SiC FIBRE-REINFORCED Ti-BASED COMPOSITE①

Lu Yuxiong, Li Douxing, Shi Nanlin, Ma Zhongyi, Bi Jing
Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110015

ABSTRACT A CVD SiC fibre-reinforced Ti-based composite was prepared by vacuum hot-press diffusion bonding technique. The SiC fibre has an amorphous carbon-rich surface coating of about 1 μm in thickness. TEM observations showed that TiC and Ti_3Si_5 are formed in the interface region due to the reaction of SiC-Ti during the high temperature preparing process, but the amorphous carbon-rich layer of the fibre can be kept and the fibre-matrix can be bonded well if the fabricating parameters selected are reasonable. The room temepratures tensile strength and elastic modulus of SiC_f(35% in volume)/Ti-15V-3Cr-3Sn-3Al composite are 1284 MPa and 210 GPa respectively.

Key words CVD SiC fibre β-Ti alloy vacuum hot press diffusion bonding technique SiC_f/Ti composite

1 INTRODUCTION

Continuous CVD SiC fibre-reinforced titanium-based composite (SiC_f/Ti composite) is one kind of advanced composite. Because SiC_f/Ti composites have high specific strength, high specific modulus and elevated temperature properties and prove to withstand the aerodynamic loads and extreme temperature required for hypersonic flight, SiC_f/Ti composites had entered into commercial manufacture abroad. It is reported[1] that Textron Speciality Materials of U.S.A had established production facility and operated in 1993. The facility′s initial goal is a monthly production rate of 400 hat-type structural shapes and 60, 1.2 m square skin panels for NASP fuselage section. But the study on SiC_f/Ti composite is just in the beginning at home[2].

Under the condition of high temperature and pressure, the reinforcement is easy to react with reactive titanium matrix and the resulting brittle reaction products can degrade the properties of the MMCs. It is very important to make good compatibility between fibre and matrix and to control interface reaction in the fabricating process of composites.

The objectives of the present study are to investigate reasonable fabricating technology of SiC_f/Ti composite, characters of CVD SiC fibre and titanium matrix, mechanical properties and fracture morphology of composite and to assess the degree of interfacial reactions. Microstructural assessment techniques included optical microscopy, scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

2 PROPERTIES OF CVD SiC FIBRE

The SiC fibre is fabricated by a radio-frequency (r.f) heating CVD technique. A continuous tungsten wire substrate of 12 μm in diameter passed into a tubular reactor at a deposition temepratures of about 1300 ℃. A mixture of hydrogen and silanes was fed into the reactor, a chemical vapour deposition took place and SiC deposited on the wire to form SiC fibre. A carbon-rich protective amorphous layer of about 1 μm thick was coated on the surface of SiC fibre in order to relax the susceptibility of surface damage and prevent the degradation of the fibre during the preperation of SiC_f/Ti composite. The uniaxial tensile strength distribution of the fibre at room temperature exhibits a sharp maximum with a moderate negative skewness. The average of the strength is 3700 MPa with a diameter of 100 μm. The elastic modulus is 410 GPa.

① Received Jan. 30, 1996; accepted Jun. 15, 1996

The SiC fibre possesses good high temperature stability and oxidation resistance. The properties of the SiC filaments can be kept after 72 h heat treatment at 850 ℃ in air.

3 SELECTION OF TITANIUM MATRIX

In this study the titanium matrix was Ti-15-3 alloy. The chemical composition(%) of the matrix was found to be Ti, 76.0; V, 15.5; Al, 2.78; Cr, 2.1; Sn, 3.6 and Si, 0.5 using EDX analyzer. It is a kind of metastable beta alloy in which the beta phase stability reflected by the molybdenum equivalency is above 8%. The Ti-15-3 matrix consisting of a *bcc* crystal structure possesses good formability, strength and corrosion resistance. It can be relatively easily fabricated to thin gage foils and the reaction zone can be reduced using lower temperature fabrication.

