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THE INTERFACE MICROSTRUCTURE OF SIC_f/AL COMPOSITES

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SUMMARY: The interface microstructure of several types of PCS-SiC_f/Al composites has been studied by means of TEM technology. The interface of composite wires fabricated by ultrasonic liquid infiltration shows no reaction occurred between the fiber and aluminum. So does the composite plate obtained by solid diffusing of composite wires at the temperature about 520°C for 1h. A HREM analysis indicates a good physical bonding of the fiber and aluminum. The interface of composites after heat treatment has also been studied by TEM. No obvious reactant observed at 550°C for 60min. While the temperature rise to 650°C there appears a 100nm wide reaction zone at the interface area.

KEYWORDS: SiC_f/Al composite, interface reaction, microstructure, heat treatment, physical bonding

INTRODUCTION

It is well known that the interface is very important to the properties of metal matrix composites[1,2]. The interfacial microstructure which is determined mainly by the types of fiber and matrix, fabricating process and heat treatment directly affects the interfacial bonding strength. It is proposed by some researchers that the tensile strength of composites increased with increasing bonding strengths in metal matrix composites[3]. However, other researchers[4] pointed out that because the variety of interfacial bonding strengths is always accompanied with interfacial reactions between the fibers and matrices which induced a interfacial brittle phase, it is often the case that there exists a moderate interfacial bonding strength with which the composites possess the best mechanical properties.

SiC is the most stable thermodynamically fiber for SiC-Al interface comparing to other reinforcements of aluminum composites such as carbon, alumina, potassium titanate and so on. However, many studies[5,6] showed that it is necessary to control the contact time of the fiber with liquid aluminum in order to obtain SiC/Al composites with excellent properties.

In this paper, the interfacial microstructure of as-received and thermal exposed PCS-SiC/Al composites has been investigate by means of TEM. The aim is to evaluate the flexibility of the fabricating process including ultrasonic liquid infiltration method for composite wires and

high temperature solid diffusing method for composite plates.

EXPERIMENTAL

PCS SiC fiber with a trade name of Nicalon reinforced industrial pure aluminum composite wires were prepared by an ultrasonic liquid infiltration method[7]. A tow of fibers passes through a crucible containing molten aluminum (about 680°C), a high intensity ultrasonic (500W, 18~20kHz) was delivered to the molten aluminum by a horn to exerted a high intensive ultrasonic field around each fiber. The aluminum melt infiltrate into the fiber bundle in virtue of the ultrasonic energy and then a composite wire with a diameter of 0.5mm obtained after it being pulled out from the crucible. In this process, the contact time of fiber and molten aluminum can be controlled to less than a second and therefore the interfacial reaction is expected to be restrained. The SiC_f/Al composite plate was obtained by plying the composite wires mentioned above in a mould and exerting high pressure at a temperature about 520°C for 30min to achieve complete solid diffusing bonding between wires. The composite wires was heat treated at 550°C and 650°C for 60min respectively.

Both the as-received and heat treated SiC/Al composites (wires and plates) have been examined in TEM. The samples for TEM study were prepared as follows. Firstly, the composite wires were ground along the longitudinal fiber direction to a thickness of 70~100μm. The composite plates were cut along the transverse or/and the longitudinal fiber direction and ground to the same thickness as the wires. Subsequently, specimens were mechanically thinned further in a Gatan dimple grinder to a thickness of 10~30μm. Finally, the specimens were thinned to perforation in a argon ion beam milling apparatus. Thinned specimens were examined in a JEM-2010 transmission electron microscope equipped with Oxford Link Isis EDX .

RESULTS AND DISCUSSION

Interface of as-received Composites

The interface microstructures of several as-received SiC_f/Al composites are shown in Fig.1. The interface is very clear as shown in the TEM micrographies and the SAD results. It indicates that good physical bonding achieved and no obvious interfacial reaction occurred during the fabricating process. So it was proved that the SiC fiber has satisfied chemical compatibility with aluminum and on the other hand the fabricating process is suitable for SiC fiber reinforced aluminum composites.

For SiC-Al system the primarily occurred interfacial reaction is

$$3SiC+4Al=3Si+A1_4C_3$$

The reaction is thermodynamically possible because from the free energy of formation for $A1_4C_3$ (-215.8kJ/mol) and that for SiC(-67.0kJ/mol) [8] the standard free energy change for this reaction is estimated to be –14.8kJ/mol. However, it is not a large value and the driving energy of the reaction is limited.

