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Growth mechanism of the tubular TiB crystals in situ formed in the coatings laser-borided on Ti–6Al–4V alloy

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ABSTRACT

Coatings containing borides were fabricated on titanium alloy by laser boriding treatment. SEM images indicate that some rod-like TiB crystals with a hollow core (filled with α-Ti before etched) are formed in the coatings. The formation of rod-like hollow TiB is attributed to the following aspects: first, because the chemical composition in some areas in the laser melt pool is hypoeutectic and in some other areas is hypereutectic due to the boron atoms dissolved in the melt distributing unevenly during rapid solidification, β-Ti firstly crystallizes as primary phases in the hypoeutectic areas of the melt pool and acts as a heterogeneous nucleus for TiB to crystallize on it, and second, because the bond between B–B is stronger than that between Ti–B and between Ti–Ti. TiB grows along the B–B zig-zag chain as well as normal to the direction of the B–B zig-zag chain to form a tubular structure with a β-Ti core in it.

1. Introduction

Laser boriding treatment is a promising way to improve the surface properties of titanium alloy. The main reinforcement phase, TiB, in situ forming in borided layers makes the microstructures and mechanical properties much better than that of the Ti substrate. That TiB is used as a strengthening phase to improve the properties of pure Ti and Ti alloy has been reported by many researchers. Gorsse et al. [1,2] reported that rod-like TiB has a high Young modulus and significantly enhances the stiffness of pure Ti. Atri et al.'s experiment [3] indicated that TiB increases the elastic and shear moduli of Ti–6Al–4V. Our experiment results [4] also showed that laser coatings containing TiB have high microhardness, excellent wear resistance and are more resistant to oxidation than the Ti–6Al–4V substrate. In recent years, some studies focus on the growth morphology of TiB for it has an effect on the mechanical properties of the coatings. Kooi et al. [5] reported that there are generally three types of TiB precipitates depending on the boron concentration in the melt pool: fine needles, plates and coarse needles (concentration of B > 1.56 wt.% in the Ti–Al–V–B quaternary system) [6], and some coarse primary TiB crystals have a hollow core filled with Ti [5,7]. They thought that coarse borides were formed at a higher temperature and some of them were hollow in structure and melt filled within and around them. The melt on cooling subsequently solidified to form the β-Ti matrix (β-Ti transforming into α-Ti below a temperature of 884 °C) both within as well as surrounding the primary boride precipitate. On the other hand, Lieberman et al. [6] also found in using the inert gas atomizing liquid melt of Ti–Al–V–B that only coarse primary and fine eutectic TiB are formed. The studies mentioned above indicate that the processing techniques as well as the solidification speed of the melt have an effect on the growth morphology of TiB crystals. So, in the present study, we performed surface alloying of Ti–6Al–4V alloy with boron powder and investigated the growth mode of the TiB crystals formed in laser coating.

2. Experiment procedures

Ti–6Al–4V samples, size of 20 mm × 20 mm × 10 mm, were abraded with abrasive paper prior to the coating operation. Ti and B mixed powders, with an average particle size of 10 μm, weight ratio of 2:1, and blended with dilute polyethylene solution, were precoated onto the surface of the samples to a thickness of about 0.3 mm and then dried. A 2 kW continuous wave CO_2 laser, with a power output of 1200 W, a spot size of 2 mm and a scanning speed of 8 mm s^{-1}, was employed to melt the surface of the samples. During processing, argon gas at a pressure of 0.4 MPa was fed through a nozzle which was coaxial with the laser beam. Metallographic samples were prepared using standard mechanical polishing procedures and then etched in a

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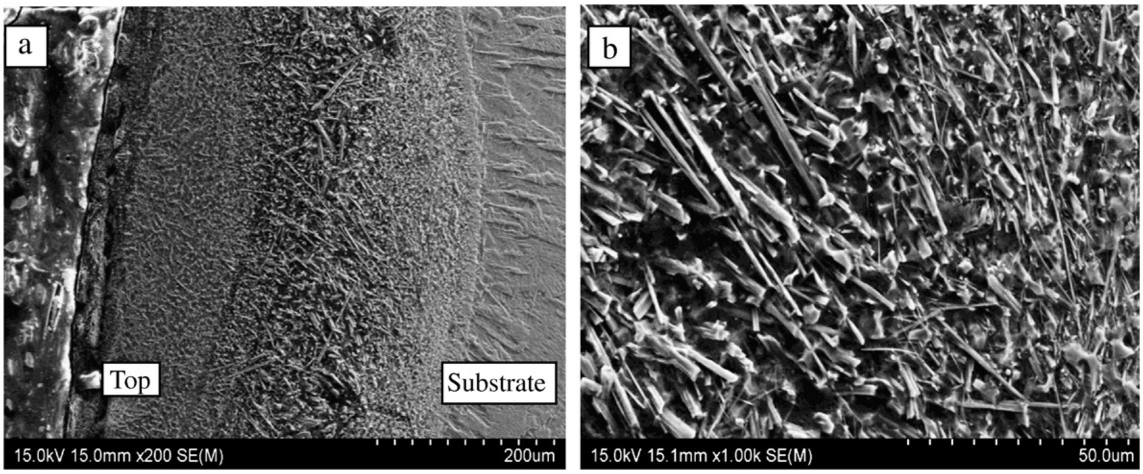