4 PROCESSING OF SiC_f/Ti-15-3 COMPOSITE

Reactive matrices, such as titanium-based alloys, are currently limited to solid state processing at relatively low temperature. In this study the composite was fabricated by the foil-fibre lay-up process which is most widely used for Ti alloy MMCS. SiC fibres are held in place with a fugitive binder to make fibre mats. Unidirectional mats of fibre are sandwiched between alternate layers of Ti-15-3 alloy foil. The SiC_f/Ti-15-3 composite was consolidated using vacuum hot-press diffusion bonding process employing pre-established temperature-pressure curve as shown in Fig. 1.

5 MICROSTRUCTURE, INTERFACE CHARACTER AND MECHANICAL PROPERTIES OF COMPOSITE

Fig. 2 is a chemically etched cross-section of the as-fabricated composite showing the metallo-

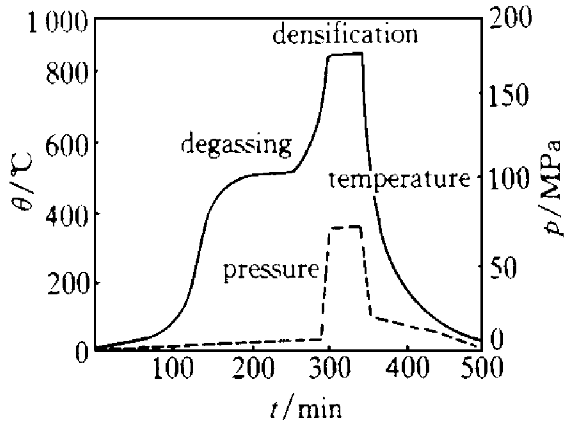

Fig. 1 Temepratur-pressure curve of vacuum hot press diffusion bonding for SiC_f/Ti-15-3 composite

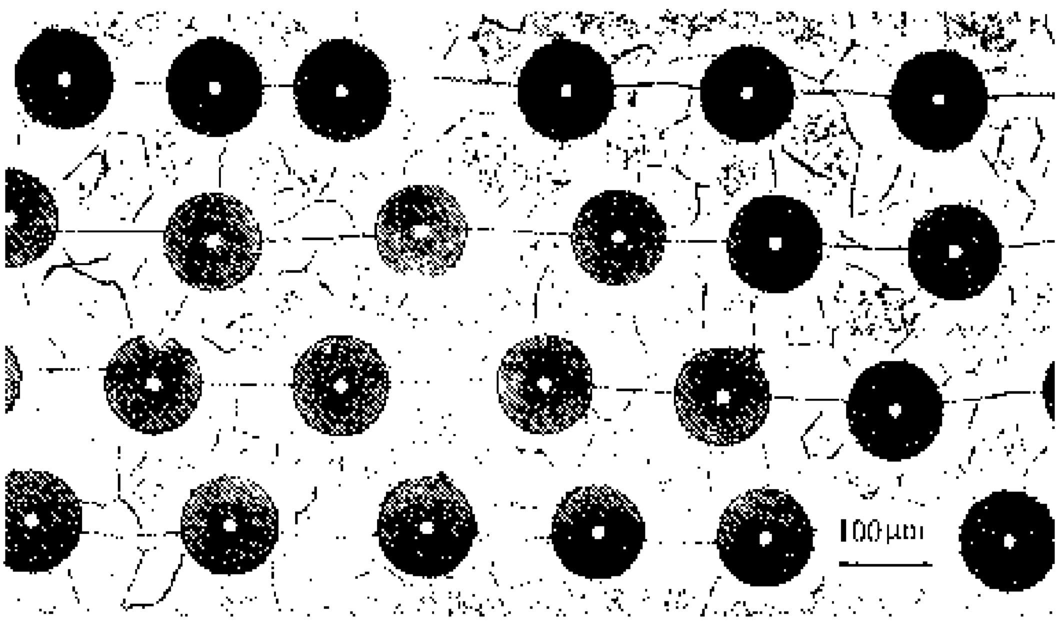

Fig. 2 Microstructure of SiC_f/Ti-15-3 composite

graphic structure. Because of the plastic deformation of the matrix around the fibres the average grain size in areas surrounding the fibres is smaller than that of the matrix material. The deformation is necessary to achieve good fibre/matrix bonding. It can be seen that interfaces of fibre/matrix and foil to foil have been completely bonded. SEM observations showed that the thickness of interface reaction region is about 700 nm (Fig. 3) in this processing condition. In the contrast, interfaces can not achieve complete bonding (Fig. 4) or form massive reaction products, when processing is unreasonable or the compatibility between SiC fibre and Ti-matrix is bad.

