Phase Orientation of $TiC-TiB_2-SiC$ Ternary Eutectic Composite Prepared by an FZ Method

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Abstract

$TiC-TiB_2-SiC$ system was a ternary eutectic, whose eutectic composition was $34TiC-22TiB_2-44SiC$ (mol%). $TiC-TiB_2-SiC$ ternary eutectic composite were synthesized by a floating zone method using TiC, TiB_2 and SiC powders as starting materials. The $TiC-TiB_2-SiC$ eutectic composite showed a lamellar texture. TiC(022), TiB_2(010) and SiC(111) of the eutectic composite were perpendicular to the growth direction. $TiC-TiB_2-SiC$ ternary eutectic composite had specific relationship among the crystal planes: TiC[011]//TiB_2[010]//SiC[112], TiC(200)//TiB_2(001)//SiC($\bar{4}02$) and TiC($\bar{1}11$)//TiB_2($10\bar{1}$)//SiC($\bar{2}20$).

Keywords : Ternary eutectic composite, $TiC-TiB_2-SiC$, Floating zone melting, Phase orientation

1. Introduction

$TiC-TiB_2-SiC$ system composites could be an excellent material possessing several combined properties of TiC, TiB_2 and SiC, such as excellent oxidation resistance, high hardness, electrical conductivity and thermal conductivity [1,2,3]. This kind of ceramic composite has been prepared by solid state sintering at high temperatures so far. On the other hand, our research group has applied melting-solidification methods to prepare the composites such as TiB_2-SiC [4], TiC-TiB_2 [5] and B_4C-TiB_2-SiC [6]. These systems were eutectic and had high hardness, good fracture toughness and high electrical conductivity. Moreover, we also studied the crystal orientation of eutectic phase in the binary eutectic composites of B_4C-TiB_2 [7] and B_4C-SiC [8] prepared by a floating zone (FZ) method. Though a few researchers reported the solid state sintering of the $TiC-TiB_2-SiC$ composites by hot-pressing and measured their mechanical properties [9,10], no study on the eutectic composition of $TiC-TiB_2-SiC$ and the crystal orientation of each eutectic phase were reported. In the present paper, $TiC-TiB_2-SiC$ ternary composites were prepared by an arc-melting method to investigate the ternary eutectic composition, and the ternary eutectic composite was prepared by a floating zone melting method. The growth direction and crystal orientation of each phase in the ternary eutectic composite were investigated.

2. Experimental and Results

TiC, TiB_2 and β-SiC powders were used as starting materials. The powders were mixed and pressed into pellets of 20 mm in the diameter and then melt-solidified by an arc-melting method. The mixture powders were isostatically pressed and sintered at 1873 K for 3.6 ks in Ar atmosphere. The rods were melted and directionally solidified by FZ using a Xe lamp heater in Ar atmosphere. The growth rate was controlled from 1.4 to 5.6×10^{-5} ms^{-1}. The crystal phase was identified by X-ray powder diffraction (XRD). The microstructure was observed by scanning electron microscope (SEM) and transmission electron microscope (TEM). The crystal orientation of the eutectic phase was investigated by electron diffraction (ED).

The phases of the $TiC-TiB_2-SiC$ composites were cubic TiC, hexagonal TiB_2 and cubic β-SiC, and no other phase appeared. Figure 1 demonstrates the $TiC-TiB_2-SiC$ ternary phase diagram. The binary eutectic points were abbreviated as BE1 for $40TiB_2-60SiC$ (mol%) [4] and BE2 for $28TiB_2-72TiC$ (mol%) [5]. TiC-SiC system was also binary eutectic. The eutectic composition was not clarified because

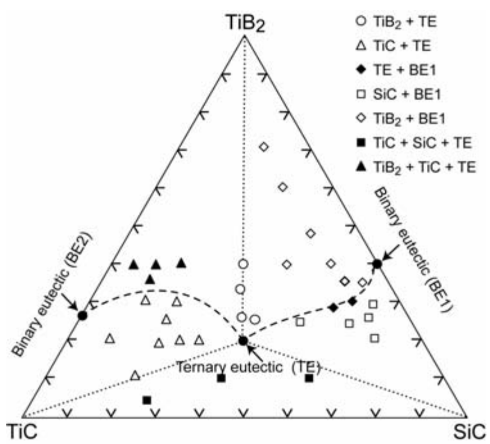

Fig. 1. Phase diagram of $TiC-TiB_2-SiC$.

