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Microstructures and mechanical properties of Ti–45Al–8.5Nb–(W,B,Y) alloy by SPS–HIP route

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Abstract

Microstructures and compression properties of Ti–45Al–8.5Nb–(W,B,Y) alloy consolidated by spark plasma sintering (SPS) and hot isostatic pressing (HIP) were investigated. The results showed that sintering temperature has a significant effect on microstructure. When the sintering temperature is 1000 °C, the dendritic microstructure of as-SPS alloy is similar to that of the alloying powder. At 1100 °C, the interfaces of these powder particles are still discernible, but near γ microstructure appear in every particle. A typical fully lamellar (FL) microstructure followed by two types of microsegregations, such as β-segregation and α-segregation, is successfully developed at 1200 °C. However, FL microstructure becomes coarser at 1300 °C. As-HIP alloy has near lamellar (NL) microstructure along with β-segregation. The morphologies of β phase in as-HIP alloy are different from those in as-SPS alloy. The alloy exhibits excellent compression properties at elevated temperatures. When compression temperature is higher than 1100 °C, high quality compressed samples without cracks can be obtained even if engineering compression strain is up to 80% for the strain rates of 1×10^{-1} to 10^{-3} S^{-1}.

Keywords: TiAl based alloy; Microstructure; Microsegregation; Compression properties

1. Introduction

High Nb containing TiAl alloys are thought to be the potential lightweight high temperature structural materials due to their low densities, high melting points, good elevated temperature strengths and environmental resistances [1–3]. The major problem limiting the practical application of those alloys is their poor ductility and formability. Those alloys reported so far are mostly fabricated by ingot metallurgy (IM) [4–6]. However, IM process of high Nb containing TiAl alloy is usually difficult due to their relatively high melting point and the extreme reactivity of Ti. Recently, powder metallurgy (PM) technique appears to be more attractive since high degrees of chemical homogeneities can be obtained and macrosegregations are avoided. PM process consists of elemental powder metallurgy (EPM) and alloying powder metallurgy (APM). EPM TiAl-based alloys have drawn intensive attention because of its low cost and convenient addition of alloy elements [7–9]. However, concentrations of impurities such as oxygen and carbon are relatively high, reducing the mechanical properties. Therefore, numerous works have been conducted on the microstructures and properties of APM TiAl-based alloys [10–12]. In this study, microstructures and compression properties of high Nb containing TiAl alloys consolidated in spark plasma sintering (SPS) 1050 furnace and HIP treatment were investigated in detail.

2. Experimental

Ti–45Al–8.5Nb–(W,B,Y) (at.%) alloying powders were produced by argon atomization process, and then were classified by Thaler sieve. The mean particle size of the alloying powders adopted in this study was less than 74 μm. SPS furnace was employed to sinter and concurrently consolidate the alloying powders for 10 min under 40 MPa at 1000, 1100, 1200 and 1300 °C, respectively. The alloying powders were filled into a graphite mold with two graphite punches pressed at both ends and dense compacts of Ø30 mm × 15 mm were obtained. Subsequently, HIP of the alloy sintered at 1200 °C was performed at 1200 °C/200 MPa/4 h to homogenize microstructure and eliminate porosity.

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The concentrations of gas elements such as oxygen and nitrogen in the alloying powders and as-SPS alloys were analyzed with the inert gas melting-IR absorption spectrometry. The concentration of carbon was measured by high frequency-IR absorption.

The final densities of these alloys were measured through Archimedes method. X-ray diffraction (XRD) analysis was conducted using Cu Kα radiation to examine the phase transformation. Microstructural observation was carried out by scanning electron microscopy using back scattering electron (BSE) imaging and energy dispersive spectroscopy (EDS). Lamellar spacing was determined by transmission electron microscopy (TEM). The lamellar spacing given in this paper was arithmetic average value measured without taking account of types of lamellar boundaries. TEM foils were prepared by twin jet electropolished in a solution of 60% (vol.%) methanol, 35% butyl alcohol and 5% perchloric acid at 15 V and −30 °C. The lamellar colony size was determined by the intersection linear method.

Compression tests were conducted using a hot simulator modeling Gleeble-1500 at 25, 600, 900, 1000, 1100, 1200 and 1250 °C in air and the strain rate of 1×10^{-1} to 10^{-3} S^{-1}. The samples were prepared by electric discharge machining in a form of column with gauge size of Ø8 mm × 12 mm from as-HIP alloys, and then polished.