TEM observations shows that in the high temperature preparing process SiC fibres react with the Ti-matrix. The morphology of the SiC/Ti interfacial region is shown in Fig. 5. It is evident that in the interfacial region the surface carbon-rich amorphous layer of SiC fibre has not yet been destroyed. Due to different matrix compositions, interfacial reaction products reported by researchers are not as the same[3-6]. For example, in this study from the observations of interfaces it is found that β-SiC particles of size 2 ~ 20 nm (Fig. 6) are dispersed in fibre surface carbon - rich layer near the fibre. In the mean time, reaction products are discovered. It is identified by HREM that resulting reaction

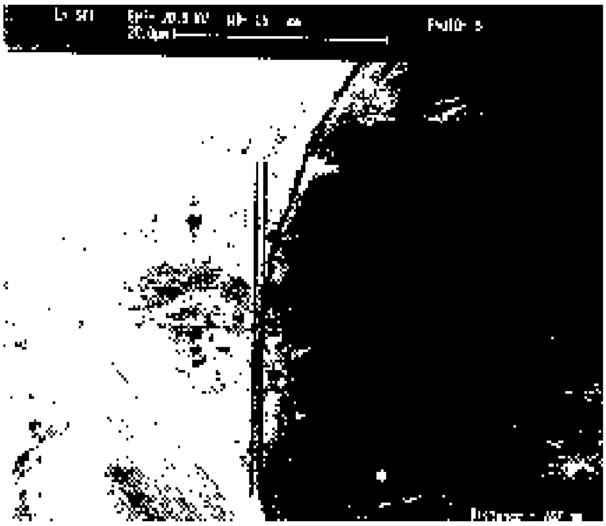

Fig. 3 Interfacial reaction zone between SiC_f and Ti-15-3

Fig. 4 Inferior bonding between fibre and matrix

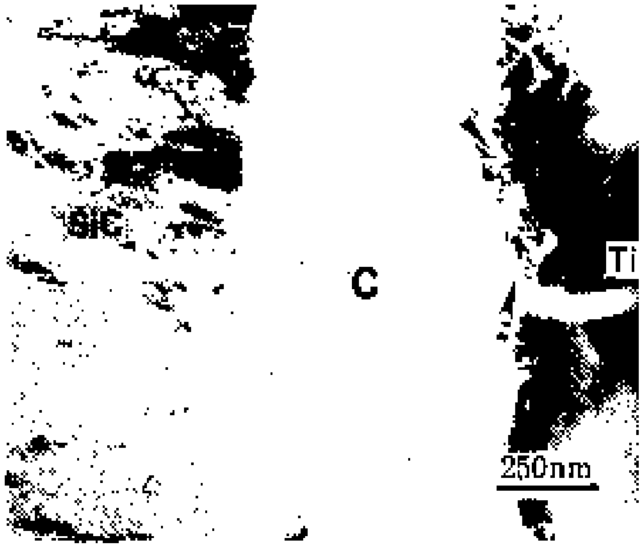

Fig. 5 Morphology of SiC_f/Ti-15-3 interfacial region

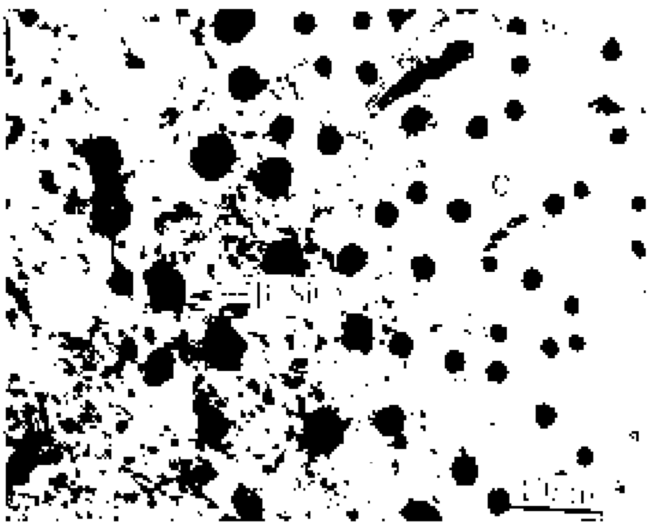

Fig. 6 Dispersive β-SiC particles in amorphous layer

products are TiC and Ti_5Si_3[7]. The interaction type between SiC fibre and Ti-matrix is as follows:

$$8Ti + 3SiC = 3TiC + Ti_5Si_3$$

Fig. 7 shows the morphology of interfacial reaction products.

Fig. 7 Morphology of interfacial reaction zone

The room temperature tensile strength obtained is 1 284 MPa and elastic modulus is 210 GPa at SiC fibre volume fraction 35%. Fig. 8 shows the fracture character on tensile specimen at room temperature. SiC fibres are prone to pulling out to some degree. Because SiC fibre is very brittle the fracture surface of fibre is quite flat and the fracture surface of titanium alloy is ductile dimple pattern.