Usually the reactant Al_4C_3 appears as needle or slice like on the interface toward the matrix side in TEM micrograph[9]. The fact that no Al_4C_3 was observed in this study means the reaction

mentioned above is not occurred during the preparation of the SiC/Al composite wires and plates. It is pointed out that the contacting time between fiber and aluminum at high temperature (~700℃) is no more than one second and the hot-press time of composite plates at ~520℃ is less than 30min. So it is believed that no interface reaction occurred under the current fabricating process.

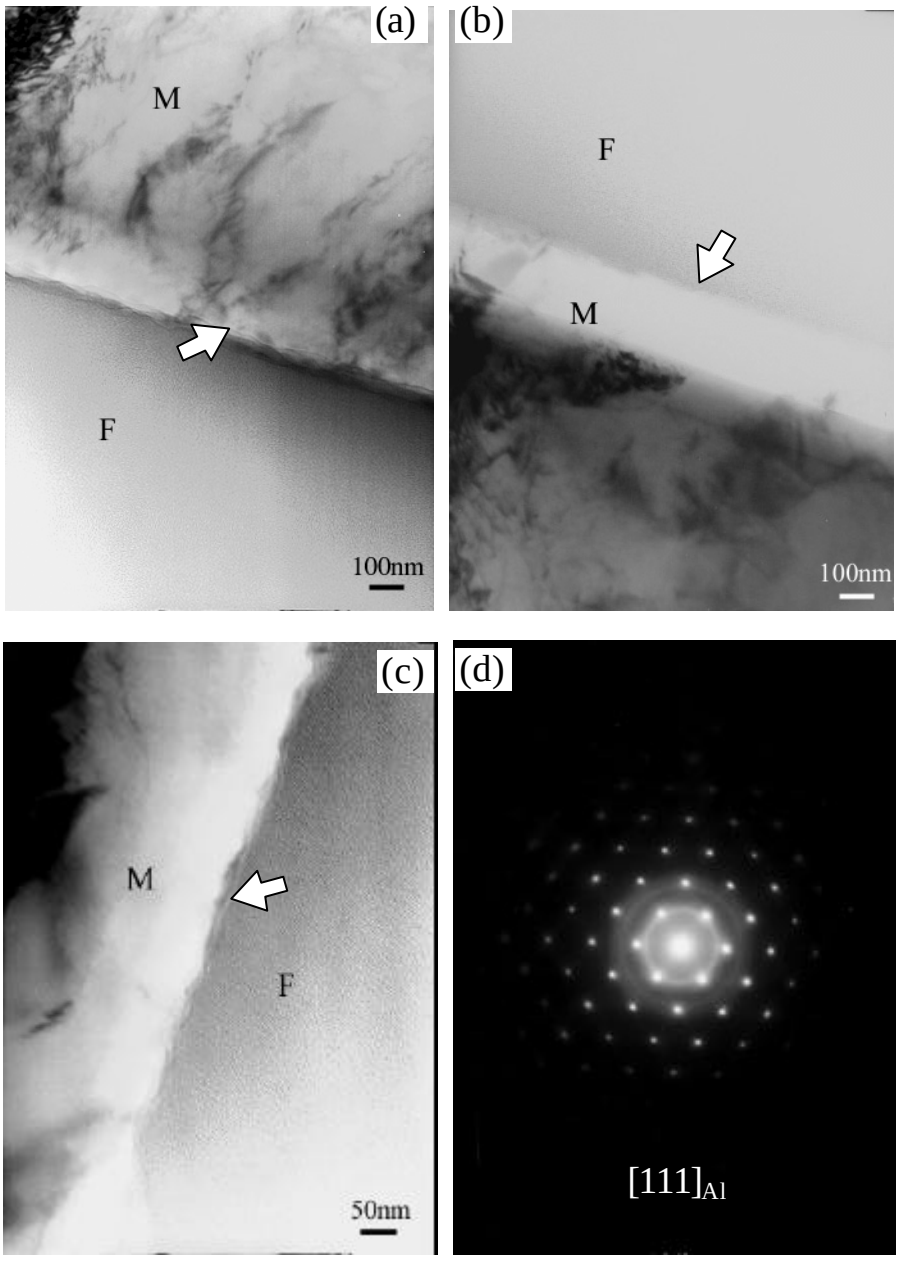


Fig.1 Interface TEM micrographies and SAD results (M denotes matrix and F denotes fiber)

(a) composite wires; (b, c) composite plate; (d) SAD pattern of interface show the [111] pattern of aluminum and diffraction circles of SiC fiber

The high resolution TEM interface microstructure of SiC_f/Al as shown in Fig.2 farther proves a clean and good bonded interface. No reactant of any size observed from the interface area.

