Journal of Alloys and Compounds 501 (2010) L1–L3

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

journal homepage: www.elsevier.com/locate/jallcom

Letter

Synthesis of Ti_2AlC by laser-induced self-propagating high-temperature sintering

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ARTICLE INFO

Article history:
Received 12 January 2010
Received in revised form 21 March 2010
Accepted 25 March 2010
Available online 3 April 2010

Keywords:
Self-propagating high-temperature sintering (SHS)
Ti_2AlC
Sn
Al
TiC

ABSTRACT

The Ti_2AlC was synthesized by laser-induced self-propagating high-temperature sintering (SHS) using 2Ti/Al/C powders as raw material. Several additives were added in the raw materials including TiC, Sn and excess Al in order to improve the reaction. The results showed that the Ti_2AlC was synthesized by means of laser-induced SHS. The majority compounds were Ti_2AlC and TiC in the sample. The content of the Ti_2AlC in the sample was approximate 83%. The TiC or excess Al additives did not improve the synthesis of Ti_2AlC. However, the Sn additive improved the synthesis of Ti_2AlC obviously. For the raw material of 2Ti/Al/C/0.3Sn, the content of Ti_2AlC in the sample attained approximate 95%.

1. Introduction

Recently, a new family of layered ceramic has attracted much attentions due to their unique physical and mechanical properties, such as high melting point, good electrical and thermal conductivity, high strength and modulus, and good machinability [1]. Among this family, Ti_2AlC is one of the most interesting materials, which has been widely studied in the Ti–Al–C system. For synthesizing Ti_2AlC, combustion synthesis, self-propagating high-temperature sintering (SHS) [2–5], hot pressing (HP) [6], hot isostatic pressing (HIP) [7], spark plasma sintering [8] have been used. With shorter reaction period and less energy consumption, SHS has great potential of volume production in industry.

As a special energy source, laser has shown its advantages of high-power density, well controllable heat source, no contamination, highly convenient operation, and security. Several compounds [9–11] were synthesized by means of laser-induced SHS. In this work, the Ti_2AlC was synthesized by means of laser-induced SHS using Ti–Al–C as raw material.

2. Experimental procedure

Ti powder (99.6%, 300 mesh), Al powder (99.0%, −200 mesh), Sn powder (99.0%, −300 mesh), and graphite powder (99.0%, −300 mesh) were mixed in the mole ratio calculated according to the 2Ti/Al/2C/0.1X (X = Al, TiC, Sn). In order to attain homogeneous mixtures, the powders were milled for 2 h in a planetary mill (XM-4x05) using ZrO_2 balls. The jars were made of stainless steel, the rotating speed was 200 rpm, the ratio of balls to powders was 5:1. Then the mixtures were coldly pressed into rods with size of 5 mm × Ø 10 mm. The combustion reactions were carried out in a CO_2 laser with 2 kW powder. The X-ray diffraction (XRD) experiments were carried out in a rotating anode X-ray diffractometer (D/MAX-2500PC) with Cu Kα radiation. The scanning electron microscope (SEM) observation was carried out in a KYKY-2800 type microscope equipped with an energy-dispersive spectroscope (EDS). The content of the Ti_2AlC in the as-synthesized product were calculated from the integrative XRD peak intensities according to the formula [12]:

$$\omega_b = \frac{I_b}{4.545 I_a + I_b + 0.382 I_c}$$

where W_b was the mass fractions of Ti_2AlC, I_a, I_b, and I_c was the integrative diffraction intensity of Ti_3AlC_2 (0 0 2), Ti_2AlC (0 0 2), and TiC (1 1 1) peak, respectively.

3. Results and discussion

Fig. 1 shows the combustion phenomena on the surface of the sample after being ignited by the laser. The laser beam was identically on the sample's surface. When the reaction was ignited, the laser was immediately turned off. Firstly, weak pink spot was formed after the laser was ignited on the surface of the sample, as shown in Fig. 1(a). With the time prolonging, the spot grew quickly and formed elliptic light, as shown in Fig. 1(b). Afterward, it emitted dazzling white light, as shown in Fig. 1(c), which indicated that amount of heat were produced. Finally, the light dimmed out, as shown in Fig. 1(d). This combustion procedure illustrated that the sintering of the sample was started from the upper surface to the bottom in the form of self-propagation.

