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Surface modification of γ-TiAl alloys by acetylene plasma deposition

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Abstract

Surfaces of two γ-TiAl alloys, Ti–47 at% Al–2at% Nb–2 at% Cr (MJ12) and Ti–47 at% Al–2 at% Nb–2 at% Mn + 0.8 at% TiB_2 (MJ47), have been modified by acetylene plasma deposition at bias voltages of −4, −5 and −6 kV for 3.6×10^3 s (1 h) and 1.44×10^4 s (4 h). Knoop hardness (HK) of the alloys is increased with the increase of bias voltage and prolonged time for the deposition. HK of MJ12 and MJ47 deposited at −6 kV for 1.44×10^4 s is, respectively, 3.36 and 3.32 times as hard as the untreated alloys. SEM and AFM analyses show that the deposited alloys compose of a number of nano-dots which reflect their surface properties. The phases analyzed by XRD are in accord with the elements analyzed by EDX.

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Keywords: γ-TiAl alloys; Acetylene plasma deposition; Knoop hardness; Surface morphology and roughness

1. Introduction

Titanium aluminides are very attractive for use as cutting tools, turbine blades, engine valves and turbocharger rotors due to their high melting point, high strength and high strength-to-weight ratio [1–3]. However, limited ductility and poor surface properties of the alloys [3–6] may required improvement. Ductility can be improved by adding of some elements, like Nb, Cr, Mn, Mo, W, Ta and V [6]. Surface properties such as hardness and wear resistance may be improved by surface modification [3,7–12]. There are many processes used to modify surfaces of alloys. Among them are chemical vapor deposition [9], plasma deposition [12], plasma-enhanced chemical vapor deposition [13], magnetron sputtering [14], ion implantation [15] and others. Due to the clean technology, plasma deposition is used to modify surface properties of γ-TiAl alloys for the present research.

2. Experiment

2.1. Alloys

Two γ-TiAl alloys used for plasma deposition are MJ12 and MJ47 and the compositions are shown in Table 1. The alloys were provided by Howmet Corp. (Whitehall, MI, USA) as 15.5 mm diameter rods and cut into 1–2 mm thick disks. The disks were polished down to 0.3 μm alumina powder and degreased with acetone.

2.2. Plasma system

An inductively coupled plasma system used for plasma deposition consists of RF power generator (Dressler model HPG 1365) discharge at 13.56 MHz in order to avoid interference from public communication [16]. The generator is connected to an antenna through a matching network and the operating power was at 150 and 250 W. The multicusp plasma chamber is made of stainless steel with 312 mm diameter, 425 mm long and 6 mm thick. The external surface of the chamber is embedded with the permanent magnet buttons [17].

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Table 1
Nominal composition (at%) of the alloys

Alloys	Ti	Al	Nb	Cr	Mn	TiB_2
MJ12	Balance	47	2	2	–	–
MJ47	Balance	47	2	–	2	0.8

2.3. Deposition

The alloy was placed in the multicusp chamber. The air was evacuated to 2.5×10^{-5} Torr pressure and argon was fed into the chamber to 10^{-3} Torr. The generator was discharged at 13.56 MHz and 150 W. The −2.4 kV bias voltage was supplied for 600 s (10 min) to clean the alloy surface and turned off. Then, the argon was evacuated to 1.6×10^{-5} Torr and acetylene was fed into the chamber to 5.8×10^{-4} Torr. The generator was operated at 250 W and deposition proceeded for 3.6×10^3 s (1 h) and 1.44×10^4 s (4 h) using −4, −5 and −6 kV bias voltages. At the end of the process, the power of the generator, bias voltage and acetylene were turned off. The air was fed into the chamber until the pressure was 760 Torr (1 atm) and the alloy was brought for further characterization.

2.4. Characterization

By using 1 gf load, Knoop hardness (HK) was measured for 10 times. The average and standard deviation were calculated. Surface morphologies were characterized using a scanning electron microscope (SEM) operated at 3 kV and an atomic force microscope (AFM) with scanning rate of 2 Hz. Deposited phases on the alloys were analyzed using an X-ray diffractometer (XRD) operated at 40 kV and 30 mA and using the Kα line from a Cu target in combination with JCPDS software [18]. Elements on the alloy surfaces were analyzed using an energy dispersive X-ray (EDX) analyzer operated at 15 kV.