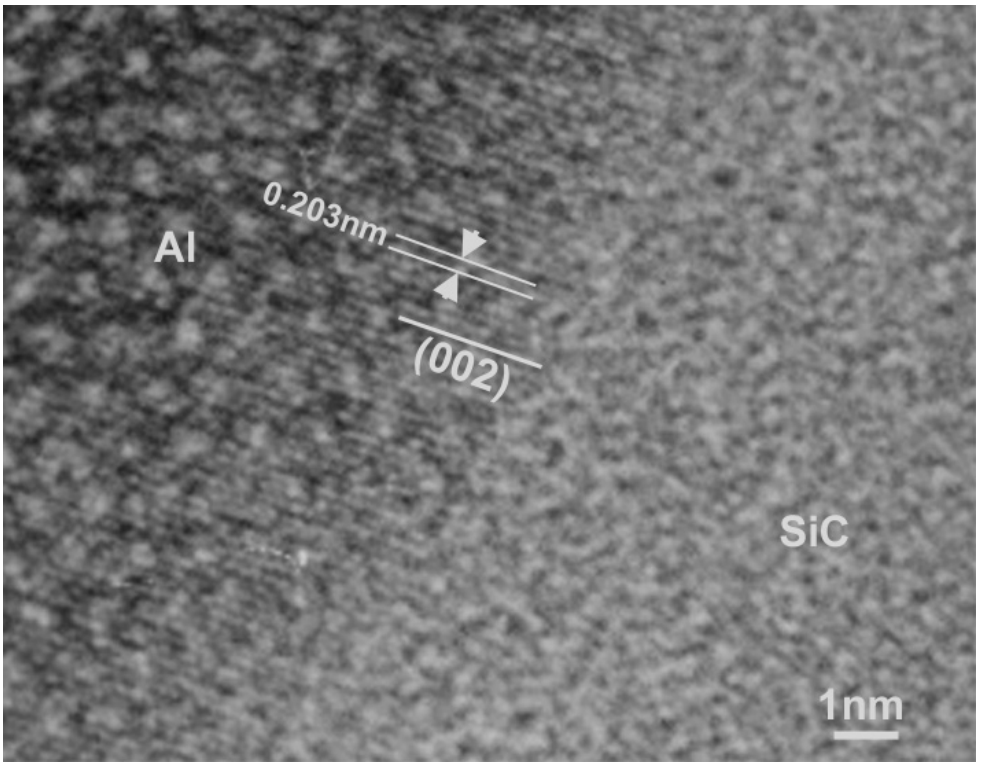


Fig.2 High resolution TEM micrograph of SiC/Al

Interface of Thermal Exposed Composites

The interface of composites after thermal expoure has also been studied by TEM. No obvious reactant was observed at 550°C for 60min as showed in Fig.3. The purpose of thermal exposure of the composite wires at 550°C is to ensure the chemical stability of fiber-matrix interface under the condition of hot-press process. It is proved from the TEM images that the hot-press temperature (~520°C) is feasible for SiC/Al composites.

