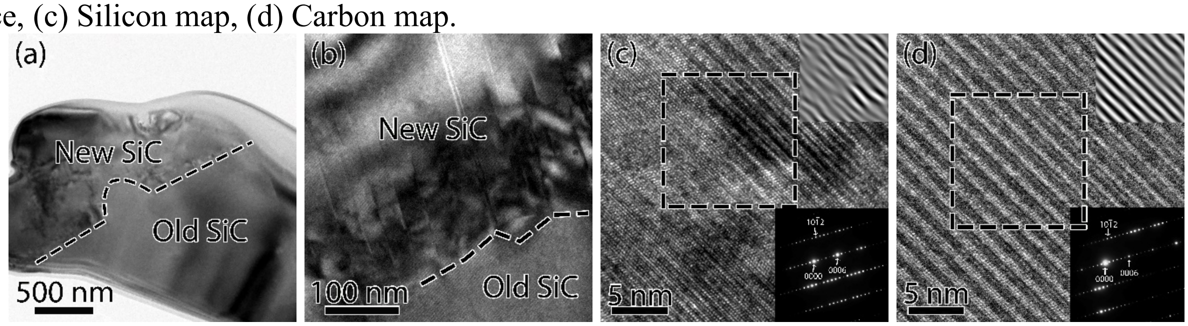

Figure 2. TEM images of an interface between "new" SiC and "old" SiC: (a) Low magnification image of the interface, (b) A sharp interface between "new" and "old" SiC, (c) HRTEM image of "new" SiC, (d) HRTEM image of "old" SiC.