Journal of Ceramic Processing Research. Vol. 10, No. 3, pp. 263~265 (2009)

J O U R N A L O F
Ceramic Processing Research

Joining of RBSiC using a preceramic polymer with Al

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Reaction-bonded silicon carbide (RBSiC) was joined using a preceramic polymer with Al as the filler. Commercial reaction bonded SiC was used for the joining experiments. The polymer-filler mixture powders were dissolved in isopropanol to produce a paste, which was then applied homogeneously to the surface of the specimens to be joined. The samples were subsequently overlapped to obtain a sandwich structure. Brazing experiments with Al as the filler were carried out in a vacuum furnace heated to 1000-1200 °C. The joining layer appeared fairly dense with good adhesion to the RBSiC. The highest strength of 206 MPa was obtained at 1200 °C for 30 minutes.

Key words: RBSiC, Joining, Preceramic polymer, Al.

Introduction

Over the past several years, there has been increasing interest in silicon carbide-based ceramics on account of their high strength and stability at high temperatures. However, the manufacture of complicated shaped components from these materials is difficult due to their poor workability. Therefore, joining techniques are attracting considerable attention. Joined parts can be made into a variety of shapes with tolerances that not readily achieved using other means. Various joining techniques, such as mechanical fastening, adhesive bonding, diffusion bonding, welding and brazing, have been reported [1-5]. Also preceramic polymers have been used to join RBSiC [6]. However, the mechanical strength was relatively lower than that of the other techniques. The purpose of this study was to join reaction-bonded SiC parts using a mixture of preceramic polymer and filler as the joint material. Mixtures of preceramic polymer and filler materials, such as Al, were used in paste form to join the RBSiC parts. The joining process was performed by brazing in a vacuum at 1000-1200 °C. The microstructure and mechanical properties of the joined parts were examined.

Experiments

Methylpolysilsesquioxane (MK, Wacker, Germany), with an average molecular weight of 9,400 g/mol, was chosen as the polymeric precursor for joining and Al was used as the filler. RBSiC was used in the joining experiments. This material was manufactured by the reaction bonding of coarse and fine powdered alpha-silicon carbide with Si using an infiltration process. The specimens were polished on one side using 6 μm grit SiC paper and cleaned ultrasonically with acetone prior to joining. The polymer/filler mixture was prepared by dry ball milling for 1 hour. The polymer-filler mixture powders were dissolved in isopropanol to yield a paste form. The paste was applied homogeneously to the surface of the specimens to be joined, and the samples were overlapped to obtain a sandwich structure. The specimens were heated to 250 °C for 2 h in air without pressure for curing. The samples were then heated to 1000-1200 °C for 30-60 minutes in a vacuum.

The microstructures of the joints were examined by scanning electron microscopy (SEM) with an energy dispersive X-ray spectrometer (EDX). The bending strength of the joints was measured using three-point bending tests. The bending tests were carried out at room temperature. After testing, the fracture surfaces were also examined by SEM.

Results and Discussion

Fig. 1 shows a SEM image and EDX line profiles of the specimen brazed with MK and Al as the filler at 1200 °C in a vacuum. A small amount of Al remained in the brazed layer. Small particles with a white color in the interface between the brazed layer and RBSiC are considered to be the oxide phase derived from the pyrolysis of the polymer. The Si phase in the RBSiC replaces the Al phase in the brazed layer during heat treatment. On the other hand, Al diffuses into the RBSiC through the dissolution of Si to form a well-defined reaction zone [3]. Fig. 2 shows a SEM images of the specimens brazed with 100 vol.% Al(a) and 90 vol.%

