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A TiAl based alloy with excellent mechanical performance prepared by gas atomization and spark plasma sintering

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ABSTRACT

Ti-46.15Al-1.87Cr-2.1Nb-(B, Si, Y) alloying powders were fabricated by gas atomization process and then consolidated by spark plasma sintering (SPS). The SPSed TiAl alloy exhibited finer grain microstructure and enhanced mechanical properties than as-cast alloy. The results indicate that TiAl alloys fabricated by the SPS process could open possibilities of application as structural materials offering fine microstructure and excellent properties.

1. Introduction

Recently, TiAl alloys have been attracting tremendous attention due to their low density (3.7 ∼ 4.1 g/cm^3), high specific strength, high strength retention at elevated temperatures, and excellent high temperature oxidation and burn resistance [1–3]. These outstanding properties qualify them great potential for innovation applications in advanced energy conversion systems, where these advanced materials could replace the heavier Ni-based superalloys at intended service temperature of 600 ∼ 900 °C [4]. However, coarse columnar microstructures usually form upon conventional solidification of most TiAl alloys [5]. Such coarse grain size results in limited ductility and damage tolerance at room temperature as well as low workability at elevated temperatures, which severely hinder their widespread applications as promising structural materials [6,7]. Therefore, in order to promote the room temperature ductility and hot workability, numerous attempts have been dedicated to explore fine grained TiAl alloy products [8,9].

Powder metallurgy is a simple, yet efficient and scalable way to synthesize a very fine grain size and achieve the homogeneity in microstructure and chemical composition. As a unique kind of powder metallurgy techniques, spark plasma sintering (SPS) can be used to produce refined microstructure since it offers rapid heating and cooling rates [10]. Nowadays, great efforts have been devoted to sintering bulk TiAl alloys by using elementary, pre-alloyed or mechanically milled powders [11–13]. By using fine initial powders, Calderon et al. have fabricated two-phase microstructures with average grain sizes varying between 100 nm and 150 nm [11]. Hwang et al. have consolidated alloys with grains less than 1 μm [12]. Molénat et al. have produced duplex microstructure with grains ranging between 2 μm and 10 μm [13]. Mechanical tests on these various sintered alloys yielded high strength and high hardness.

In this work, TiAl alloy powders have been produced by gas atomization process, and then consolidated by using SPS technique. The microstructure and mechanical properties of SPSed TiAl alloy samples have also been investigated.

2. Experimental details

The Ti-46.15Al-1.87Cr-2.1Nb-(B, Si, Y) (at.%) ingot was prepared using consumable electrode arc melting technique in an argon atmosphere and remelted in induction furnace in order to achieve composition homogeneity. The obtained ingot was used to produce

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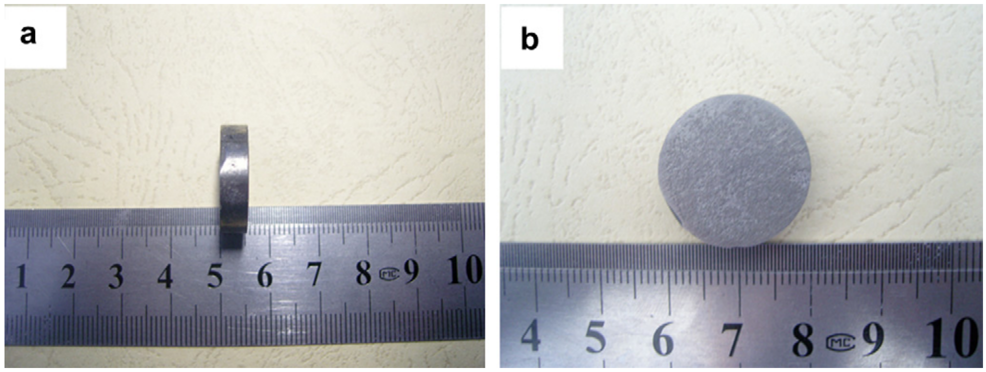

