

## A Novel *in-situ* Synthesis Route of $\text{Ti}_3\text{SiC}_2$ -SiC Composite by Liquid Silicon Infiltration

LU Cui-Ying<sup>1,2</sup>, YIN Xiao-Wei<sup>2</sup>, LI Xiang-Ming<sup>2</sup>

(1. School of Chemistry and Chemical Engineering, Yulin College, Yulin 71900, China; 2. National Key Laboratory of Thermostructure Composite Materials, Northwestern Polytechnical University, Xi'an 710072, China)

**Abstract:** The aim of the present work was to prepare  $\text{Ti}_3\text{SiC}_2$ -SiC composite by using liquid silicon infiltration (LSI) from TiC/C preform. XRD, SEM and EDS were used to identify the formed phases and analyze the microstructures of the obtained composites. The results show that the composites are made of  $\text{Ti}_3\text{SiC}_2$  and small SiC. The surface morphologies of  $\text{Ti}_3\text{SiC}_2$  exhibit plate-like structure with the grain size of 3–10  $\mu\text{m}$ . The hardness of S1550-1, S1550-3 and S1550-4 is 6.8 GPa, 7.1 GPa and 7.8 GPa for a load of 10 kg, respectively. Their density is in the range of 3.55–3.96  $\text{g}/\text{cm}^3$ . All the experimental results prove that the novel *in situ* synthesis route of  $\text{Ti}_3\text{SiC}_2$ -SiC composite by LSI is feasible.

**Key words:** LSI; novel *in-situ* route of synthesis; TiC/C preforms;  $\text{Ti}_3\text{SiC}_2$ -SiC composites

The inability of monolithic ceramic to deform plastically and redistribute local stress is a crucial factor limiting its applications. This brittle failure behavior can be overcome by adding fiber, whisker, dispersed particles, etc. These addition processes are costly, complex and exhibit long manufacturing time, though they can improve the toughness of monolithic ceramic. In addition, the additions also decrease the mechanical properties and the reliability of ceramic. So, many researchers have been attempting to dope metals such as Al, Cu, Mo or Ti into ceramics to form ternary carbide phase ( $\text{M}_{n+1}\text{AX}_n$ ) ( $n=1-3$ ) to resolve the problem<sup>[1-4]</sup>, where M=early transition metal, A = an A-group element (usually group 13–14), and X=C or N. Among  $\text{M}_{n+1}\text{AX}_n$ ,  $\text{Ti}_3\text{SiC}_2$  system has been paid more attention recently because of its explicit industrial application prospects as a high temperature structural material in the temperature range of 1200–1400 °C.

The ternary carbide  $\text{Ti}_3\text{SiC}_2$  is an attractive new material for the combined merits of metals and ceramics. On the one hand, it has good thermal and electrical conductor, and relatively soft like metals. On the other hand, like ceramics, it is elastically stiff and exhibits excellent high temperature mechanical properties. It is resistant to thermal shock and unusual tolerant to damage. Above all, unlike conventional carbides, it is easy to be machined

by conventional tools without lubricant, which is of great technological importance for their applications. Some literatures reported that  $\text{Ti}_3\text{SiC}_2$  could improve the mechanical properties of C/SiC composites when it was added into composite matrix. Up to now,  $\text{Ti}_3\text{SiC}_2$  has been industrially applied in high speed train. It may also be potentially used in the fields such as high temperature structural materials, self-lubricating materials, electrode materials, etc.

Since  $\text{Ti}_3\text{SiC}_2$  was first synthesized by Jeit Schko *et al*<sup>[5]</sup> from  $\text{TiH}_2$ , Si and graphite at 2000 °C through chemical reaction and tested its crystal structure, some different synthesis routes have been tried such as combustion synthesis<sup>[6-8]</sup>, reactive sintering<sup>[9-10]</sup>, hot-pressing<sup>[11]</sup>, hot-isocratic pressing<sup>[12-13]</sup> and other methods. But they have yielded limited successes<sup>[8,10,14-15]</sup>. Moreover, thermodynamic phase diagram shows that the region of  $\text{Ti}_3\text{SiC}_2$  is very narrow. Hence, developing a new satisfying class of fabrication has been one of the focuses of  $\text{Ti}_3\text{SiC}_2$  fabrication.

