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Laser remelting of plasma-sprayed conventional and nanostructured Al_2O_3–13 wt.%TiO_2 coatings on titanium alloy

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ABSTRACT

Plasma-sprayed microstructured and nanostructured Al_2O_3–13 wt.%TiO_2 coatings were successfully deposited on Ti–6Al–4V titanium alloy substrates with commercial Metco 130 powder and as-prepared nanostructured feedstock, respectively. The as-sprayed coatings were remelted by a CO_2 laser to further enhance their compactness and bonding strength. The effects of laser remelting on the microstructure, phase constituents and mechanical properties of the ceramic coatings were investigated by scanning electron microscope, X-ray diffractometer and Vickers microhardness tester. The results indicate that the laser-remelted coatings exhibit more compact and homogenous structure as well as strong metallurgical bonding to the substrates. The dominating metastable γ-Al_2O_3 phase in the as-sprayed coatings transforms to stable α-Al_2O_3 during laser remelting. The microhardness value of the as-sprayed Metco 130 and nanostructured Al_2O_3–13 wt.%TiO_2 coatings is in the range of 700–1000 $HV_{0.3}$, while the microhardness values of the corresponding remelted coatings are enhanced to 1000–1350 $HV_{0.3}$ and 1100–1800 $HV_{0.3}$, respectively. With the decrease of laser scanning velocity, the microhardness is increased.

1. Introduction

Titanium is the ninth most abundant element and the fourth most abundant structural metal in the Earth's crust, and has also been detected in meteorites, the Moon, the Sun and other stars [1,2]. Owing to its high specific strength, low elastic modulus, good resistance to corrosion as well as high melting point, titanium and its alloys have found wide applications in a diverse range of fields as key structural components, including aerospace, chemical and marine industries [3–5]. However, titanium and its alloys have poor wear and abrasion resistance because of their low hardness, which definitely hampers their potential wider applications [6,7]. Preparation of a protective coating offering superior surface performances such as high hardness on the surfaces of titanium and its alloys is a promising solution to improve their surface properties while keeping the advantageous bulk properties unaffected.

Many techniques including thermal oxidation [8], physical vapor deposition [9], plasma spraying [10] and microarc oxidation [11] have been proposed to fabricate a hard and wear resistant coating on the titanium components. Among these, plasma spraying is most widely used because of its simplicity and versatility [12,13]. Plasma-sprayed Al_2O_3 and Al_2O_3–TiO_2 ceramic coatings have been developed for a wide variety of applications that require resistance to wear, erosion and corrosion due to their thermal, chemical and mechanical stability [14]. Unfortunately, limited bonding strength at the coating–substrate interface and high porosity are two major shortcomings of plasma spraying [15,16]. However, such defects are eliminable by post-laser treatment. Many investigations of post-treatment by laser have been performed on the plasma-sprayed coatings, which may contribute to the enhancement of the coating strength and chemical homogeneity, elimination of high porosity, as well as the development of a metallurgical bonding at the coating–substrate interface providing strengthened coating adhesion [17–19].

Over the past decades, nanostructured materials have been the focus of scientific research due to their superior properties associated with a nanostructure [20,21]. Compared with their conventional counterparts, plasma-sprayed nanostructured Al_2O_3–13 wt.%TiO_2 coatings derived from agglomerated feedstocks have been reported to exhibit novel and attractive properties such as high bonding strength, superior toughness, abrasive wear and corrosion resistance [22–24]. To date, extensive investigations have been done on laser surface remelting of plasma-sprayed conventional Al_2O_3–TiO_2 ceramic coatings [25–27]. Nevertheless, few investigations on laser remelting of plasma-sprayed

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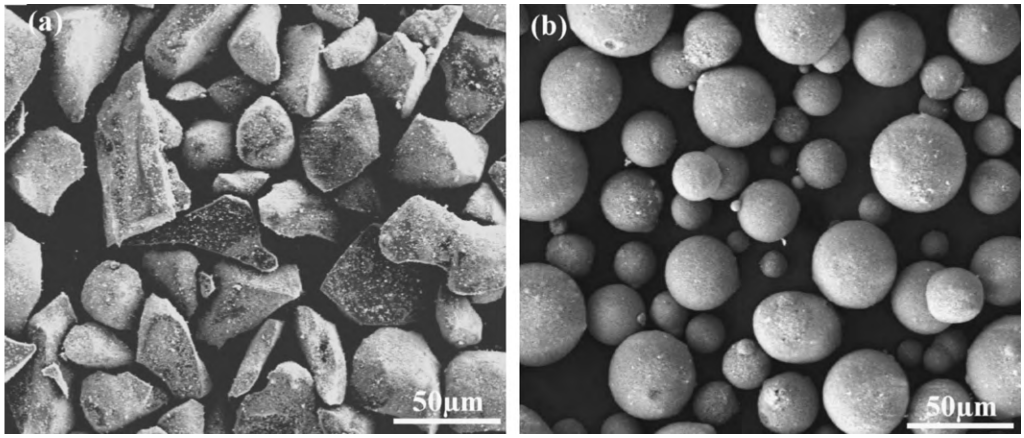

Fig. 1. Scanning electron micrographs of the Al_2O_3–13 wt.%TiO_2 feedstock used for plasma spraying: (a) as-received conventional Metco 130 powders and (b) as-prepared nanostructured powders.