Fig. 1. Outer appearance of TiAl alloy samples sintered at (a) 1050 °C, and (b) 1150 °C.

the alloying powders by Ar gas atomization process. Then the microstructure of gas atomized powders was characterized by X-ray diffraction (XRD), and scanning electron microscopy (SEM). The sintering experiments were carried out on a DR.Sinter Model SPS1000 apparatus. The samples were heated to desired temperature (1050 °C or 1150 °C) at a heating rate of 100 °C/min under a vacuum of 12 Pa, and then held for 10 min under a specific pressure of 40 MPa. The sintered samples have a dimension of Φ 20 mm × 5 mm. Fig. 1 shows the outer appearance of the TiAl alloy samples sintered at 1050 °C and 1150 °C.

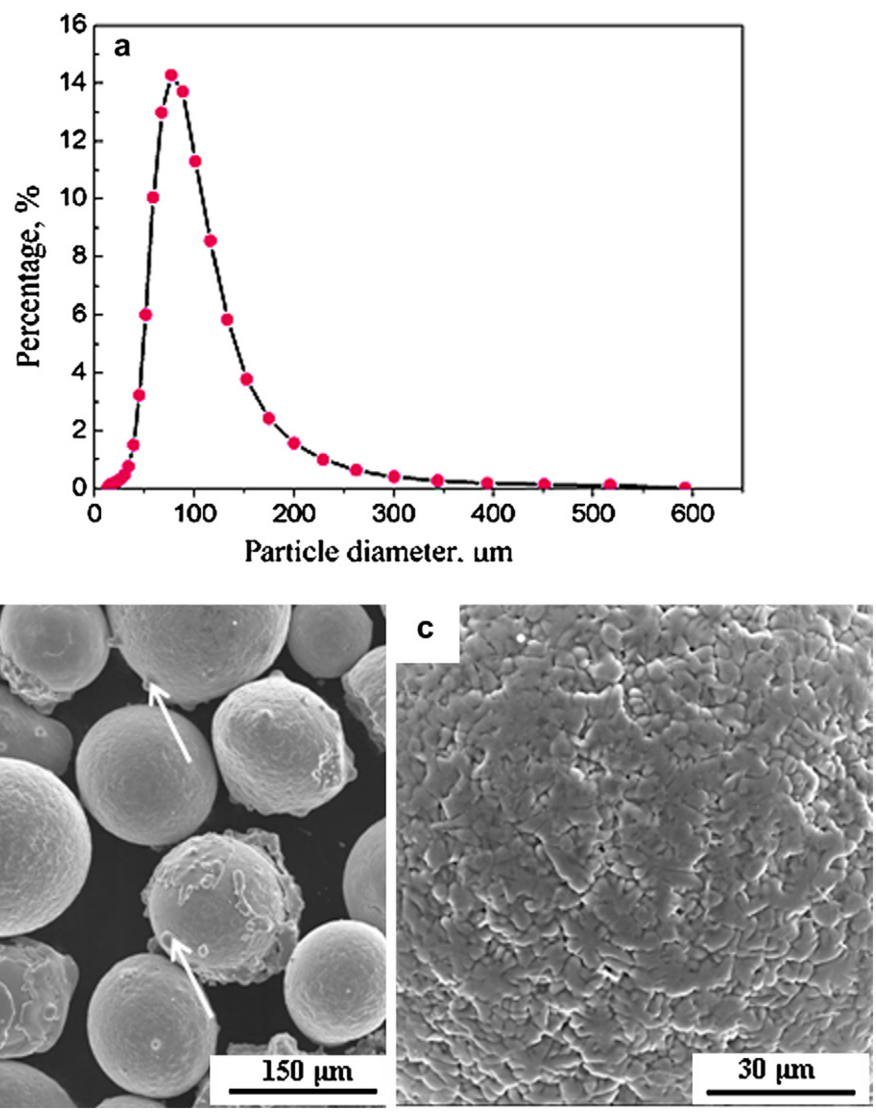

Fig. 2. Particle size distribution (a), and SEM images (b) and (c) of TiAl alloying powders.