Table 1
Impurities concentrations in adopted alloying powders and as-SPS alloys

Impurities	O	N	C
Alloying powders (ppm)	1150	140	24
SPS alloy (ppm)	1170	145	35

3. Results

3.1. Microstructure of as-SPS Ti–45Al–8.5Nb–(W,B,Y) alloy

Relative densities of >99.5% were achieved in as-SPS samples when sintering temperature is higher than 1100 °C. Table 1 shows the impurities concentrations in the alloying powders and as-SPS alloys. It indicates that the oxygen and nitrogen concentrations slightly increase, but carbon concentration rapidly increases. This is correlated with the characteristics of SPS pro-

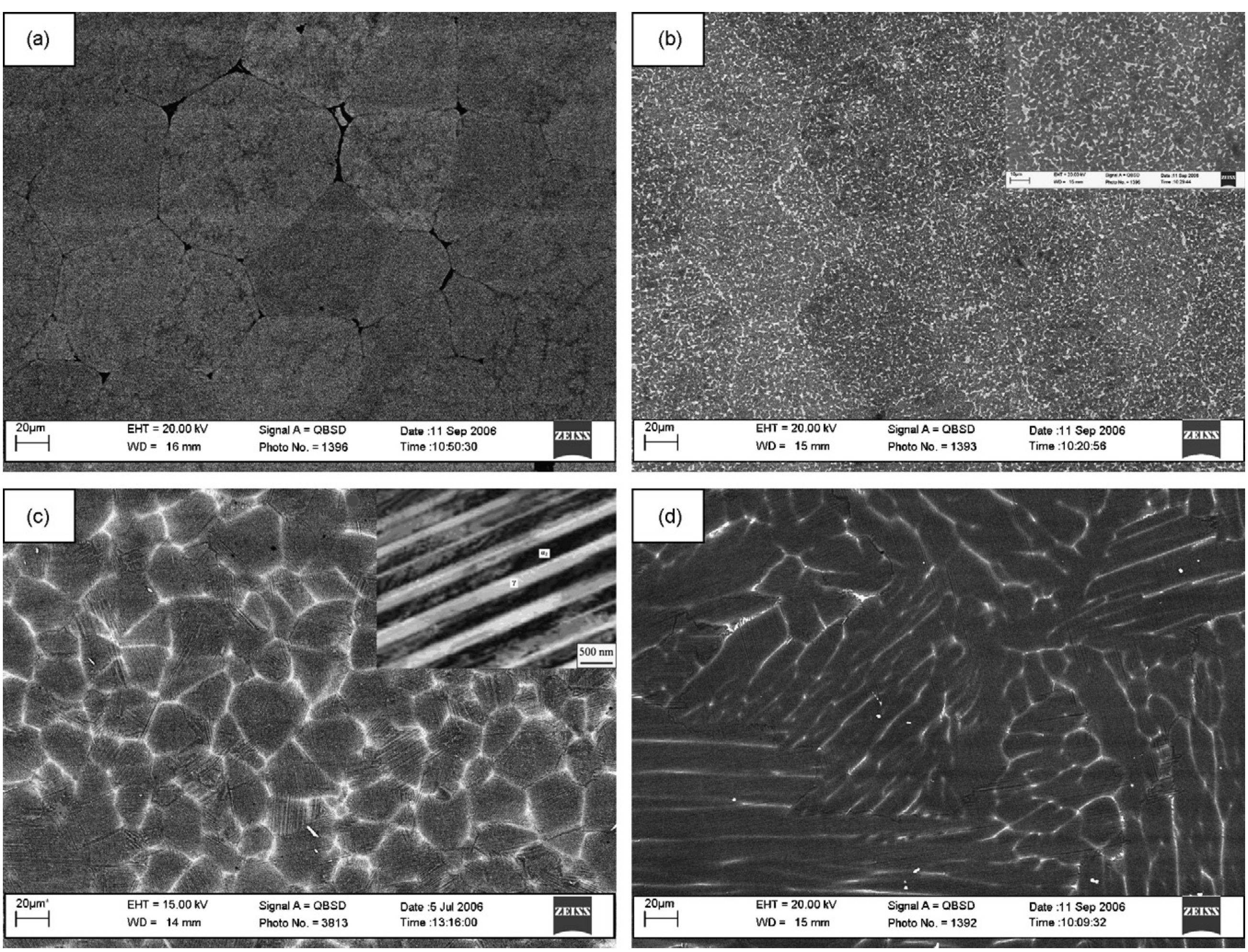

Fig. 1. Microstructures of Ti–45Al–8.5Nb–(W,B,Y) sintered at the different temperatures: (a) 1000 °C; (b) 1100 °C; (c) 1200 °C; (d) 1300 °C.