3. Results and discussion

3.1. Hardness

Knoop hardness of MJ12 and MJ47 is shown in Fig. 1. Hardness is increased with the increase of bias voltage and prolonged time for deposition. The rate of HK increase of MJ47 with the increase of voltage is higher than that of MJ12. At −6 kV for 1.44×10^4 s, hardness values of MJ12 and MJ47 are 789.8 ± 49.4 and 960.9 ± 92.8 kg mm^{-2}, which are 3.36 and 3.32 times as hard as the untreated alloys, respectively. This shows that hardness of the alloys was successfully improved by acetylene plasma deposition.

3.2. SEM and AFM

SEM and AFM of the alloys are shown in Figs. 2 and 3. SEM micrographs show the characteristic of deposited surfaces composing of a number of nano-dots of less than 100 nm × 100 nm in area. The trace on the surfaces reflects the roughness value. AFM analysis also shows the

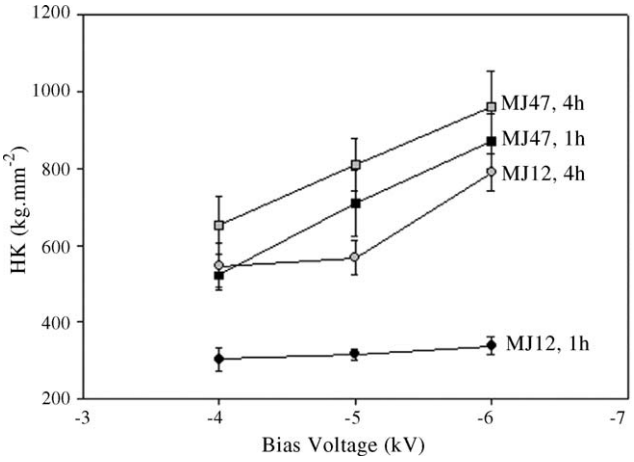
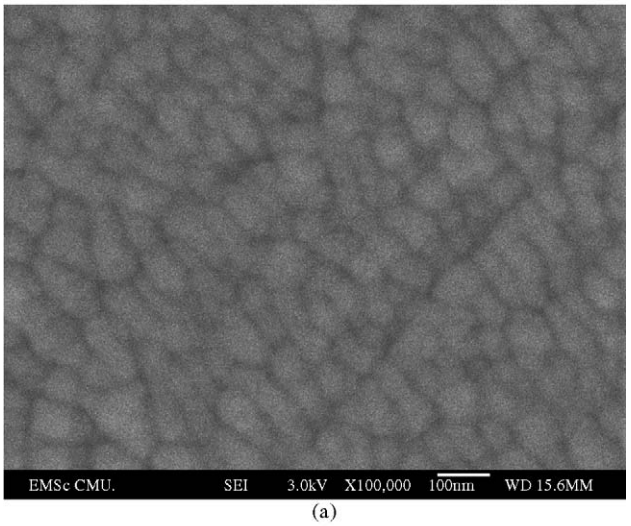
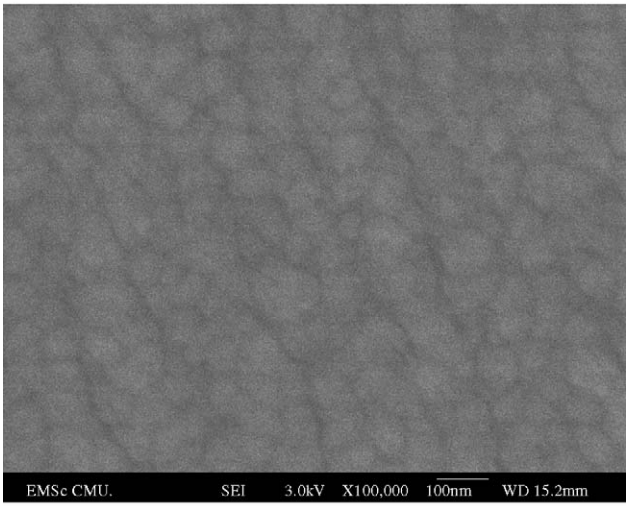


Fig. 1. HK of MJ12 and MJ47 deposited at −4, −5 and −6 kV for 3.6×10^3 s (1 h) and 1.44×10^4 s (4 h).



(a)



(b)

Fig. 2. SEM micrographs of (a) MJ12 deposited at −5 kV and (b) MJ47 deposited at −4 kV for 1.44×10^4 s.