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Short communication

Enhanced mechanical properties of Ti-6Al-2Zr-1Mo-1V with ultrafine crystallites and nano-scale twins fabricated by selective laser melting

Xu Wu[a], Chao Cai[a,b,*], Lei Yang[a,c], Wan Liu[d], Wei Li[a], Ming Li[a], Jie Liu[a,**], Kun Zhou[b], Yusheng Shi[a]

[a] State Key Laboratory of Materials Processing and Die & Mould Technology, Huazhong University of Science and Technology, Wuhan 430074, China
[b] Singapore Centre for 3D Printing, School of Mechanical and Aerospace Engineering, Nanyang Technological University, 639798 Singapore, Singapore
[c] Department of Mechanical Engineering, KU Leuven (Catholic University of Leuven), Leuven 3001, Belgium
[d] Hubei Rehabilitation Assistive Technology Centre, Wuhan 430074, China

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ABSTRACT

Ti-6Al-2Zr-1Mo-1V (TA15) with ultrafine crystallites and numerous nano-scale twins were successfully prepared by selective laser melting (SLM). The room-temperature and high-temperature (500 °C) tensile properties of SLM-fabricated samples were visibly higher than those of TA15 fabricated by conventional techniques, other near α titanium alloys and even comparable to TA15-based composites.

1. Introduction

The manufacture of complex-shaped titanium (Ti) alloy parts with high mechanical performance still remains a challenge for industrial applications due to complicated raw material processing, difficult-to-machine properties and high machining costs. Selective laser melting (SLM), as a promising additive manufacturing (AM) technology, enables directly rapid fabrication of Ti alloy parts with any extremely complex configuration through layer-by-layer accumulation fabrication [1]. These SLM-fabricated Ti alloy parts not only show nearly full density but also possess excellent mechanical properties comparable or even better than those obtained by conventional methods. Previous studies have mainly focused on improving room-temperature properties of SLM-processed Ti alloy parts via optimizing processing parameters by controlling their final microstructure. Though room-temperature strength is one of important criteria for evaluating the mechanical performance of parts, high-temperature tensile properties are more worthy of attention for certain special Ti alloys used in an extreme environment [2]. For instance, near α Ti alloys are designed for serving in a harshly high-temperature environment and widely applied in the aerospace industry [3]. However, few studies reported on the mechanical performance of near α titanium alloys fabricated by SLM, especially high-temperature tensile properties.

In this work, near α titanium alloy Ti-6Al-2Zr-1Mo-1V referred to as TA15 in Chinese industrial community was prepared by SLM. This work concentrated on investigating and establishing a correlation between microstructural characteristics and mechanical performance of the SLM-processed samples, and their mechanical performance was compared with that of their counterparts obtained by casting, a process widely used for manufacturing aerospace engine components.

2. Material and experiment

2.1. Feedstock material

The gas atomized spherical TA15 powder with an average particle size of 34.9 μm provided by AMC Powders Company, China was chosen as the feedstock material. The counterpart of cast ingot was provided by the same factory.

2.2. SLM experiment

Details regarding the SLM equipment and procedure have been addressed in our previous publication [4]. Based on a series of preliminary experiments, the SLM process parameters were optimized and set as follows: the laser power of 230 W, the scanning speed of 675 mm/

* Corresponding author at: State Key Laboratory of Materials Processing and Die & Mould Technology, Huazhong University of Science and Technology, Wuhan 430074, China.
** Corresponding author.
E-mail addresses: chaocai@hust.edu.cn (C. Cai), hustliuj@hust.edu.cn (J. Liu).