Liquid silicon infiltration (LSI) is a cost-effective route to fabricate silicon-containing materials. It can undergo at lower temperature, shorter reaction time, and yield higher compact, net-shape material. It has the advantages of gas-phase reaction-bonding and chemical vapor infiltration. The reaction or deposition times are

Received date: 2010-01-25; Modified date: 2010-04-23; Published online: 2010-06-01

Foundation item: National Nature Science Foundation of China (50802074)

Biography: LU Cui-Ying (1968–), female, PhD, associate professor. E-mail: lucuiying126@126.com

Corresponding author: YIN Xiao-Wei, PhD, professor. E-mail: yinxw@nwpu.edu.cn

much shorter than those of gas-phase processes. The liquid silicon-carbon reaction is intermediate in rate between the slower gas-phase processes and the extremely fast "self-propagating high-temperature synthesis (SHS)" reactions. Recently, LSI has been also applied to fabricate composites. For example, the German Aerospace Centre (DLR) in 1990s developed C/C-SiC composites for space application<sup>[16]</sup>. However, up to now, there are no reports about fabrication of  $\text{Ti}_3\text{SiC}_2$ -SiC composite from TiC/C preform by LSI.

The objective of this work is to synthesize  $\text{Ti}_3\text{SiC}_2$ -SiC composite from TiC/C preform by LSI processing and characterize it. The reaction mechanisms are also presented.

## 1 Experimental procedures

### 1.1 Selection of raw materials

Ti, Si and C powders were usually used as raw materials for synthesis of  $\text{Ti}_3\text{SiC}_2$  ternary system. However, in the present work, TiC (1  $\mu\text{m}$  in diameter), Si (45  $\mu\text{m}$  in diameter) and C (50  $\mu\text{m}$  in diameter) powder were selected instead. The reasons are as follows, first, raw materials for synthesis are usually selected based on thermodynamic phase diagram. They must not be in the same stable equilibrium region in phase diagram because their identical chemical potential results in no reactions with each other<sup>[17]</sup>. It is known that the two groups of raw materials of Ti/SiC/C and TiC/Si/C are not in the same stable phase diagram, that is, have no identical chemical potentials respectively. Therefore, both the materials can be used to synthesize ternary system of Ti-Si-C. Second, literatures<sup>[11,18-19]</sup> reported that XRD main peak of TiC first increased, then decreased and even disappeared with increasing temperature during the synthesis of  $\text{Ti}_3\text{SiC}_2$  from Ti, Si and C powders, which indicated that TiC was the intermediate for  $\text{Ti}_3\text{SiC}_2$  formation. It reacted with other substances and changed easily into  $\text{Ti}_3\text{SiC}_2$  at some temperatures. Last, the partial replace of TiC of C and/or Ti could decrease the heat release from reactions and Si

evaporation, and facilitate the formation of  $\text{Ti}_3\text{SiC}_2$ .

### 1.2 Synthesis procures of $\text{Ti}_3\text{SiC}_2$

Synthesis procures of  $\text{Ti}_3\text{SiC}_2$  contained two steps. The first step was to fabricate the TiC/C preform as follows, CMC of 4g was dissolved into distilled water of 0.5L. The mixture of TiC and C (the mass ratio of TiC to C shown in Table 1) was put into the above water solution forming into slurry. After the slurry was ball-milled for 2h at 120r/min, it was frozen for 6h in a freeze-drying machine, and then dried in vacuum for 24 h. The TiC-C mixture was ball-milled again for 2 h, and dry pressed into preforms of 60mm×15mm×5mm. In the second step, the as-received TiC/C preforms were placed in a furnace and then underwent temperature-programming of 20°C/min in Ar atmosphere. When the temperature was up to the appointed temperatures, the preforms were infiltrated with liquid silicon (45  $\mu\text{m}$  in diameter) for 20min (based on reference [20] and our previous exploratory work), then the temperature decreased at a rate of 2°C/min to 1400°C, then kept for 2h, and finally cooled to room-temperature. Table 1 shows the infiltration conditions of preforms.

### 1.3 Characterization

Phase analysis was conducted by X-Ray Diffraction (XRD), via a computer-controlled diffractometer ( $\chi'$ Pert Pro, Philips, Netherlands). Microstructures of the samples were characterized by SEM, and back-scattered electron image (BSE).