6 CONCLUSIONS

The continuous SiC fibre reinforced titanium alloy composite was fabricated using CVD SiC fibre and Ti-15V-3Cr-3Sn-3Al matrix via vacuum hot-press diffusion bonding technique. When fabricating parameters selected are reasonable, SiC fibres have good bonding with Ti-matrix. Although in the high temperature preparing process SiC fibre had reacted with Ti-matrix, it is identified that in the interfacial region the surface carbon-rich amorphous layer of SiC fibre is not destroyed. In the reinforcing condition of 35% SiC fibre, the room temeprature tensile strength and elastic modulus of SiC_f/Ti-15-3 composite are 1 284 MPa and 210 GPa respectively.

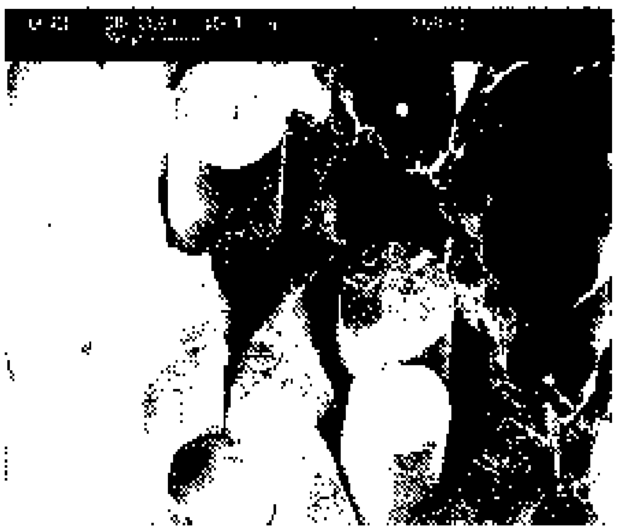

Fig. 8 Tensile fracture morphology of SiC_f/Ti-15-3 composite

REFERENCES

1 Textron Speciality Materials. Metallurgia, 1992, July: 236.
2 Lu Yuxiong, Bi Jing, Shi Nanlin, Ma Zhongyi. Chinese Journal of Materials Research, 1996, 10(3): (in press).
3 Hall E L, Ritter A M. J Mater Res, 1993, 8: 1158.
4 Lerch B A, Hull D R, Leonhardt T A. Composites, 1990, 21: 216.
5 Bilba K, Manaud J P, Petitcorps Y L, Quenisset J M. Mater Sci Eng, 1991, A135: 141.
6 Hall I W, Lirn J L, Lepeticorps Y, Bilba K. J Mater Sci, 1992, 27: 3835.
7 Yu Liguo, Lu Yuxiong, Li Douxing, Ye Hengqiang. Acta Metallurgica Sinica, 1996, 32(3): 318.

(Edited by Peng Chaoqun)