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Wear behavior of low-pressure plasma-sprayed AlCuFe quasicrystalline coating on titanium alloy

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Abstract

The wear-resistant AlCuFe quasicrystalline coating was fabricated on substrate of titanium alloy by low-pressure plasma-spraying (LPPS) method. The LPPS AlCuFe quasicrystalline coating has a rapidly solidified lamellar microstructure consisting of mainly icosahedral phase and small amount of cubic phase peaks. The results showed that AlCuFe quasicrystalline coating improved the wear resistance of titanium-based alloys under dry sliding wear test conditions. The excellent wear resistance may be attributed to the high hardness of AlCuFe quasicrystal and the formation of the tribofilm.

Keywords: Wear resistance; AlCuFe quasicrystalline coating; Titanium alloy; Low-pressure plasma-spraying

1. Introduction

Titanium and its alloys are extensively applied in aerospace, chemical, petrochemical and marine industries as structure materials due to their high specific strength and excellent corrosion resistance [1,2]. They are also one of the most attractive metallic biomedical materials because of their outstanding biocompatibility, bio-corrosion resistance, absence of tissue toxicity and allergic reactions, and high strength and low elastic modulus compatible to natural human bones [3,4]. Nevertheless, high and unstable friction coefficient and poor wear resistance are currently the main obstacles that restricted titanium alloys from industrial and biomedical applications as tribological components [1].

Production of a low friction and wear resistant coating by surface engineering method is one of the most prospective means to improve the tribological properties of titanium alloys. Many surface engineering methods such as physical vapor deposition [5], chemical vapor deposit [6], ion implantation [7,8] and thermal oxidation [9], etc., were used to improve the tribological properties of titanium alloys. However, coatings made by these technologies are too thin to apply in severe wear conditions.

Quasicrystal is a new class of materials characterized with quasi-period order. The phase with five-fold rotational symmetry was first reported in Al–Mn alloy by Shechtman and Chan [10], which aroused great interest among material scientists. Due to its special structure, quasicrystals exhibit a series of unique properties such as low conductivity with positive thermal coefficient [11], low friction coefficient [12], excellent oxidation and corrosion resistance [13,14]. The shortcoming of quasicrystals generally manifests itself as extreme brittleness in bulk form. They cannot be applied as structural materials due to their brittle nature at ambient temperature. However, the combination of excellent physical and mechanical properties makes them the potential materials for surface application [12,15–19]. With the characteristics of quasicrystals, it is expected that the formation of AlCuFe quasicrystalline coating on titanium alloy would improve the wear resistance of the alloy. This paper reports the investigations of low-plasma-sprayed AlCuFe quasicrystalline coating on the titanium alloy and the subsequent wear-resistant properties.

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Table 1
Conditions for the LPPS deposition of the coatings

Volts (V)	Current (A)	Argon gas (l/min)	Hydrogen gas (l/min)	Powder feed rate (g/min)	Substrate temperature (°C)	Chamber pressure (Pa)
55–60	550–580	60	20	20	~400	5×10^3

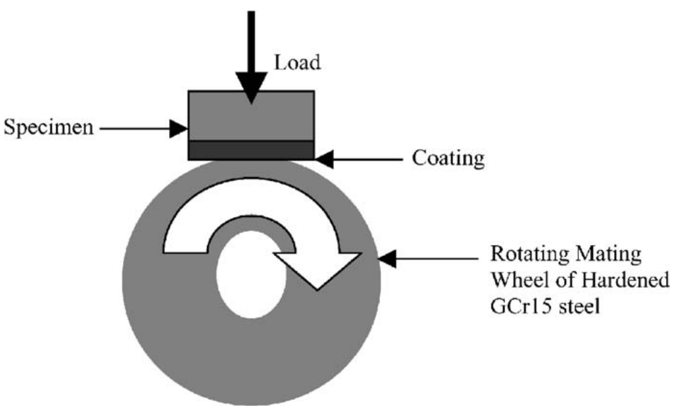

Fig. 1. Schematic illustration of the block-on-wheel dry sliding wear tester.