Hardness was measured by using a Vickers indenter on the polished surfaces (first up to 1 mm diamond powder, then ENGIS S1313-T4 (1/10  $\mu\text{m}$ ) diamond polishing paste). At least 20 indentations were the largest dimension of 10kg. The indentation diagonal,  $d$ , was measured in the SEM and the Vickers hardness,  $H$ , was calculated by using the equation as below<sup>[20]</sup>.

$$H(\text{GPa}) = \left( \frac{18187 \times P}{d^2} \right) \quad (1)$$

Where,  $P$  is the indenter load in kg and  $d$  is in  $\mu\text{m}$ .

Table 1 The name and infiltration conditions of preforms

Samples	Mass ratio of TiC to C	Infiltration temperature and time	Heat-treatment temperature and time
S1500	8:1	1500°C, 20min	1400°C, 2 h
S1550-1	8:1	1550°C, 20min	1400°C, 2 h
S1550-2	8:1	1550°C, 20min	1400°C, 2 h
S1550-3	15:1	1550°C, 20min	1400°C, 2 h
S1550-4	10:1	1550°C, 20min	1400°C, 2 h
S1550-5	5:1	1550°C, 20min	1400°C, 2 h
S1600	8:1	1600°C, 20min	1400°C, 2 h

From these cracks, an estimate of the fracture toughness was calculated by using<sup>[21]</sup>:

$$K_{IC}(\text{MPa} \cdot \text{m}^{1/2}) = 0.016 \left( \frac{E}{H} \right)^{0.5} \left( \frac{P}{c^{1.5}} \right) \quad (2)$$

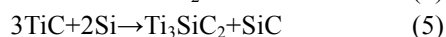
Where  $E$  is the Young's modulus (320 GPa);  $P$  is the indentation load in N, and  $c$  is the crack length.

The density of samples was determined by Archimedes.

## 2 Results and discussion

### 2.1 Phase analysis

Figure 1 presents the XRD patterns of samples infiltrated in the temperature range of 1500–1600°C. For the sample heated to 1500°C, the peaks of SiC and Si are obviously detected, and the peaks of  $\text{Ti}_3\text{SiC}_2$  and  $\text{TiSi}_2$  phases are very low. Because the overlapping of the peaks of TiC and SiC, it is difficult to identify SiC and TiC based on the XRD patterns. According to SEM and EDS analysis, there is no TiC left. Many literatures reported that  $\text{TiSi}_2$  usually formed at low temperatures. Therefore, it is reasonably proposed that S1500 consists of SiC, Si,  $\text{Ti}_3\text{SiC}_2$  and  $\text{TiSi}_2$ . This suggests the following chemical reactions occur at the temperature,



When the sample is heated to 1550°C, the peaks of  $\text{Ti}_3\text{SiC}_2$  phase increase. No peaks of TiC and other Ti-containing phase are detected, which indicates that all TiC particles take part into reactions to form  $\text{Ti}_3\text{SiC}_2$ . With temperature increasing, the main peaks of  $\text{Ti}_3\text{SiC}_2$  decrease gradually and even disappear. This indicates that the  $\text{Ti}_3\text{SiC}_2$  is unstable above 1600°C, which is consistent with some literatures about the thermal instability of  $\text{Ti}_3\text{SiC}_2$ . Li *et al.*<sup>[22]</sup> suggested that TiC can be formed

from the decomposition of  $\text{Ti}_3\text{SiC}_2$  at high temperature (1500°C) in the presence of excess carbon. Tong *et al.*<sup>[9]</sup> reported the formation of TiC as a result of the decomposition of  $\text{Ti}_3\text{SiC}_2$ , when  $\text{Ti}_3\text{SiC}_2$  and SiC were being hot pressed at 1500–1600°C. Racault *et al.*<sup>[10]</sup> showed that heating of  $\text{Ti}_3\text{SiC}_2$  powders in graphite crucibles at 1350°C would result in the formation of  $\text{TiC}_x$  and SiC.  $\text{Ti}_3\text{SiC}_2$  would decompose into TiC and SiC in the present of C and O, especial amorphous carbon. But in our work, there is no TiC detected even at high temperature. Thermally, the decompose reactions of  $\text{Ti}_3\text{SiC}_2$  are as follows,

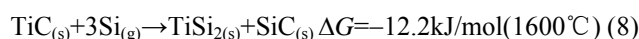
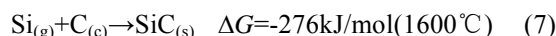
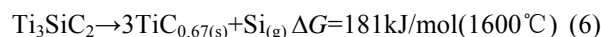


