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Microstructure and interface thermal stability of C/Mo double-coated SiC fiber reinforced γ-TiAl matrix composites

Xian LUO, Chao LI, Yan-qing YANG, Hai-man XU, Xiao-yu LI, Shuai LIU, Peng-tao LI

State Key Laboratory of Solidification Processing, Northwestern Polytechnical University, Xi'an 710072, China

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Abstract: C/Mo duplex coating interfacially modified SiC fiber-reinforced γ-TiAl matrix composite (SiC_f/C/Mo/γ-TiAl) was prepared by foil−fiber−foil method to investigate its interfacial modification effect. SiC_f/C/TiAl composites were also prepared under the same processing condition for comparision. Both kinds of the composites were thermally exposed in vacuum at 800 and 900 °C for different durations in order to study thermal stability of the interfacial zone. With the aids of scanning electron microscope (SEM) and energy dispersive spectrometer (EDS), the interfacial microstructures of the composites were investigated. The results reveal that, although adding the Mo coating, the interfacial reaction product of the SiC_f/C/Mo/TiAl composite is the same with that of the SiC_f/C/TiAl composite, which is TiC/Ti_2AlC between the coating and the matrix. However, C/Mo duplex coating is more efficient in hindering interfacial reaction than C single coating at 900 °C and below. In addition, a new layer of interfacial reaction product was found between Ti_2AlC and the matrix after 900 °C, 200 h thermal exposure, which is rich in V and close to the chemical composition of B_2 phase.

Key words: Mo coating; TiAl alloy; SiC fiber; titanium matrix composite; interfacial reaction; thermal stability

1 Introduction

For high-temperature structural materials used in the fields of aeronautics and astronautics, high working temperature, high specific strength, high specific modulus and good oxidation resistance are crucial indices. Concerning these merits above, titanium aluminide intermetallics based on γ-TiAl have drawn growing attention [1]. In order to have better mechanical properties, continuous fiber reinforced γ-TiAl composites have been investigated by many researchers. Different fibers have been studied, such as Mo fiber, Ti fiber, Al_2O_3 fiber, TiNb fiber and CVD-SiC fiber [2−6]. Among them, only CVD-SiC fiber has the highest strength and modulus as well as the lowest density, so SiC fiber-reinforced γ-TiAl matrix composites have been paid much attention to.

However, the TiAl−SiC system is not a chemical equilibrium system, as fiber/matrix interfacial reaction would occur to form reaction products during the fabrication and utilization of the composites at elevated temperatures. It was reported that the interfacial reaction layer of SiC_f/Ti−43Al−9V composite is TiC/Ti_2AlC/$(Ti,V)_5(Si,Al)_3$ [7] and that of SiC_f/Ti−48Al composite is TiC/Ti_2AlC+Ti_3AlC/$(Ti,V)_5(Si,Al)_3$ [8]. Generally, these brittle reaction products are detrimental to mechanical properties of the composites. One of the effective approaches of slowing down interfacial reaction is the application of a barrier coating. For example, C coating, B_4C coating and Gd/GdB_x duplex coating have been utilized [9,10]. Most of these coatings show good performance on retarding interfacial reaction to some extent. However, for a coating, it is not sufficient to consider only its ability to reduce interfacial reaction, moreover, its thermal expansion compatibility is also very important.

In this work, C/Mo duplex coating was chosen to modify the interfacial zone of the SiC fiber reinforced γ-TiAl matrix composite (SiC_f/γ-TiAl). The idea is based on the following five considerations: 1) Coefficients of thermal expansion of the two coatings (C: 10×10^{-6} °C^{-1},

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Corresponding author: Xian LUO; Tel: +86-29-88460536; Fax: +86-29-88460499; E-mail: luoxian@nwpu.edu.cn

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Mo: (5.8−6.2)×10^{-6} °C^{-1}) [11] coordinate with that of SiC fiber (4.5×10^{-6} °C^{-1}) and the γ-TiAl matrix ((12−14)×10^{-6} °C^{-1}) [12,13]; 2) Mo coating is a ductile coating, and can relieve thermal residual stresses; 3) Both of the coatings can reduce the interfacial reaction to some extent [14−17]; 4) Mo is a β-stabilizer of titanium alloys. Once Mo atoms diffuse into TiAl matrix, the ductility of the matrix can be improved [18]; 5) C and Mo display good chemical stability with each other [19]. Our previous study of SiC_f/C/Mo/Ti6Al4V composite also indicates that the two coatings can exist harmoniously below 900 °C [16].

