Microstructure transformations of laser-surface-melted near-alpha titanium alloy

G.X. Luo, G.Q. Wu, Z. Huang, Z.J. Ruan*

Department of Material Science and Engineering, Beijing University of Aeronautics and Astronautics, Xueyuan Road 37, Haidian District, Beijing 100191, PR China

ARTICLE DATA

Article history:
Received 22 March 2007
Received in revised form
11 November 2008
Accepted 10 December 2008

Keywords:
Titanium alloy
Laser processing
Heat treatment
Microstructure

ABSTRACT

Microstructural transformations of near-alpha titanium alloy under laser-surface -melted and post-heat treated conditions were systematically investigated. The results show that, after laser surface melting treatment, a melted zone and a heat-affected zone are formed in the titanium alloy. The melted zone consists of columnar grains, which are characterized by fine a'' phase, distributed dispersively in acicular martensite phase α'. Martensite transformation occurs at a lower temperature in post-heating process. The α phase in the laser-surface-melted zone is further refined during the recrystallization, and a fine dispersive $\alpha+\beta$ microstructure is formed when experienced post-heat treatment at an elevated temperature.

1. Introduction

Titanium alloys for structure application at high temperature are generally near-α alloys which have good elevated temperature properties and weldability similar to α-titanium alloy and good processing plasticity comparable to $\alpha+\beta$ alloy [1]. Microstructural feature of titanium alloys, which is one of important factors controlling mechanical properties, are sensitive to the heating temperature, holding time and cooling rate of heat treatment [2,3].

Nowadays, high power lasers are frequently used in the field of surface treatments including laser melting, laser alloying and laser cladding. The common feature of these processes is to improve the surface properties by modifying the microstructure feature and (or) composition of the work-piece while maintaining other original properties [4–6]. With high heating rate and cooling rate, laser surface processing generally results in the obvious refinement of the surface microstructure compared to conventionally solidified materials [7–9]. It has been proved that fine microstructures are beneficial to the acceleration of the diffusion bonding process and the simultaneous decrease of the bonding temperature [10–12]. Accordingly, laser surface modification is an effective technique to improve the diffusion bond weldability of dissimilar materials.

In our study, laser surface melting (or cladding) technique is applied to dissimilar diffusion bonding of near-alpha titanium alloys to other high temperature structural materials, to gain sound joints at lower bonding temperature in less bonding time. The present paper is mainly aimed at investigating microstructural characteristics of laser surface melted titanium alloy and its transformation during post-heat treatment.

2. Experimental Procedure

The substrate material is BT20 near-alpha titanium alloy with the nominal composition (wt.%) of 5.5~7.0Al, 1.4~2.5Zr, 0.5~1.8Mo, and 0.8~2.3 V in the form of 50×20×6 mm rectangular plate.

Surface-melting experiments were performed using a continuous wave transverse flow CO_2 laser material pro-

* *Corresponding author*. Tel./fax: +86 108 231 3240.
E-mail address: guoqingwu@buaa.edu.cn (G.Q. Wu).

1044-5803/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.matchar.2008.12.009

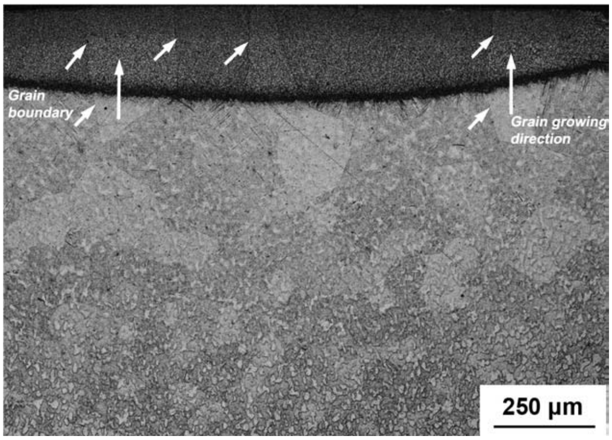

Fig. 1 – Cross-sectional micrograph of laser surface melted BT20 titanium alloy (the arrows marking the columnar grains nucleated at coarse grains in HAZ and grown vertically to molten pool bottom).

cessing system. Laser processing parameters are: laser power 0.8~1 kW, beam diameter 3 mm, laser scan speed 150~250 mm/min. A shielding gas of argon was used to prevent the specimen from oxidizing during laser processing. After laser surface melting treatment, the specimens sealed in quartz tube under vacuum condition were annealed at different temperatures for 60 min and cooled with quartz tube under the air condition.

Microstructures are investigated using optical microscopy (OM), transmission electron microscopy (TEM) and scanning electron microscopy (SEM) with a secondary electron detector. The phases were examined by X-ray diffraction (XRD) using a D/max2200PC Rigaku X-ray diffractometer with Cu–Kα radiation. Differential scanning calorimetry (DSC), typed of a Perkin–Elmer DSC-6 differential scanning calorimeter, was adopted to measure the microstructural transformation behaviors of the laser melted layer at a heating rate of 0.33 c/s under an argon flow. The sample weights 15 mg, and the test temperature range is 20~1200 °C.