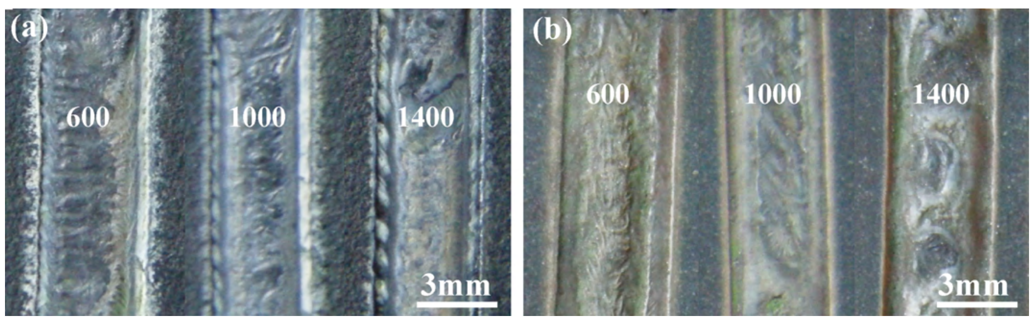

Fig. 2. Digital macro-photographs of LRmC: (a) C–LRmC and (b) N–LRmC (600, 1000 and 1400 correspond to Experimental No. 1, No. 3 and No. 5, respectively).

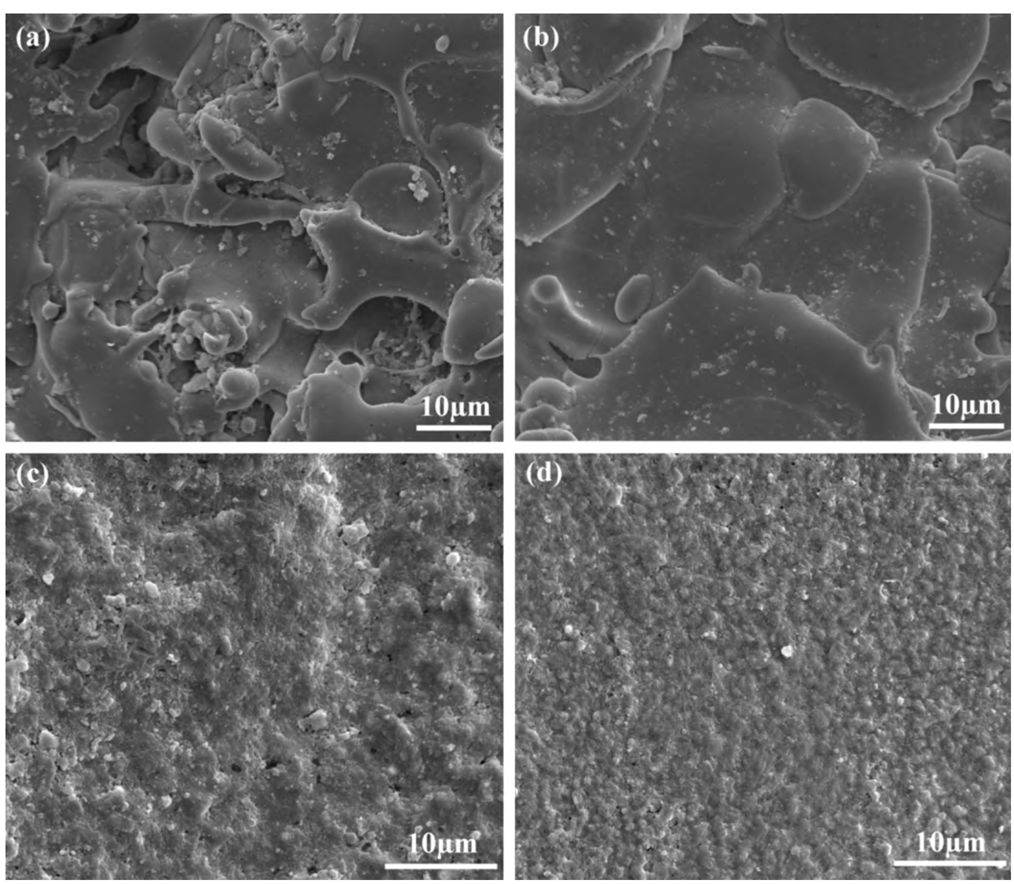

Fig. 3. Surface morphologies of (a) as-sprayed conventional Metco 130 coatings, (b) as-sprayed nanostructured Al_2O_3–13 wt.%TiO_2 coatings, (c) C–LRmC, and (d) N–LRmC.