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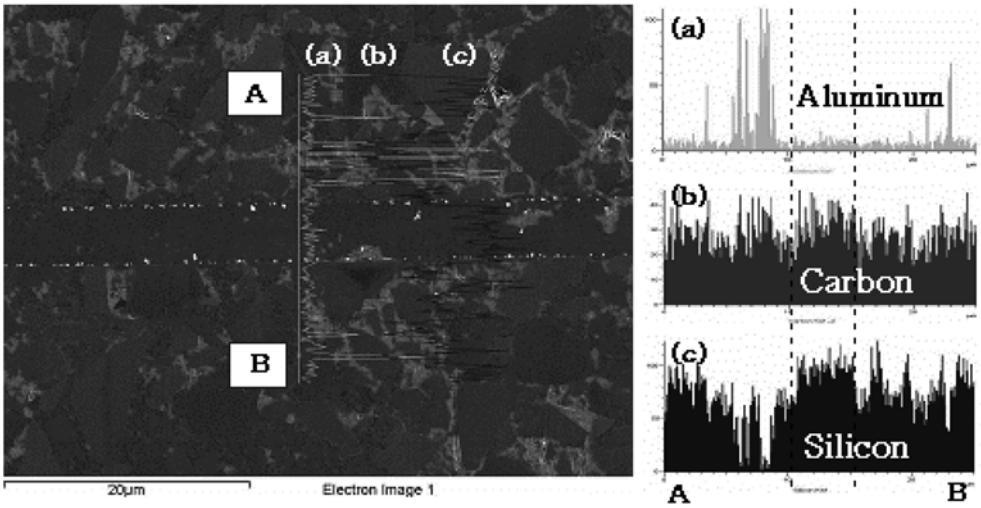

Fig. 1. Microstructure of RBSiC brazed at 1200 °C for 60 minutes : EDX line profile of the ceramic interlayer.

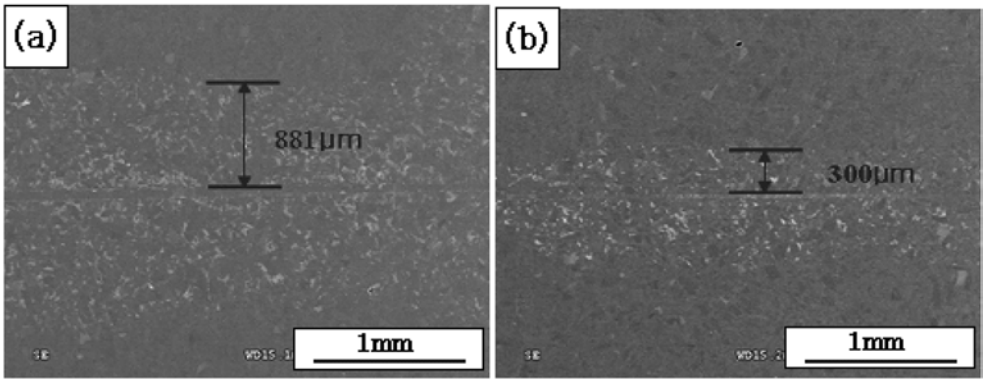

Fig. 2. Microstructures of RBSiC brazed with (a) Al and (b) 90 vol.% Al, 10 vol.% MK at 1200 °C for 60 minutes.

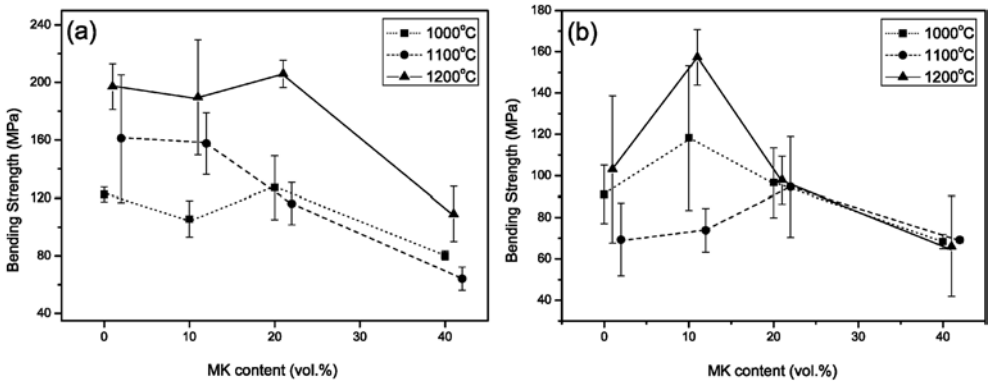

Fig. 3. Bending strength of the specimen brazed with various compositions at 1000-1200 °C for (a) 30 minutes and (b) 60 minutes.

Al and 10 vol.% MK(b) at 1200 °C in a vacuum. The thickness of the reaction layer brazed with MK was lower than that of the specimen brazed with pure Al. It is believed that the thickness of the reaction layer was inhibited by the Si-O-C glass phase derived from MK during pyrolysis.