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doi:10.1016/j.jallcom.2010.03.218

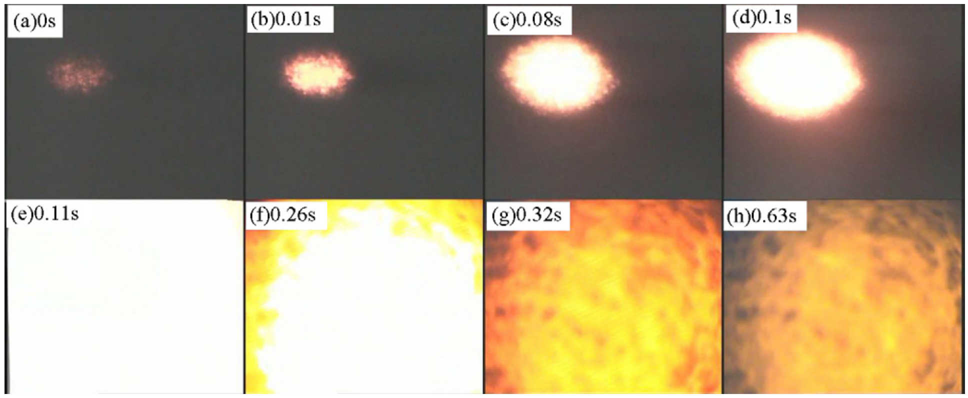

Fig. 1. Combustion phenomenon of the surface of the sample.

Fig. 2 shows the XRD pattern and microstructure of the sample synthesized from the 2Ti/Al/C reactants powders. As shown in Fig. 2(a), the XRD pattern indicated that the Ti_2AlC was the dominant phase. However, some TiC was synthesized as impurity in. Fig. 2(b) indicated that the sample was mainly composed of small amounts of TiC faceted grains and large amounts of Ti_2AlC lathed grains (identified by EDS). The average size of the TiC grain was approximate 2 μm. The average length and width of the Ti_2AlC was 10–20 μm and 2 μm, respectively. The content of the Ti_2AlC was approximate 83%.

Fig. 3 indicates the XRD pattern of the product synthesized using the 2Ti/Al/C/0.1X (X = Al, TiC and Sn) raw material. Comparing to the XRD pattern shown in Fig. 2(a), the peak intensity of the TiC secondary phase was slightly stronger than that of synthesizing with the TiC and excess Al additives, as shown in Fig. 3. However, the peak intensity of the Ti_2AlC synthesized with the Sn additive decreased. The content of the Ti_2AlC synthesized with Sn, TiC and excess Al additive was 86%, 78% and 79%, respectively.

The above XRD results suggested that the Al and TiC additives did not improve the synthesis of Ti_2AlC. However, the Sn additive with proper quantity improved the formation of the Ti_2AlC.

Fig. 4(a) shows the XRD pattern of the product synthesized using the 2Ti/Al/C/0.3Sn as raw material. It was clear that, the sample was mainly composed of Ti_2AlC. As illustrated in Fig. 4(a), the TiC peaks of the sample were very weak, which indicated that its content was low. Fig. 4(b) is the fracture micrograph of this sample. From the image we can see that, the sample was basically composed of

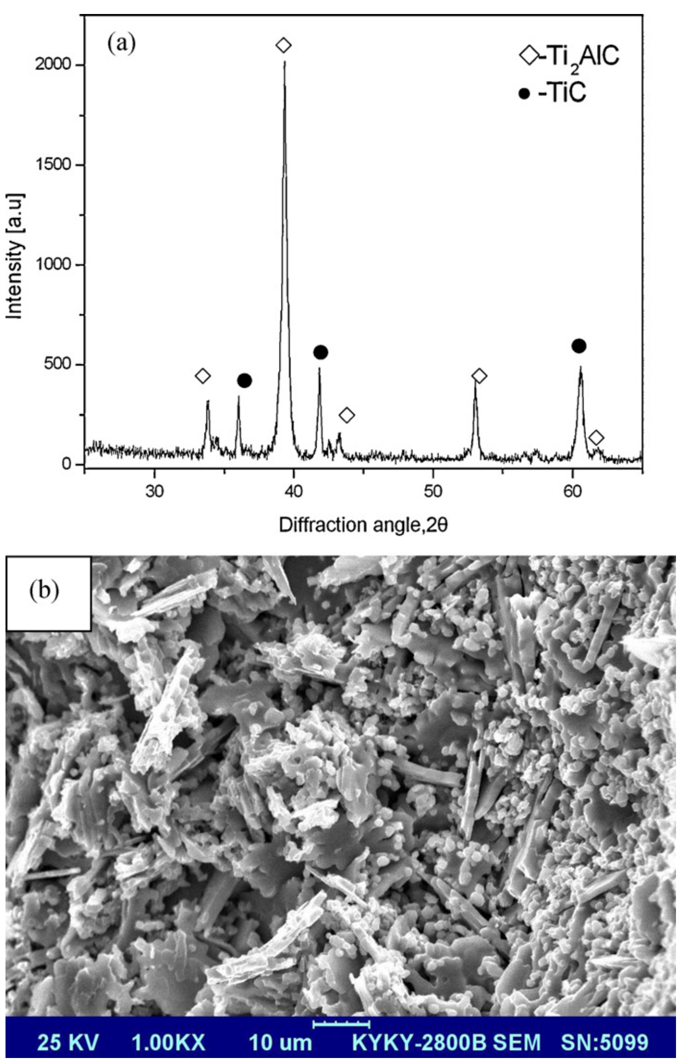

Fig. 2. (a) XRD and (b) SEM of the synthesized sample from 2Ti/Al/C reactants powders.