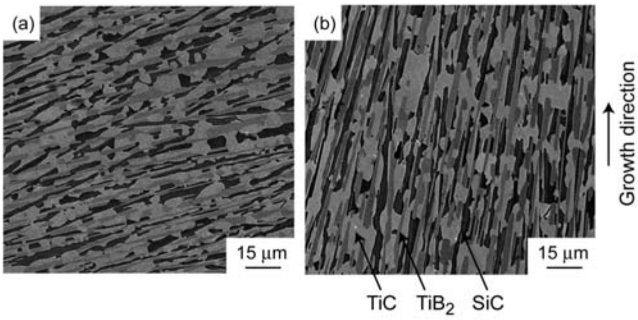

Fig. 2. SEM images of $TiC-TiB_2-SiC$ eutectic composite. (a) perpendicular and (b) parallel to growth direction.

SiC easily decomposed and evaporated at high temperature. The $TiC-TiB_2-SiC$ ternary eutectic composition was determined as $34TiC-22TiB_2-44SiC$ (mol%) and abbreviated as TE. Figure 2 shows the SEM photographs of the $TiC-TiB_2-SiC$ eutectic composite prepared by FZ at the cross-section perpendicular (a) and parallel (b) to the growth direction. TiC, TiB_2 and SiC grains showed lamellar texture of 3, 3 and 2 μm in the thickness, respectively, and paralleled to each other along the growth direction (Fig. 2 (b)). The intensities of TiC(220), TiB_2(100), and SiC(111) peaks in the ternary eutectic composite were significant, whereas the strongest peaks of each component in the powder sample should be TiC(200), TiB_2(101) and SiC(111). Therefore, TiC(220), TiB_2(100) and SiC(111) planes could be almost perpen-dicular to the growth direction of the ternary composite.

Figure 3 shows the TEM image of $34TiC-22TiB_2-44SiC$ (mol%) ternary eutectic composite prepared by FZ at the cross-section perpendicular to the growth direction (a) and the electron diffraction patterns at the interface of $TiC-TiB_2$ (b) and TiB_2-SiC (c). The spots from TiB_2 were underlined. The ED patterns of TiC[011] and TiB_2[010] were obtained at the interface of TiC and TiB_2, implying these zone axis were parallel to each other (Fig. 3 (b)). TiC(200) and TiB_2(001) located at the solid line across the (000), suggesting these planes parallel. TiC($1\bar{1}1$) and TiB_2($10\bar{1}$) located at the dash line through the (000), indicating these planes also parallel. At the interface of TiB_2 and SiC grains, the relationship of TiB_2[010]// SiC[112], TiB_2(001)//SiC($40\bar{2}$) and TiB_2($10\bar{1}$)//SiC($\bar{2}02$) were obtained (Fig. 3 (c)). Therefore, the ternary eutectic composite prepared by FZ had the parallel relation direction and planes: TiC[011]//TiB_2[010]//SiC[112], TiC(200)// TiB_2(001)//SiC($40\bar{2}$) and TiC($1\bar{1}1$)//TiB_2($10\bar{1}$)// SiC($\bar{2}02$).

3. Summary

$TiC-TiB_2-SiC$ was a ternary eutectic system. The eutectic composition was $34TiC-22TiB_2-44SiC$ (mol%), and had a lamellar texture. TiC(022), TiB_2(010) and SiC(111) of the eutectic composite were perpendicular to the growth direction. $TiC-TiB_2-SiC$ ternary eutectic composite had the relationship among crystal planes: TiC[011]//TiB_2[010]// SiC[112], TiC(200)//TiB_2(001)//SiC($40\bar{2}$) and TiC($1\bar{1}1$)// TiB_2($10\bar{1}$)//SiC($\bar{2}20$).

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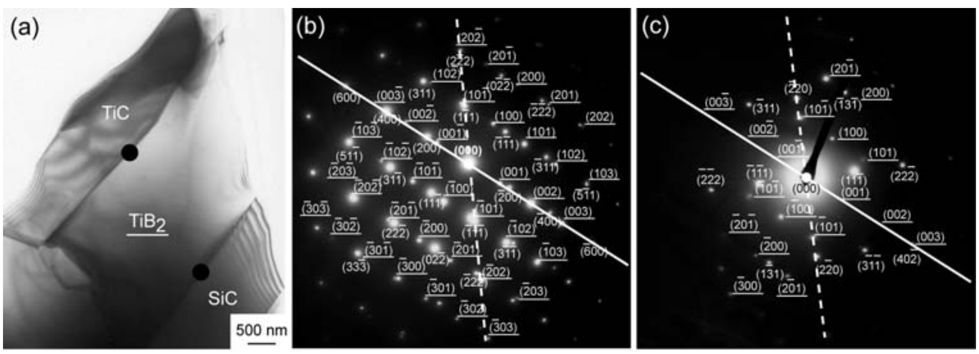

Fig. 3. TEM image of $TiC-TiB_2-SiC$ ternary eutectic composite perpendicular to growth direction (a) and the electron diffraction pattern at the interface of $TiC-TiB_2$ (b) and TiB_2-SiC (c). (underlines: TiB_2).