Fig. 3 shows the bending strength as a function of the MK content. The strength of the RBSiC brazed for 30 minutes were preserved up to 20 vol.% MK, and then decreased with further increases in the MK content (Fig 4(a)). The strength of the brazed RBSiC was also dependent on the brazing temperature. The strength of the brazed RBSiC increased with an increase with brazing temperature. The highest strength of 206 MPa was obtained with the specimen brazed with 20 vol% MK at 1200 °C for 30 minutes. Lower strengths were obtained in the case of the RBSiC brazed for 60 minutes (Fig 4(b)) than those from the RBSiC brazed for 30 minutes.

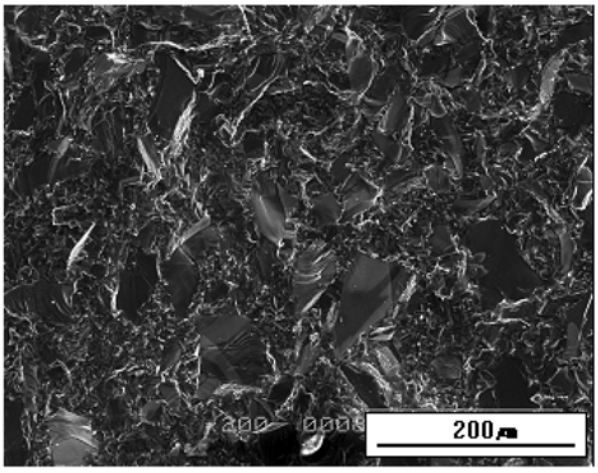

Fig. 4. Fracture surface of a brazed RBSiC.

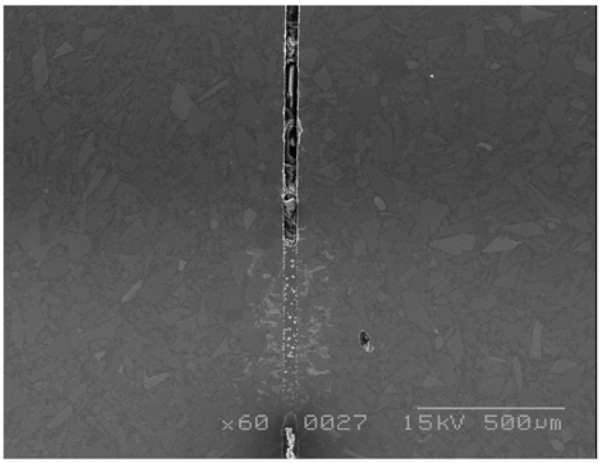

Fig. 5. Microstructure of RBSiC brazed with 60 vol.% Al, 40 vol.% MK at 1200 °C.

However, a different trend was observed. With increasing MK content, the strength increased with the maximum being obtained at 10 vol.% MK. When the brazing time was extended, the amount of brittle Al_4C_3 phase increased, which resulted in a decrease in strength [3]. When MK was added, the reaction zone with Al was reduced and the influence of the brittle phase was also reduced.

Fig. 4 shows the fracture surface of a specimen brazed with 80 vol.% Al and 20 vol.% MK at 1200 °C for 30 minutes in a vacuum. Large SiC particles were found in the fracture surface. This means that fracture occurred in the bulk ceramic not in the brazed region.

Fig. 5 shows a SEM image of a specimen brazed with 40 vol.% MK at 1200 °C for 30 minutes in a vacuum. Pores were observed in the joint layer, which reduced the strength of the specimen. It is believed that the flow of the Al melt was inhibited by the Si-O-C glass phase derived from MK during brazing resulting in low densification.

Conclusions

Mixtures of preceramic polymer and Al as a filler were used to join RBSiC. The Si phase in the RBSiC was found to replace the Al phase in the brazed layer during heat treatment. On the other hand, Al diffused into the RBSiC through the dissolution of Si to form a well-defined reaction zone. The strength of the brazed RBSiC was preserved up to 20 vol.% MK but decreased with further increases in MK content. The strength increased when the brazing temperature was increased from 1000 °C to 1200 °C. The highest strength of 206 MPa was obtained at 1200 °C for 30 minutes.

Acknowledgments

This study was supported by the Ministry of Commerce, Industry and Energy, Republic of Korea.

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