Fig. 1. SEM images of the coating.

solution of HF, HNO_3 and H_2O in a volume ratio of 2:1:47 to reveal the growth morphology of the compounds. The microstructures of the coatings were identified using su-70 SEM and H-800 TEM, respectively.

3. Results and discussions

From Fig. 1a, the general view of the coating, we can see that a fine microstructure is formed both at the top and the bottom and coarse

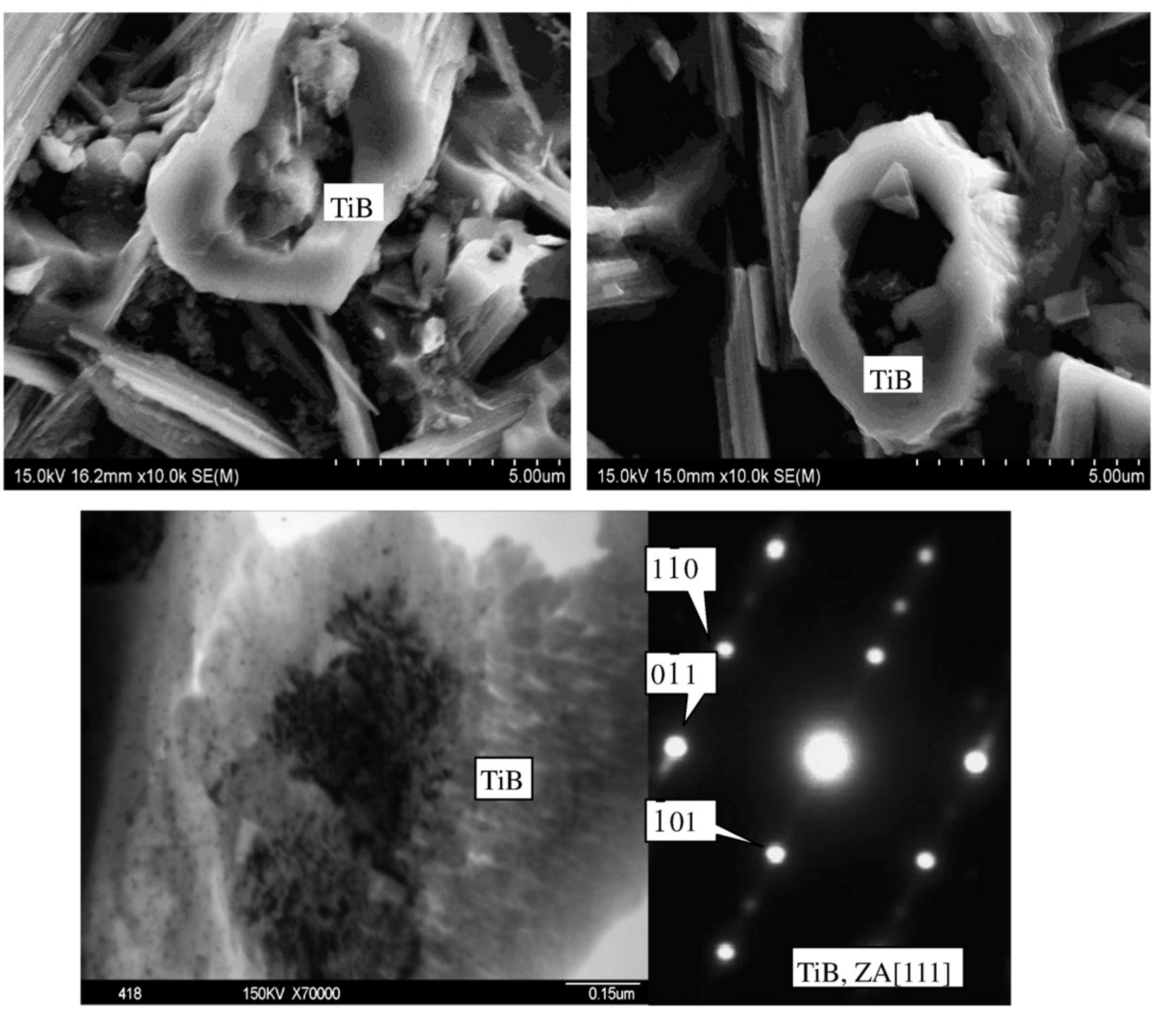

Fig. 2. SEM and TEM images of the TiB crystal with a hollow core.