Figure 2 shows the XRD patterns of S1550-1, S1550-3, S1550-4. only  $\text{Ti}_3\text{SiC}_2$  and SiC phases can be identified. The peaks of  $\text{Ti}_3\text{SiC}_2$  become high with the decreasing amount of C powder in preforms (Sample S1550-5 can't be infiltrated successfully), which are much higher than that of SiC. These results show that the amount of C powder has great negative effect on the formation of  $\text{Ti}_3\text{SiC}_2$ , which again confirms the above conclusion that the existence of C is not favor of the formation of  $\text{Ti}_3\text{SiC}_2$ .

Figure 3 compares the ways of silicon contacting with the preforms (In the process of fabrication of S1550-1, the TiC/C preform is buried in dry silicon power. For the case of fabrication of S1550-2, the TiC/C preform is wrapped in pulpy silicon). The  $\text{Ti}_3\text{SiC}_2$  peaks of S1550-2 are much higher than that of S1550-1. This might be attributed to the differences of silicon evaporation rate in two cases. For S1550-2, silicon powder more easily evaporates and causes not enough silicon for infiltration. Although the embedding way has positive effect on the formation of  $\text{Ti}_3\text{SiC}_2$ , it is difficult to fabricate bulk  $\text{Ti}_3\text{SiC}_2$ .

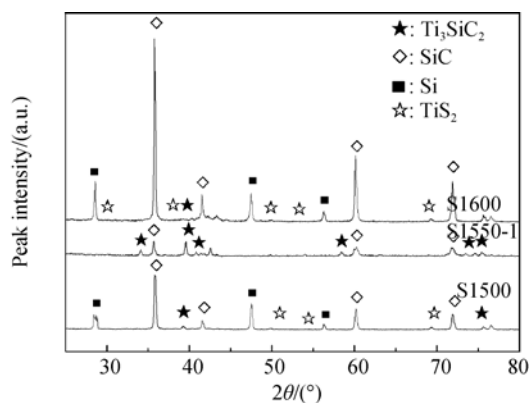


Fig. 1 XRD patterns of S1500, S1550-1 and S1600

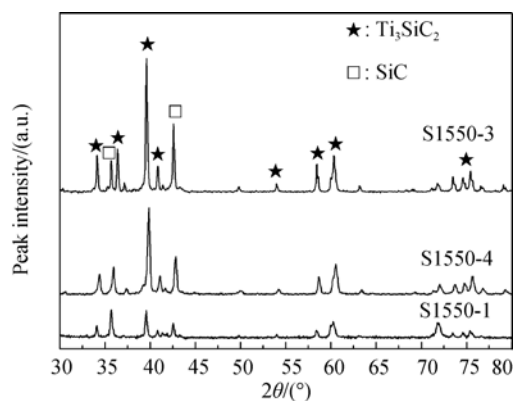


Fig. 2 XRD patterns of S1550-1, S1550-3 and S1550-4

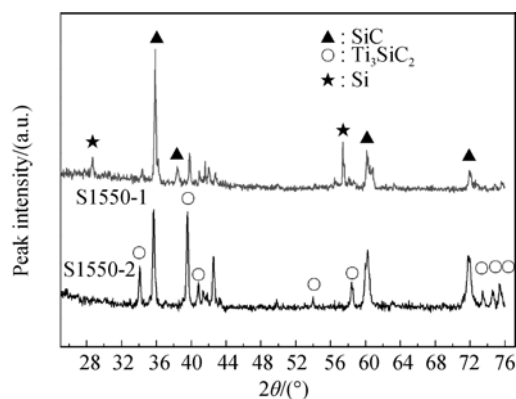


Fig. 3 XRD patterns of S1550-1 and S1550-2

## 2.2 Content of $\text{Ti}_3\text{SiC}_2$

The content of the  $\text{Ti}_3\text{SiC}_2$  phases in the synthesized composites can be estimated from the integrated XRD peak intensities. The calculation equation is referenced to the literature<sup>[23]</sup> as follows,

$$W_{\text{TSC}} = 1.80 / (1.80 + I_{\text{SiC}} / I_{\text{TSC}})$$

$$W_{\text{SiC}} = (I_{\text{TC}} / I_{\text{TSC}}) / (1.80 + I_{\text{SiC}} / I_{\text{TSC}})$$

Where,  $W_{\text{TSC}}$ ,  $W_{\text{SiC}}$ : mass percentage of  $\text{Ti}_3\text{SiC}_2$  and SiC, respectively, and  $I_{\text{TSC}}$ ,  $I_{\text{SiC}}$ : main XRD peak intensity of  $\text{Ti}_3\text{SiC}_2$  and SiC, respectively.