2. Experimental procedures

As received Ti alloy bar stock with a chemical composition of Al: 2.5 wt%, V: 5 wt% and Mo: 5 wt% was machined into coupons with a dimension of $13\times10\times2.5$ mm. In order to improve the adherence of the coating, these coupons were then grit blasted, using 250-Am alumina grit, to obtain a sharp-peaked surface contour with a roughness average of R_a 4–5 μm. A quasicrystalline coating with nominal composition (at%) of AlCuFe was vacuum-plasma-sprayed onto surfaces of the specimens. The deposition parameters for the coating production were listed in Table 1. During the spraying, the sample was rotated.

The hardness profiles along the depth direction from the coating to titanium alloy substrate were measured by a MH-6 semiautomatic Vickers hardness tester with a testing load of 50 g and a loading time of 10 s. Room-temperature wear resistance of the coating and titanium alloy were evaluated on sliding wear tester (as shown in Fig. 1), where specimens, $10\times10\times13$ mm in size, were ground to 600 grit finish before the wear test and were forced against a rotating wheel of hardened GCr15 steel (HRC65). The load applied to the samples, wheel speed and sliding time were controllable. The original titanium alloy was selected as the reference material for all the wear tests for comparison purpose. Each test sample is matched with a reference sample and each test was repeated three times. Wear mass loss was measured using an electronic balance (Sartorius, BS110) with an accuracy of 0.1 mg. All tests were carried out at room

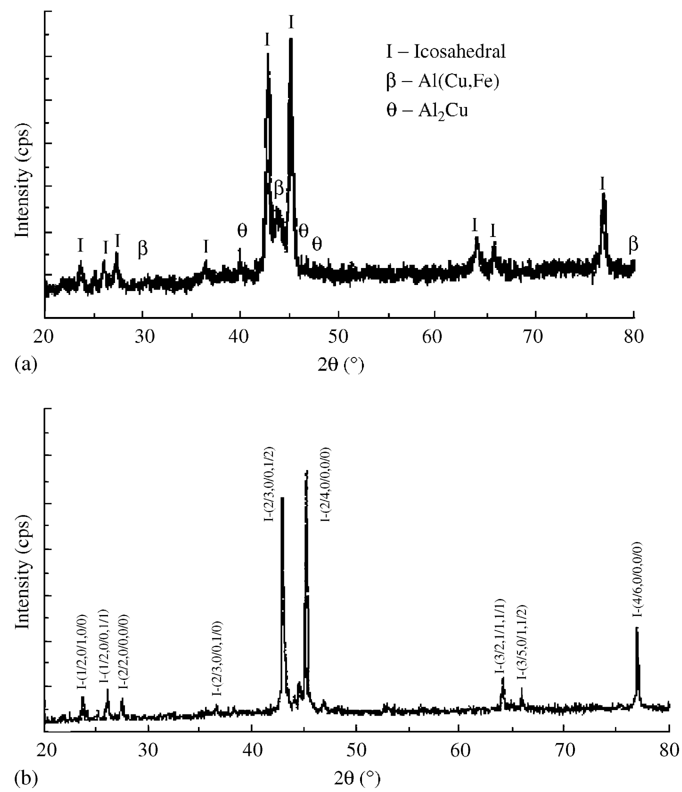

Fig. 2. X-ray diffraction pattern of as-sprayed AlCuFe coating before (a) and after (b) annealing at 800 °C for 2 h.

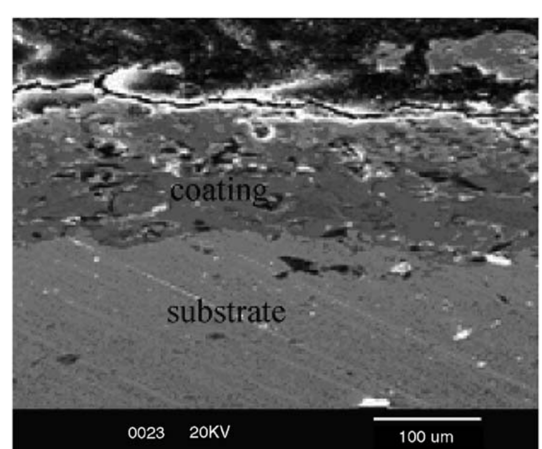

Fig. 3. Cross-sectional morphology of LPPS Al–Cu–Fe quasicrystalline coating.