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Research Article

Synthesis of Ti-TiAl3 Composite by Resistive Sintering

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Abstract: In the present work, Ti-$TiAl_3$ metallic-intermetallic in situ composites were synthesized by one step resistive sintering method. Process time had been completed in 90 second using 1.5-1.7 Volt and 2000 Amper direct current. Ti and Al elemental powders were mixed by the stoichiometric ratio corresponding to the $TiAl_3$ intermetallic phases' with molar proportion of 1:3. We aimed to obtain some residual ductile Ti phase as well as the $TiAl_3$ major phase in structure. XRD analyses detected the only phases in the composite were Ti and $TiAl_3$. $TiAl_2$ phase also detected as trace peak in the XRD Chart. SEM examinations showed a dense microstructure with low amount of porosity. The relative density of the sample measured according to Archimedes' principle was 98,7%, and the microhardness of the sample was about 455±20 HV.

1. Introduction

Intermetallic compounds have been the focus of research and development efforts in recent years. The interest in intermetallics comes from their high hardness and their ability to maintain their strength at high temperatures. In particular, silicides and aluminides have high oxidation and corrosion resistance [1-4]. With their high melting points, low density and high oxidation resistance titanium aluminides have particular attention for high temperature structural applications [6-8].
The intermetallic composition of $TiAl_3$ has been extensively investigated as a potential high temperature structural material. This is a combination of excellent properties such as low density (3,4 g/cm^3) [3], high melting point (1350°C)[3] and excellent oxidation resistance. However, room temperature brittleness and poor high temperature resistance limit engineering practices. One way of achieving this dilemma is to add a reinforcing phase to the TiAl3 matrix [4].
This paper aims to provide a new approach to produce metallic intermetallic matrix composites (Ti-$TiAl_3$) in 90 seconds using electric current activated sintering (ECAS) methods. ECAS system enables to produce intermetallics in a few seconds. It simultaneously applies an electric current along with a mechanical pressure in order to consolidate powders or synthesize and simultaneously densify specific products with desired configuration and density [5-7]. In our previous study [6] we produced Ti-$TiAl_3$ intermetallic composites in 20 minutes but in this study we achieved to synthesize powders just during one and half minutes. The microstructures and phase constituents were characterized by scanning electron microscopy (SEM-EDS) and X-Ray Difraction (XRD). The relative densities of test materials are measured using by Archimedes principle and their microhardness were measured by using vickers micro hardness tester.

2.Materials And Method

Powder materials from titanium (99.5 % purity, 35-44 μm) and aluminum (99.8 % purity, 35-44 μm) were used as starting materials to manufacture Ti-$TiAl_3$ metallic intermetallic compound. Ti and Al powders were mixed in stoichiometric ratio corresponding to the Ti-Al phase diagram given in, Figure 1. After ball milling, powder mixture was cold-pressed before sintering to form a cylindrical compact in a metallic die under a uniaxial pressure of 200 MPa. Dimensions of the compact were 15 mm diameter and 5 mm thickness. The production of intermetallic compound was performed via electric current activated sintering technique in an open atmosphere at 2000 Amper for 90 seconds.

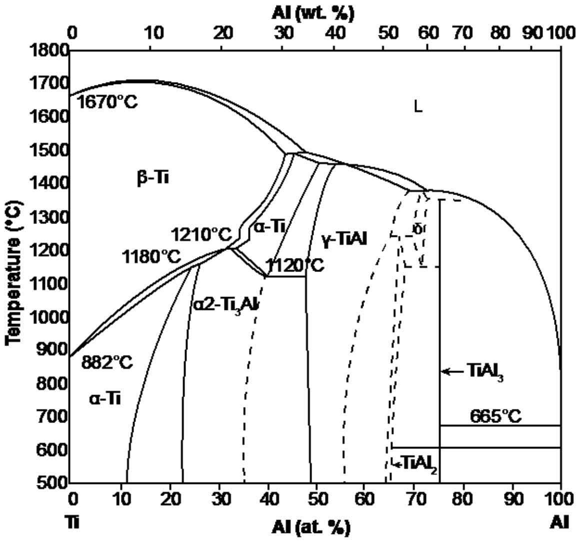


Figure 1. *Ti-Al Phase diagram*

3. Characterization

The morphologies of the samples and the presence of the phases formed were examined by scanning electron microscopy (SEM-EDS). Also X-ray diffraction (XRD) analysis using CuKα radiation with a wavelength of 1.5418 A over a 2θ range of 10–80º were done. The micro-hardness of the test materials was measured using by a Vickers indentation technique with a load of 0.98 N using Leica WMHT-Mod model Vickers hardness instrument.

4. Results And Discussion

4.1. SEM-EDS Analyses

After ball milling process, 250 rpm, for 30 minutes, Ti and Al starting powders are mixed and homogeneously distribution of the particles can be seen in Figure 2. With titanium and aluminum starting powders, the Ti-TiAl$_3$ composite was produced in order to provide the ductile Ti phase reinforcement without completely reacting and converting to TiAl$_3$. The optimum time for the reaction was 90 seconds and the desired compound was wt.%50Ti-50Al. Titanium (unreacted) was allowed to leave with the in situ production technique. As it seen in Figure 3, gray islands are unreacted Ti whereas the darker areas are TiAl$_3$ intermetallic phase. SEM-EDS analyses also supports this results (Figure 4).