$W_{\text{TSC}}$  of S1550-1, S1550-3 and S1550-4 are 67.9%, 90.17%, 90.22%, and  $W_{\text{SiC}}$  of S1550-1, S1550-3 and S1550-4 are 32%, 9.8%, 9.7%, respectively. The porosities of these samples determined from the Archimedes are 4.8%, 4.2% and 4.3%. Based on these results, it is reasonable that S1550-3 and S1550-4 have negligible

porosities, around 95% dense, and contains SiC as the minor phases.

## 2.3 Morphology

Figures 4 and 5 show the back-scattered electron (BSE), second electronic images (SEM) and EDS of the samples listed in Table 1. Combined with XRD analysis, it is proposed that the bright area is  $\text{Ti}_3\text{SiC}_2$  or  $\text{TiSi}_2$ . The gray zone is the un-reacted Si, and the dark gray area is SiC. From SEM, the plate-like structure of  $\text{Ti}_3\text{SiC}_2$  can be clearly seen. The crystals grow well and there aren't almost any pores. The sizes of plate-shaped crystal grains are about 3.0–10.0  $\mu\text{m}$ .

## 2.4 Mechanical properties

The results of the hardness measurements of S1550-1, S1550-3 and S1550-4 reach HV 6.8, 7.1 and 7.8 with a 10 kg load, respectively. The mechanical properties of the composites are closely related to their phase constitution and microstructure. The hardness is different mainly because the dominant structures are different in the three cases, and the hardness of SiC is much higher than that of  $\text{Ti}_3\text{SiC}_2$  (4 GPa).

An estimate of the fracture toughness is calculated by using Eq.(2). The fracture toughness of S1550-1, S1550-3 and S1550-4 is in the range of 11.5–12.9  $\text{MPa}\cdot\text{m}^{1/2}$ . These values are in the range of 8 to 16  $\text{MPa}\cdot\text{m}^{1/2}$  depending on grain size and/or crack extension. The densities of S1550-1, S1550-3 and S1550-4 determined by Archimedes are 3.55–3.96  $\text{g}/\text{cm}^3$  between that of pure  $\text{Ti}_3\text{SiC}_2$  (4.53  $\text{g}/\text{cm}^3$ ) and that of SiC (3.16–3.2  $\text{g}/\text{cm}^3$ ).