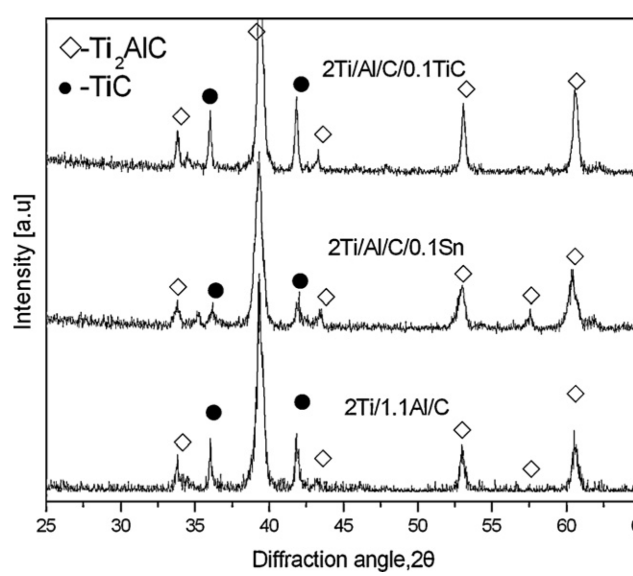

Fig. 3. XRD of the synthesized product after addition of different additive.

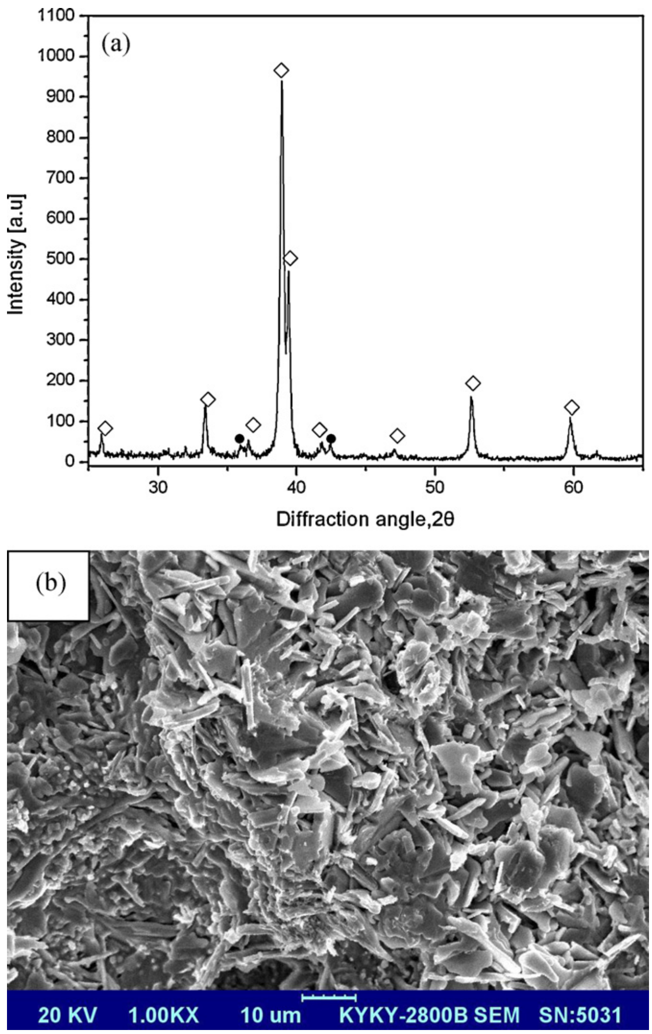

Fig. 4. (a) XRD and (b) SEM of the synthesized sample from 2Ti/Al/C/0.3Sn reactants powders.

Ti_2AlC. And, it was very difficult to find the TiC grains. The content of the Ti_2AlC was estimated to be 95% for this sample.

The above results showed that the sample with higher Ti_2AlC content was synthesized by laser-induced SHS. Using new additive of Sn, higher purity Ti_2AlC was obtained. Compared to previous work without containing additive [2–5], Ti_2AlC content in the sample was increased by about 10%.

In the further, the effects of laser process parameters on the synthesis of Ti_2AlC will be studied.

4. Conclusions

The Ti_2AlC with content of approximate 83% was synthesized using Ti–Al–C powder as raw material by laser-induced self-propagating high-temperature synthesis. The appropriate Sn additive improved the synthesis of Ti_2AlC. For the raw material of 2Ti/Al/C/0.3Sn, the content of Ti_2AlC in the product was about 95%.

Acknowledgement

This work was supported by the Science Foundation of Yanshan University for the Excellent Ph.D. Students (No. YSU200902).

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