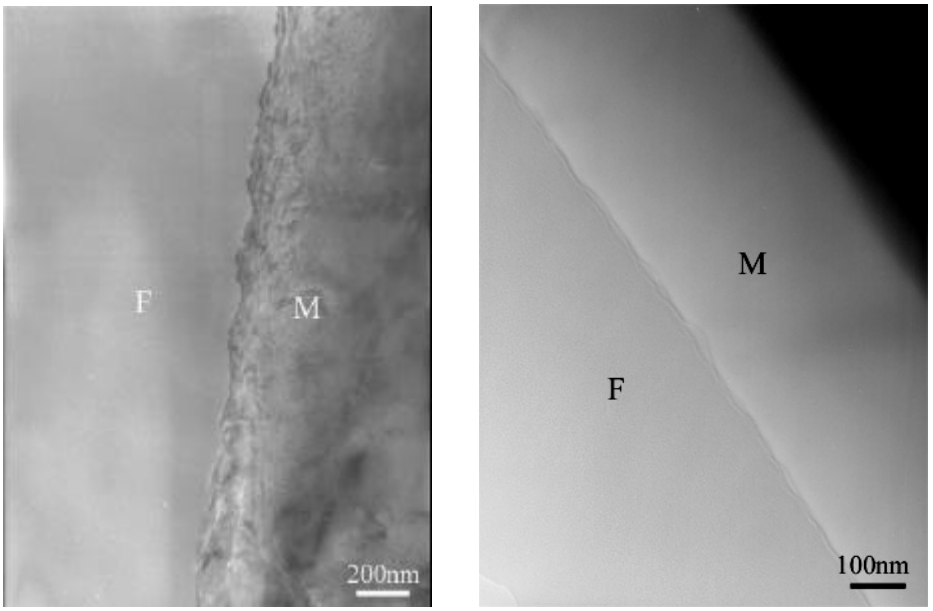
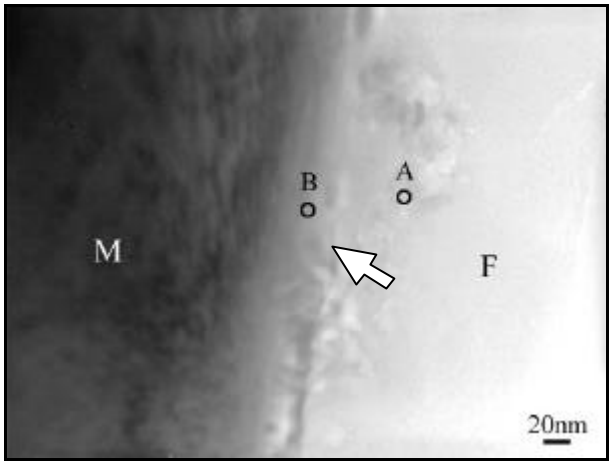


Fig.3 TEM interface micrographies of SiC/Al composite wires after thermal exposure at 550°C×60min

While the temperature rise to 650°C, there appears a 100nm wide reaction zone at the interface area. It is reported that when the thermal exposure temperature exceeds 600°C (for 30min) the tensile strength of SiC fiber decreased rapidly[10], which indicates that the fibers react with the aluminum at this time. However, the reactant is still in very small size and no needle or slice like Al_4C_3 was observed.



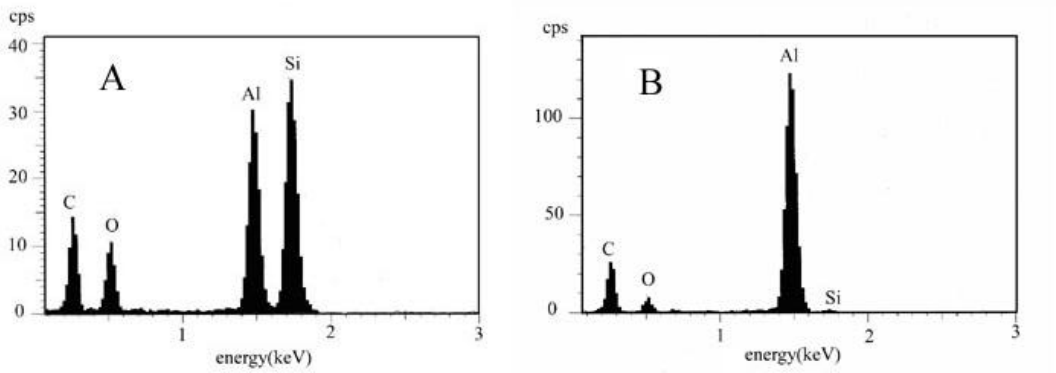


Fig.4 TEM micrograph and EDX results of SiC/Al composite wires after thermal exposure at 650°C×60min (the arrow shows the interface position, A area is in the fiber and B area is in the matrix near interface)

CONCLUSION

(1) The as received SiC_f/Al composites, including wires fabricated by ultrasonic liquid infiltration method and plates made by hot-press solid diffusing process, possess a good physical bonding interface without any visible reactant.

(2) The SiC_f/Al composites which were thermal exposed at 550°C for 60min remain a unchanged interface in appearance.

(3) A reaction zone comprising very small reactant was observed at the interface area of SiC/Al composite wires after thermal exposed at 650°C for 60min.

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