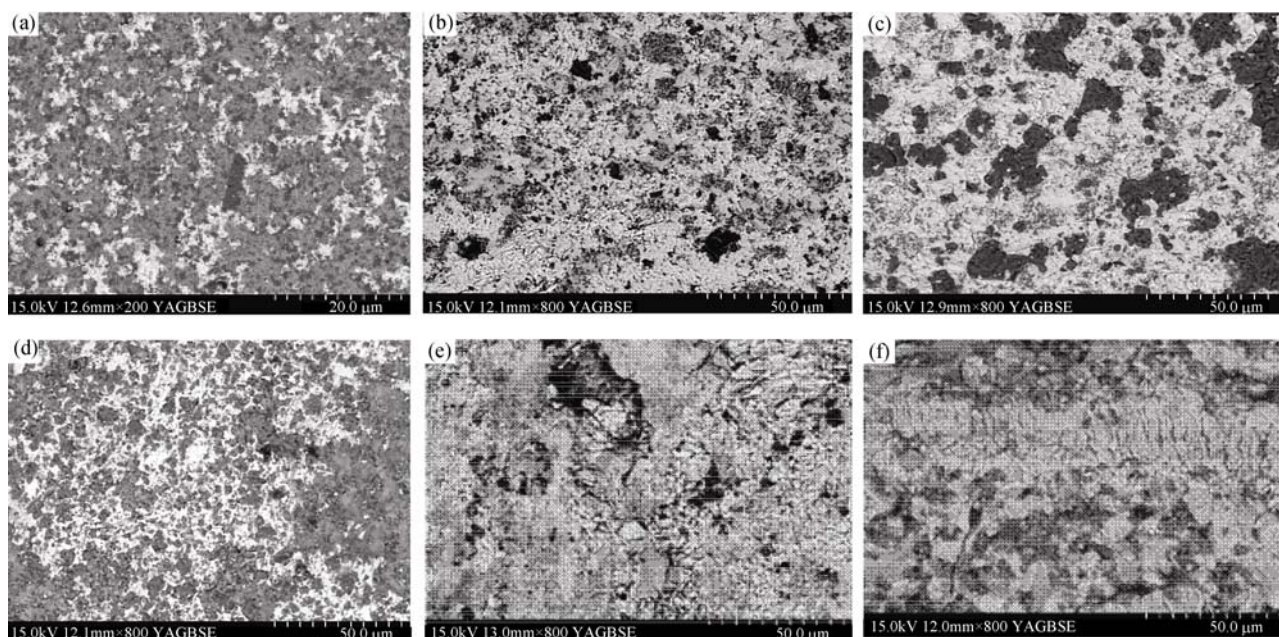


Fig. 4 BSE micrographs of the samples listed in Table 1  
(a) S1500; (b) S1550-1; (c) S1550-2; (d) S1600; (e) S1550-3; (f) S1550-4

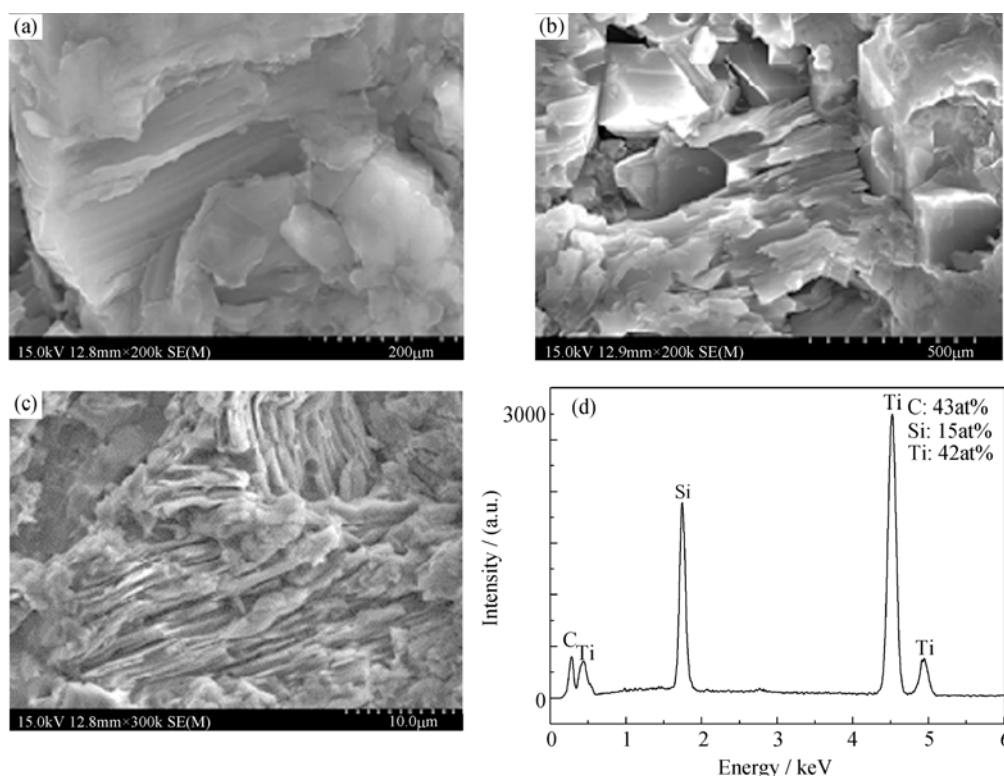
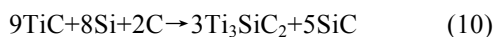
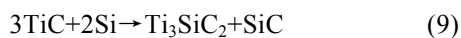


