Advanced Powder Technology 23 (2012) 264–267

Contents lists available at SciVerse ScienceDirect

Advanced Powder Technology

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

Rapid Communication

The effect of type of atmospheric gas on milling behavior of nanostructured Ti6Al4V alloy

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ARTICLE INFO

Article history:
Received 6 June 2011
Received in revised form 10 November 2011
Accepted 6 January 2012
Available online 11 February 2012

Keywords:
Milling atmosphere
Oxygen and nitrogen
Ti–6Al–4V
Mechanical alloying

ABSTRACT

Recently fabrication of titanium alloys through solid state processes such as mechanical alloying has been greatly taken into consideration. In the present investigation the effects of common atmospheric impurities, oxygen and nitrogen, on the fabrication procedure and milling behavior of nanostructured Ti–6Al–4V alloy during mechanical alloying (MA) was studied. In this regards, elemental powders were milled under three different protective atmospheres of air, 90% and 99.998% pure Argon. Results indicated that, samples milled under Ar with 90% purity featured the best behavior and reached a nanostructure and subsequent amorphous state in shorter time periods. This was considered to be due to Ti lattice distortion made by interstitial element such as O_2 and N_2.

1. Introduction

Titanium and titanium alloys have been widely employed in industrial and biomedical applications because of relatively low module of elasticity, low density, high specific strength, good biocompatibility and corrosion resistance [1–3]. Among those, Ti6Al4V (Ti–6 wt.%Al–4 wt.%V) has been the most promising highly used $\alpha + \beta$ titanium alloy [4–7].

Conventional methods of producing titanium and its alloys include melting and casting processes [8,9]. Due to high temperature required to melt titanium, density difference of titanium and alloying elements and high oxidation tendency of titanium, production methods involving melting and solidification are accompanied by significant difficulties [10,11]. In order to overcome these shortcomings, powder metallurgy and solid state production processes have attracted great amount of investment.

Among powder metallurgy methods, mechanical alloying (MA) seems to be the most promising and applicable of all. This is due to its effectiveness in fabrication of wide range of nanostructure alloys and amorphous phases in solid state [12]. In this regard, atmospheric contamination resulting from milling protective atmosphere is one important factor in MA processes. Considering powders high surface to volume ratio, they are extremely prone to lattice absorption of interstitial elements such as oxygen and nitrogen which consequently leads to production of oxides and nitrides [13]. In the current study, the effect of oxygen and nitrogen present in protective atmosphere on production of nanostructured Ti–6Al–4V alloy by MA has been taken into investigation. The present report focuses mainly on the characterization and simultaneously, some preliminary measurements on the physical properties of powders fabricated through this approach.

2. Experimental procedure

Elemental powders of Ti, Al and V with average particle size of 400, 70 and 20 μm, purity of 99.99, 99.97 and 99.99 wt.% and particle shape of irregular, oblong and edged, were mixed in the desired composition (Ti–6 wt.%Al–4 wt.%V), respectively. The SEM micrographs of as-received powder and X-ray pattern of starting powder mixture are presented in Figs. 1 and 2. In order to investigate the effect of O_2 and N_2, three different atmospheres of (99.998% pure Argon, 3 ppm O_2, 2 ppm N_2, 3 ppm H_2O) (90% pure Argon, 4% O_2, 5% N_2, 0.8% $H_2O/CO_2/CO$) and air were used. In order to increase the accuracy of the study, gas concentration was examined by Beifen 3420A gas chromatograph (GC).

Mechanical milling was conducted in SPEX 8000 ball mill and milling parameters are given in Table 1.

In this research, titanium, aluminum and vanadium powders were first, hand-mixed considering stoichiometric percentage, and then divided into three vials under above mentioned protective atmospheres. Small quantities of powder were withdrawn from milled materials after different time periods.

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0921-8831/$ - see front matter
doi:10.1016/j.apt.2012.01.003