Fabrication of TiAl Target by Mechanical Alloying and Applications in Physical Vapour Deposition Coating

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Abstract

The research involves the development of a powder metallurgical route for producing good quality TiAl targets for making physical vapour deposition (PVD) coatings. Mixtures of elemental titanium and aluminium powders were mechanically milled using a novel discus milling technique under various conditions. Hot isotropic pressing (HIP) was then employed for consolidation of the mechanically alloyed powders. A cathodic arc vapour deposition process was applied to produce a TiAlN coating. Microstructural examination was conducted on the target material and PVD coatings, using X-ray diffractometry (XRD), X-ray photoelectron spectrometry (XPS) and scanning electron microscopy (SEM). It has been found that combining mechanical alloying and HIP enable us to produce fairly good quality of TiAl based target. The PVD coatings obtained from the TiAl target showed very high microhardness values.

Keywords: Mechanical alloying; TiAl intermetallic; composite powder; physical vapour deposition; Coating

1. Introduction

The exceptional mechanical properties, e.g. high specific strength, excellent corrosion resistance and good high-temperature, and good workability make titanium and its alloys occupy a critical position in the inventory of the aerospace industry. TiAl intermetallic alloys are therefore of both scientific and technological interests and have been extensively investigated over the past two decades. Nowadays a major challenge in the applications of TiAl intermetallics comes from their production difficulties and high cost. Powder metallurgy, particularly mechanical alloying has proven efficient in obtaining high level of structural and chemical homogeneity in TiAl alloys. The process is also cost effective. In this study, a novel mechanical alloying technique, discus milling, was explored to produce mechanically alloyed Ti/Al composite powder, which is then consolidated by hot isostatic pressing (HIP) to fabricate a TiAl alloy target material for physical vapour deposition. The effects of processing parameters on the properties of the target have been investigated. Preliminary characterization on the coating is also reported.

2. Experimental and results

The starting materials were a commercial purity Ti powder (average particle size: 150-300μm) and an Al powder (average particle size: 70-100μm). The two component powders were mixed at a nominal composition of Ti-50at% Al. The detailed description of the discus milling can be found elsewhere [1]. About 300 g of the mixture was mechanically milled in a discus mill under different milling conditions. An argon atmosphere was used throughout the milling and an isopropyl alcohol was used as the process control agent (PCA). In order to study the effect of milling parameters, the milling time was varied from 4 hours to 12 hours, the amount of PCA from 1 wt% to 3 wt% and the powder-to-medium ratio from 1:4.4 to 1:22. Thermal analysis was conducted for each as-milled sample using a simultaneous SDT 2960 analyser. Microstructural examinations were carried out using optical microscopy and scanning electron microscopy. X-ray diffraction analysis was employed to determine the phase constituents in the samples.

As with the previous investigation [1], this study reveals that the dominant process parameters of the milling are the milling time, the ball-to-powder mass ratio as well as the amount of process control agent (PCA). It has been found that, for the powder processed with a short milling time, eg 4 hours, a coarse composite structure was formed, with Al particle size being in the range of 0.5 mm to 2 mm in diameter. Further milling gradually led to a significantly refined structure. Fig. 1 presents an example, where the 12h milled powder exhibited a high level of mechanical mixing and refined particle size.

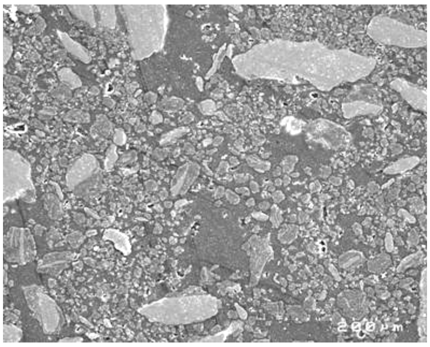

Fig. 1. SEM micrograph of the 12h milled composite powder.

It has been found that the ball-to-powder mass ratio plays an important role in obtaining mechanical alloying from elementary powders. The present study provided more confirmatory evidences on the effect of ball-to-powder mass ratio. Little mixing was observed when the ratio of 4.4 was used. After 12h of milling, only Al was plastically deformed and cold welded around the Ti particles, which did not undergo noticeable change in particle size or shape. Larger ball-to-powder ratio imparts more impact energy to the powder, which in turn causes more internal energy/internal strain and a finer grain size. This was confirmed from XRD patterns obtained from the samples milled with different ratios, as shown in Fig. 2, where some broad and overlapped peaks were observed.

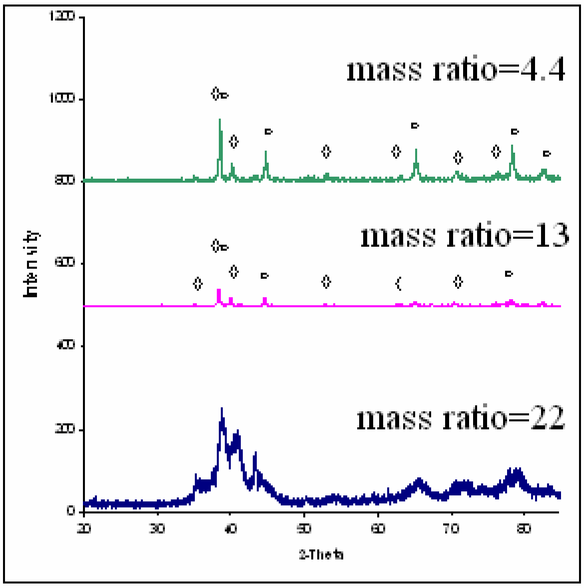

Fig. 2. XRD spectra of discus milled Ti-50Al composite powder with different ball-to-powder mass ratios.

A systematic investigation into the effects of milling parameters on the final microstructures of the consolidated bulk target led to a combination of optimum process parameters, i.e. 12 hours of milling, 13 or 22 of ball-to-powder mass ratio and 3% PCA addition. Several bulk targets were successfully produced using hot isostatic pressing (HIP) technique. The targets were then used to produce TiAlN based coating on H13 steel coupons. X-ray photoelectron spectroscopy analysis confirmed the presence of nitrogen bonding with Ti and Al (see Fig. 3). Microhardness test shows that the TiAlN coating had an average $HV_{0.05}$ value of 2400.

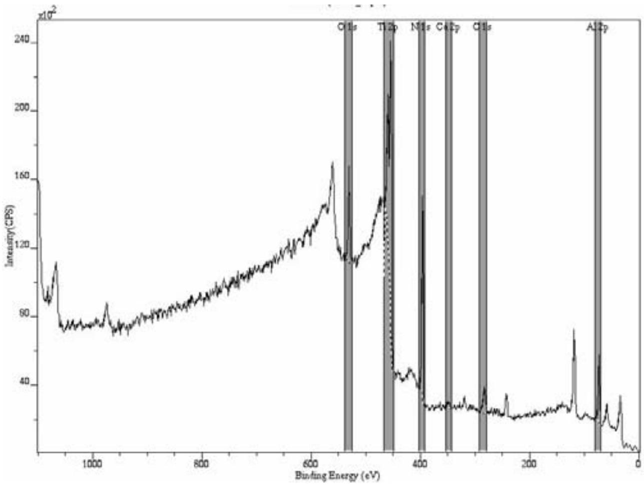

Fig. 3. XPS spectrum of the coating produced by a cathodic arc deposition system. Nitrogen is clearly shown in the coating as well as Ti and Al.

3. References

1. Z.G. Liu, S. Raynova, and D.L. Zhang. Metall. Mater. Trans. A, **37A**, 225 (2006)