Synthesis and Characterization of Nano Ti-50%Al by Mechanical Alloying

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1. Abstract

In this study, powder metallurgy process of TiAl nano alloys were performed via mechanical alloying (MA) of Ti-50%Al powder using planetary ball milling equipment. The characteristics of the powder samples including the compositions and microstructure changes were investigated by using X-ray diffraction and field emission scanning electron microscopy (FESEM) coupled with Energy-dispersive X-ray spectroscopy (EDX). Estimation by using Scherrer equation indicated that MA performed at different duration up to 15 have successfully refine the crystallite size from 89.51nm of Al to 28.29nm, and 67.6nm of Ti down to minimum of 17.17nm. Longer MA duration also exhibits a better effect on the thermal behaviour of Ti50%Al powders and micro-hardness value with gradual increased along with MA duration.

Keywords: TiAl alloys, mechanical alloying, nanostructured materials, thermal properties

2. Introduction

Over the past decades, intermetallic titanium aluminides particularly γ-TiAl based alloys, have gained a great deal of attention in numerous structural, non-structural and functional applications in different engineering fields [1-2]. Equipped with low density, high specific strength to weight ratio, good oxidation and corrosion resistance at elevated temperature [3-4], γ-TiAl based alloys are considered as a very promising material for potential replacement of Nickel base super-alloy and conventional titanium alloys in a high-temperature structure applications especially in aerospace, automotive and power turbine market [5-6]. However, the development and the actual utilization γ -based TiAl for structural applications are plagued by poor ductility and fracture toughness at room temperature [7-8]. The ductility of the γ -based TiAl alloy is very sensitive to microstructures. For example, the duplex (α2/γ) structure is significantly more ductile at room temperature, compared to lamellar or single equaxed γ structure [9].

New age strategies in the development of novel class material were by controlling of the microstructure to achieve a set of desired properties [10]. Advancement in micro alloying, composition modification, grain refinement to nanometer size and refining near-gamma grains and the lamellar colonies through heat treatment is a viable method to improve ductility as well as mechanical strength. One of the most promising methods to synthesize materials which can produce ultrafine, homogenous and manipulable microstructures is by mechanical alloying [11-12]. Hence, the production of an ultrafine and homogenous powder is predicted to overcome the scattering in mechanical properties due to the segregation in the composition of TiAl alloys in conventional manufactured by casting routes [13].

The purpose of this work is to synthesize and evaluate the formation of Ti-Al nano alloys compounds during MA process of elemental Ti and Al powders. The effect of subsequent heat treatment to powder processed up to 15h was also been studied. In addition, the thermal and mechanical properties of alloys product were investigated to .

3. Experimental

The MA processes were carried out using Retsch PM 100 planetary ball mill for duration varying from 5 to 15 h. Elemental powders of Ti (99.5%)-100 mesh and Al (99.97%) were mixed together to form a composition of Ti50Al50 (at.%). For each experiment, 5g of the powder mixture were poured into a tungsten carbide (WC) jar (250 ml). Tungsten carbide balls (ø10 mm) were used as a milling media with the ball-to-powder weight ratio is approximately up to 20:1. Small amount of Hexane was added as process control agent (PCA) to prevent excessive agglomeration of the powders to the milling tools. The jar then was air tight sealed and back-filled with pure Argon (99.9%) where the pressure in the jar was kept at 0.1 MPa. The rotation speed is set at 300 rpm with interval time at every 5 minutes. The milling was interrupted at selected 5h, 8h, 10h, 12h and 15h and a small amount of powder was removed for characterizations.

The MA process parameters and conditions as shown in Table 1 below;

***Table. 1**: MA parameters and conditions for Ti50%Al powders.*

Parameters	Conditions
Milling Type	Planetary ball mill (Retsch PM 100)
Milling jar	Tungsten Carbide, WC (250ml)
Grinding balls	Tungsten Carbide, WC (ø10mm)
Starting powder	Ti , 100 mesh (99.5% purity), Al (99.97% purity)
Rotation speed	Up to 300 rpm
Milling duration	Up to 15 hours
Ball-to-powder mass ratio	Up to 20:1
Process control agent	Hexane
Environment	Ar (99.9% purity)

The Ti50%Al powders samples were mechanically alloyed under different parameters and conditions as in Table 2.

***Table.2**: MA group for Ti50%Al powders.*

Group		Rotation Energy	PCA's	Ball to Powder Mass Ratio
A	-	200rpm	nil	10:1
B	-	300rpm	Hexane (50%wt)	10:1
C	-	400rpm	Hexane (50%wt)	10:1
D	-	300rpm	Hexane (50%wt)	20:1
E	-	300rpm	Hexane (25%wt)	20:1

The surface morphology and microstructure of the processed powder were characterized by using a Zeiss Evo 50 scanning electron microscopy (SEM) at an accelerating voltage of 10 kV. X-ray measurements were applied to the samples to identify the powder component, phase transformation and structural changes of their crystal structure with a Rigaku Minitron X-ray diffractometer, using Cu Kα radiation (λ=1.54062 A°). Step-scanning has been carried out from 20 to 80Θ with a counting time of 5s every 0.02Θ. The crystallite size of the milled