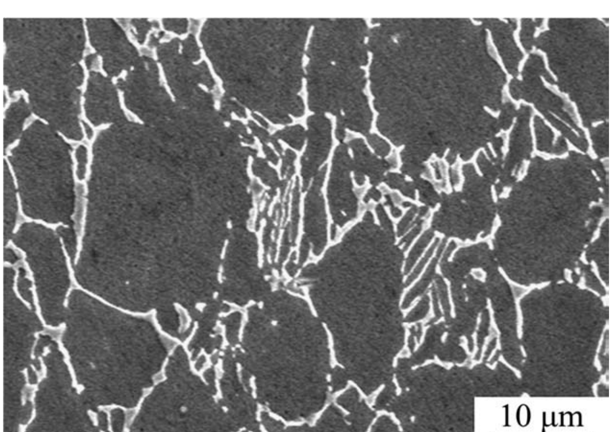

Fig. 2 – SEM image by secondary electron detector of BT20 alloy substrate.

3. Results and Discussion

The cross-sectional macrograph of laser-surface melted BT20 alloy is shown in Fig. 1. It can be seen that the specimen is divided into three zones, namely laser-melted zone (LMZ), heat-affected zone (HAZ) and substrate. The BT20 substrate in

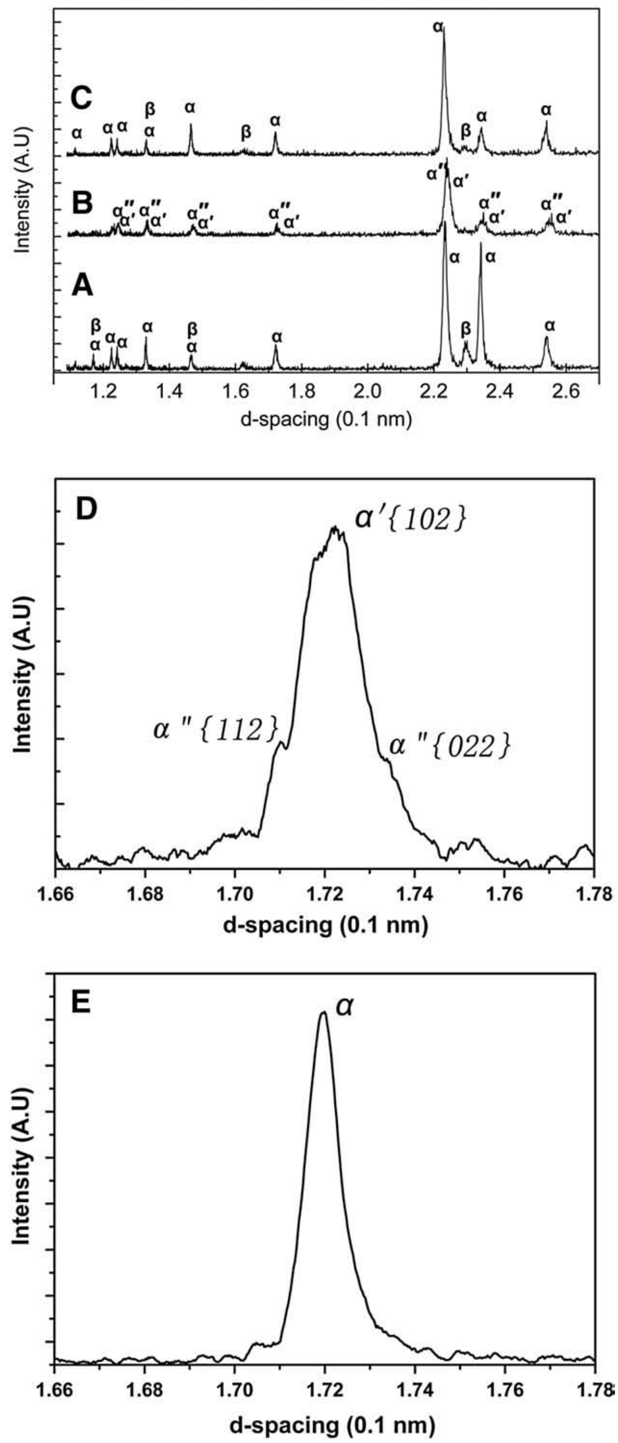

Fig. 3 – XRD patterns of laser surface melted BT20 alloy: (A) substrate, (B) as-melted, (C) as-annealed at 850 °C for 1 h, (D) as-melted by slow scanning rate and (E) as-annealed at 850 °C for 1 h by slow scanning rate.