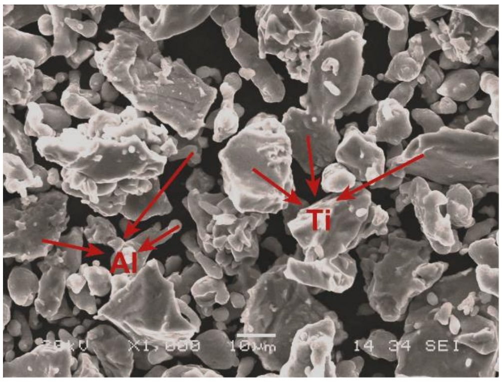
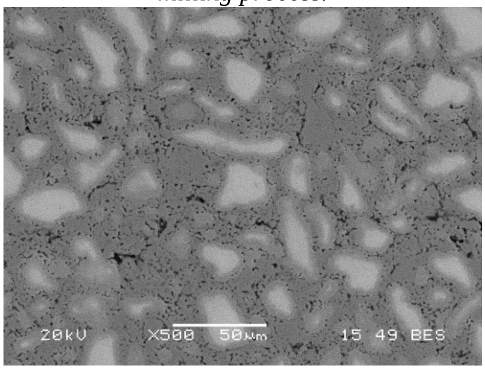
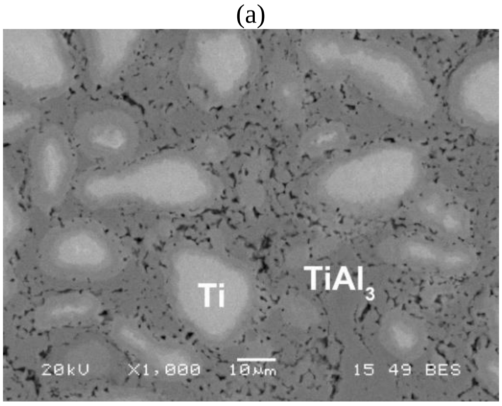


Figure 1. *SEM micrographs of Ti-Al powders after ball milling process.*



(a)



(b)

Figure 2. *SEM micrographs of Ti-TiAl$_3$ in situ composite*

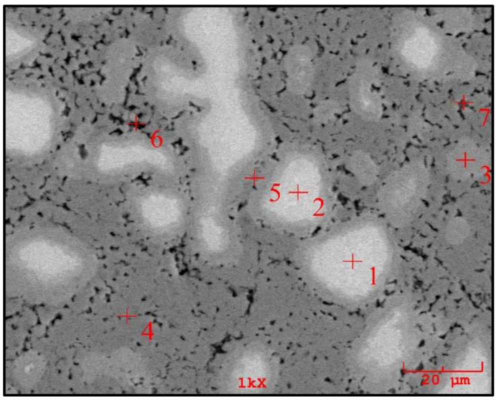


Figure 4. *SEM-EDS Analyses of Ti-TiAl$_3$ composite.*

Table 1. *wt.% for Ti-TiAl$_3$ composite.*

No	**wt.%**		
	Ti	**Al**	**O**
1	98,231	1,761	-
2	97,130	2,870	-
3	43,114	56,886	-
4	31,712	68,288	-
5	36,352	63,648	-
6	33,894	66,106	-
7	31,590	68,410	-

4.2. X-Ray Analysis

The main phases in Ti-TiAl$_3$ composites are Ti and TiAl$_3$ as exhibited in XRD graph as desired, can be seen in Figure 5, a slight amount of oxygen and another type of titanium aluminides (TiAl$_2$) also detected from XRD Analyses.

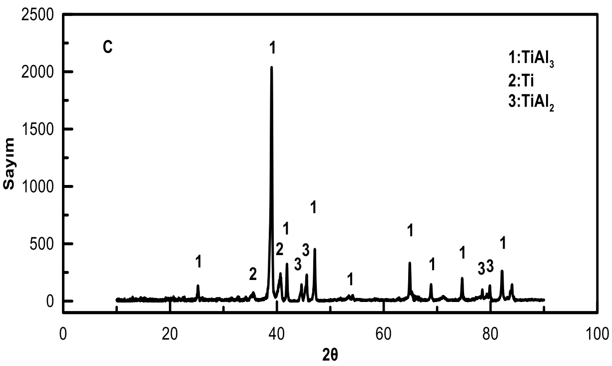


Figure 5. *XRD Analyses of Ti-TiAl$_3$ sample*

4.3.Hardness

The hardness value of Ti-TiAl$_3$ in situ composites is 455±20 HV. This hardness value is very close to the 450 HV value found in the literature for TiAl3, consistent with the literature[9]. The presence of ductile titanium in the composite structure leads to a slight decrease in hardness, which can be interpreted as an increase in ductility.

5. Conclusion

Ti-TiAl$_3$ in-situ composites were manufactured successfully by one-step electric current activated/assisted sintering (ECAS) method in 90 seconds in a steel mold without using any inert gas or vacuum medium.

- The presence of Ti and TiAl$_3$ phases were verified by XRD and SEM-EDS analysis.

- Produced composites in 90 seconds, have remarkable high hardness values as much as 455 HV.

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