Fig. 5 SEM micrographs and EDS pattern of the samples

(a) S1550-1; (b) S1550-3; (c) S1550-4; (d) EDS of S1550-4

Based on the experimental observation, the reaction mechanism which leads to the final formation of  $\text{Ti}_3\text{SiC}_2$  may include the following two stages. The first stage is that the solid silicon becomes liquid state. The liquid silicon facilitates the formation of  $\text{Ti}_3\text{SiC}_2$  attributing to not only the easy infiltration of TiC and Si with each other, but also the rapid diffusion of TiC in liquid silicon. The second stage is the formation of  $\text{Ti}_3\text{SiC}_2$ . However, too high temperature will cause the decomposition of  $\text{Ti}_3\text{SiC}_2$  as shown in Eq.6. The possible reactions are as follows



### 3 Conclusions

The present study demonstrated the possibility of the production of  $\text{Ti}_3\text{SiC}_2$  ceramic composite at  $1550^\circ\text{C}$  via infiltrating Si-melt into preform of TiC and C. The final material has negligible porosity and about 95% dense, and it contains SiC, Si and  $\text{TiSi}_2$  as the minor phases. The synthesis temperature should not be above  $1600^\circ\text{C}$  and the ratio of TiC to C should be small enough to easily form  $\text{Ti}_3\text{SiC}_2$ .

### References:

- [1] Buchheit A A, Fahrenholtz W G, Hilmas G E, et al. Thermal properties of a reaction hot pressed  $\text{Mo} \leq 5\text{Si}_3\text{C} \leq 1$  ceramic. *Intermetallics*, 2008, **16**(7): 1047–1052.
- [2] Li H, Peng L M, Gong M, et al. Processing and microstructure of  $\text{Ti}_3\text{SiC}_2 / \text{M}$  ( $\text{M} = \text{Ni}$  or  $\text{Co}$ ) composites. *Composites Letter*, 2005, **59**(21): 2647–2649.
- [3] Pritchett M, Magtoto N, Tong J, et al. Copper metallization of hydroxyl-modified amorphous Si:C:H films. *Thin Solid Films*, 2003, **440**(1/2): 100–108.
- [4] Zhou W B, Mei B C, Zhu J Q. Synthesis of high-purity  $\text{Ti}_3\text{SiC}_2$  and  $\text{Ti}_3\text{AlC}_2$  by spark plasma sintering (SPS) technique. *Journal of Material Science*, 2005, **40**(8): 2099–2100.
- [5] Jeitschko W, Nowotny H. The crystal structure of  $\text{Ti}_3\text{SiC}_2$ : a new complex carbide. *Monatsh Chemistry*, 1967, **98**(2): 329–337.
- [6] Lis J, Miyamoto Y, Pampuch R, et al.  $\text{Ti}_3\text{SiC}_2$ -based materials prepared by HIP-SHS techniques. *Material Letter*, 1995, **22**(3): 163–168.
- [7] Klemm H, Tanihata K, Miyamoto Y. Gas pressure combustion sintering and hot isostatic pressing in the Ti-Si-C system. *Journal of Material Science*, 1993, **28**(6): 1557–1562.
- [8] Pampuch R, Stobierski L, Tymkiewicz M. Solid combustion synthesis of  $\text{Ti}_3\text{SiC}_2$ . *Journal of European Ceramic Society*, 1989, **5**(5): 283–287.
- [9] Tong X, Okano T, Kano T, et al. Synthesis and high temperature mechanical properties of  $\text{Ti}_3\text{SiC}_2/\text{SiC}$  composite. *Journal of Material Science*, 1995, **30**(12): 3087–3090.