In order to evaluate the modification effect of C/Mo duplex coating on SiC fiber-reinforced γ-TiAl matrix composite, single C coating with the same thickness was used for comparison. The interfacial microstructures and thermal stability of the SiC_f/C/TiAl and SiC_f/C/Mo/TiAl composites were comparatively studied under the same conditions.

2 Experimental

Ti−43Al−9V foils were utilized as matrix of the composites, which mainly contain γ phase as well as some α_2 and B_2 phases. The initial microstructure of the foils was near lamellar structure [20]. The reinforcement SiC fiber (100−120 μm in diameter) applied in this work was fabricated in China by chemical vapor deposition (CVD). The fiber has a tungsten core with a diameter of about 12 μm. As shown in Fig. 1, two kinds of fiber coatings were prepared: 3.3 μm-thick C coating, and 2 μm-thick C coating + 1.3 μm-thick Mo coating, respectively. C coating was deposited by chemical vapor deposition (CVD) while Mo coating was deposited by magnetron sputtering. The composites were fabricated by foil–fiber–foil (FFF) method plus vacuum hot-pressing (VHP) under 1150 °C, 150 MPa, 40 min.

After the preparation of the composites, part of the composites were cut into small pieces for thermal exposure treatment in vacuum. The vacuum thermal exposure conditions include (800 °C, 100 h), (800 °C, 200 h), (900 °C, 100 h), (900 °C, 200 h) and (900 °C, 220 h), respectively. After that, metallographic specimens were prepared by conventional preparation methods of metallographic samples. Microstructures and chemical composition of the as-prepared and thermally-exposed composites were then studied by an SUPRA 55 SEM and an Oxford INCA EDS, respectively.

3 Results and discussion

3.1 Interfacial microstructure of as-prepared composites

Figures 2(a) and (b) show lower magnification

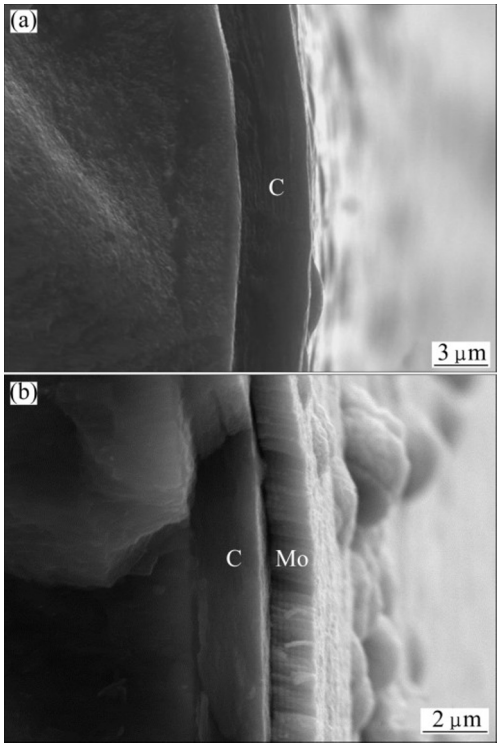

Fig. 1 Coating on surface of SiC fiber: (a) C single coating; (b) C/Mo duplex coating

micrographs of the as-prepared SiC_f/C/TiAl and SiC_f/C/Mo/TiAl composites, respectively. The black layer around the SiC fiber is C coating. The white layer in Fig. 2(b) next to the C coating is Mo coating. It can be seen that, although the two composites have the same total coating thicknesses (3.3 μm) before processing, C/Mo duplex coating performs better on blocking the interfacial reaction than C single coating. This good result is reflected on the thickness of interfacical reaction zone. Figures 2(c) and (d) are higher magnification micrographs of the interfacial zones of the two composites. One can further see that the interfacial reaction layer in the SiC_f/C/TiAl composite is distinctly thicker than that in the SiC_f/C/Mo/TiAl composite.

The interfacial microstructure of SiC_f/C/Ti−43Al−9V composite fabricated by FFF method plus VHP under 1150 °C, 150 MPa, 40 min has been investigated in Refs. [7] and [21]. Their results reveal that the interfacial phase sequence is SiC/C coating/TiC/Ti_2AlC/γ-TiAl from fiber side to the matrix. The only difference between ZHANG's study [7,21] and this work is the thickness of C coating, which are 1 μm and 3.3 μm, respectively. The thicker the C coating is, the longer duration it can block the chemical reaction between SiC and the matrix. So, the interfacial phase sequence of the as-prepared SiC_f/C/TiAl composite in this work should be also C coating/TiC/Ti_2AlC.

In order to study the element distribution