- [10] Racault C, Langlais F, Naslain R. On the chemical vapor deposition of  $\text{Ti}_3\text{SiC}_2$  from  $\text{TiCl}_4\text{-SiCl}_4\text{-CH}_4\text{-H}_2$  gas mixtures. Part I A thermodynamic approach. *Journal of Material Science*, 1994, **29(10)**: 3384–3392.
- [11] Barsoum M W, El-Raghy T. Synthesis and characterization of a remarkable ceramic:  $\text{Ti}_3\text{SiC}_2$ . *Journal of America Ceramic Society*. 1996, **79(7)**: 1953–1956.
- [12] Gao N F, Miyamoto Y, Zhang D. Dense  $\text{Ti}_3\text{SiC}_2$  prepared by reactive HIP. *Journal of Material Science*, 1999, **34(18)**: 4385–4392.
- [13] Li J F, Sato F, Watanabe R. Synthesis of  $\text{Ti}_3\text{SiC}_2$  polycrystals by hot-isostatic pressing of the elemental powders. *Journal of Material Science Letter*, 1999, **18(19)**: 1595–1597.
- [14] Okano T, Yano T, Iseki T. Synthesis and mechanical properties of  $\text{Ti}_3\text{SiC}_2$  ceramics. *Transtion Material Research Society Jpn.*, 1993, **14A(4)**: 597–600.
- [15] Arunajatesan S, Carim A H. Synthesis of titanium silicon carbide. *Journal of America Ceramic Society*, 1995, **78(3)**: 667–672.
- [16] Krenkel W, Schanz P. Fiber ceramic structures based on liquid impregnation technique. *Acta Astronautica*, 1992, **28(August)**: 159–169.
- [17] Racaul C, Langlais F. Solid-state synthesis and characterization of the ternary phase  $\text{Ti}_3\text{SiC}_2$ . *Journal of Materials Science*, 1994, **29(19)**: 5023–5040.
- [18] Zhu J Q, Mei B C, Chen Y L. Synthesis of  $\text{Ti}_3\text{SiC}_2$  by spark plasma (SPS) with the addition of Aluminum. *Journal of Inorganic Materials*, 2003, **18(6)**: 700–703 (in Chinese).
- [19] Barsoum M W. The  $\text{M(N+1)AX-N}$  Phases: a new class of solids: thermodynamically stable nanolaminates. *Prog. Solid St. Chem.*, 2000, **28(1-4)**: 201–281.
- [20] Tong C Q, Cheng L F, Yin X W, *et al.* Processin of 2D C / $\text{SiC-ZrB}_2$  composites by slurry infiltration and reactive melt infiltration. *Journal of Aeronautical Materials*, 2009, **29(4)**: 76–80.
- [21] HO-DUC Linh H, EL-RAGHY Tamer, Michel W Barsoum. Synthesis and characterization of 0.3 V $\text{fTiC-Ti}_3\text{SiC}_2$  and 0.3 V $\text{fSiC-Ti}_3\text{SiC}_2$  composites. *Journal of Alloys and Compounds*, 2003, **350(1/2)**: 303–312.
- [22] Li S B, Xie J X, Zhang L T, *et al.* *In situ* synthesis of  $\text{Ti}_3\text{SiC}_2/\text{SiC}$  composite by displacement reaction of Si and TiC. *Material Science Engineering A*, 2004, **381(1/2)**: 51–56.
- [23] Zhang Z F, Sun Z M, Hashimoto A T. Fabrication and microstructure characterization of  $\text{Ti}_3\text{SiC}_2$ . *Journal of American Ceramic Society*, 2003, **86(3)**: 431–436.

## 渗硅技术原位制备 $\text{Ti}_3\text{SiC}_2\text{-SiC}$ 复合材料的新工艺

卢翠英<sup>1,2</sup>, 殷小玮<sup>2</sup>, 李向明<sup>2</sup>

(1. 榆林学院 化工与化学学院, 榆林 719000; 2. 西北工业大学 超高温结构复合材料国防科技重点实验室, 西安 710072)

**摘 要:** 提出制备  $\text{Ti}_3\text{SiC}_2\text{-SiC}$  复合材料的一种新思路, 即利用液态硅渗透  $\text{TiC/C}$  预制体原位反应制备  $\text{Ti}_3\text{SiC}_2\text{-SiC}$  复合材料, 并采用 XRD、SEM 和 EDS 考察了材料的显微结构和力学性能。结果表明: 制备出材料主要由  $\text{Ti}_3\text{SiC}_2$  相组成,  $\text{SiC}$  相含量较少;  $\text{Ti}_3\text{SiC}_2$  晶相呈现出 3~10 $\mu\text{m}$  大小的层状结构; 施加 10kg 的压力下测得样品 S1550-1, S1550-3 和 S1550-4 的硬度分别为 6.8GPa、7.1GPa 和 7.8GPa, 它们的密度在 3.55~3.96g/cm<sup>3</sup> 范围内。实验结果表明, 利用液态硅渗透技术原位制备  $\text{Ti}_3\text{SiC}_2\text{-SiC}$  复合材料是一种可行的新工艺。

**关 键 词:** 液态硅渗透; 新型原位合成;  $\text{TiC/C}$  预制体;  $\text{Ti}_3\text{SiC}_2\text{-SiC}$  复合材料

中图分类号: TQ33

文献标识码: A