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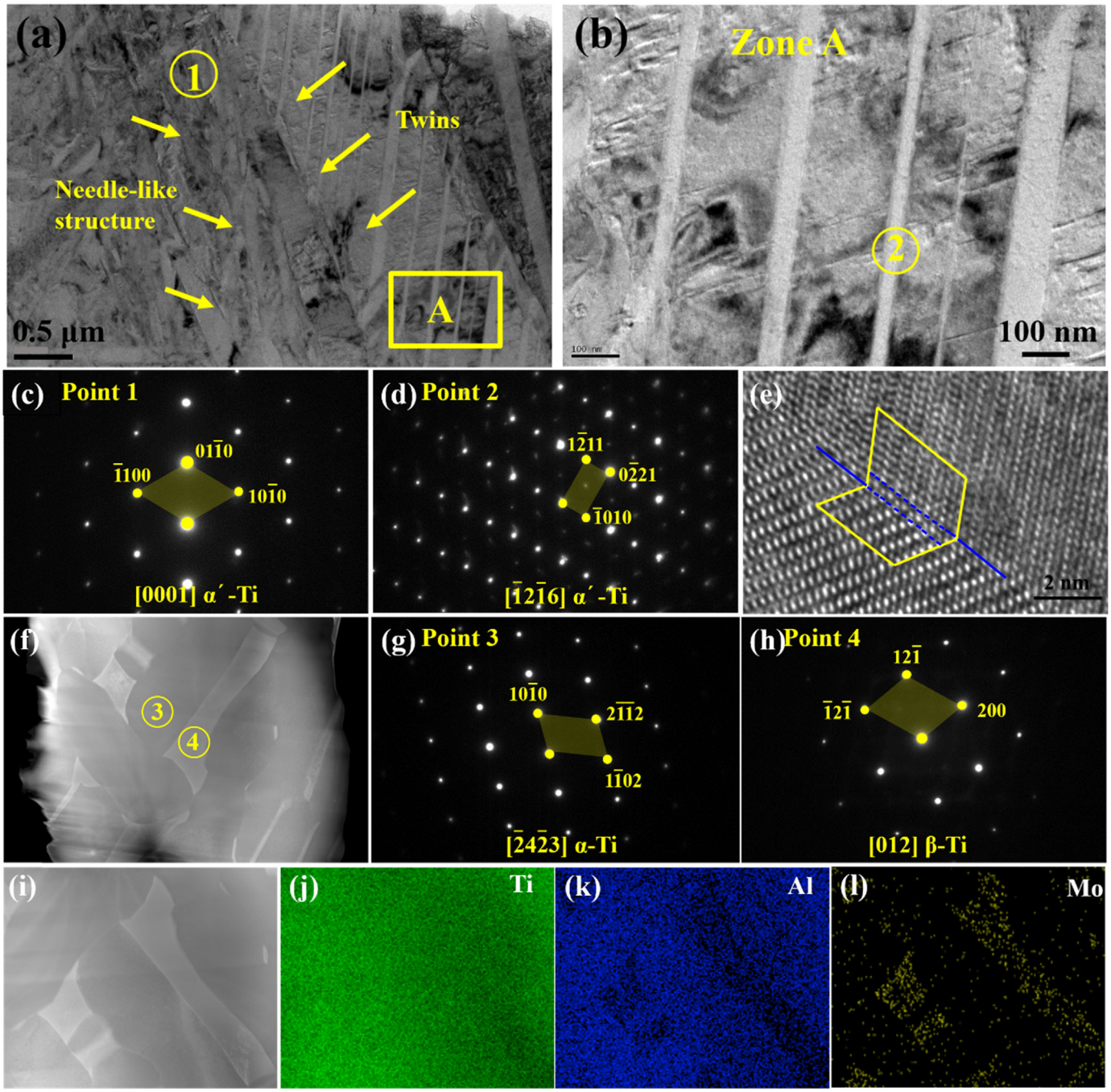

Fig. 1. TEM results of the SLM-fabricated sample: (a) bright-field image, (b) higher magnification images of nano-sized twins, (c) SAD patterns of matrix, (d) SAD patterns of the nano-sized twins, (e) HRTEM image of nano-sized twins. TEM results of the cast sample: (f) HAADF image, (g) SAD patterns of dark grey matrix, (h) SAD patterns of light grey area, (i)-(l) magnified microstructure and EDS elemental mappings of Ti, Al, Mo, respectively.

s, the scanning space of 0.12 mm, the layer thickness of 0.03 mm, the baseplate preheating temperature of 200 °C, and the zigzag scan pattern with 67° rotations between adjacent layers.

2.3. Characterization

The phase identification of the samples was detected by an X-ray diffractometer (XRD) (XRD-7000S, Japan). Transmission electron microscopy (TEM) were conducted on FEI Tecnai G20 and the TEM thin foil was prepared by focused ion beam (FIB, Quanta 3D FEG). The metallographic samples were ground, polished and etched with Kroll reagent for 20 s. The microstructure and crystallographic orientation of the samples was characterized using scanning electron microscope (JSM-7600F, Japan) and Sirion 200 instrument with a TSL/EDAX system (Holland), respectively. Tensile tests were performed using a test machine (Zwick/Roell Z010, Germany) under room and high temperatures (500 °C) with a cross-head speed of 1 mm/min.

3. Results and discussion

The representative finer needle-like α′ matrix with width approximately 1 μm and length below 10 μm could be better seen in the SLM-fabricated sample from Fig. 1(a)-(b). It is also distinctly found a high density of parallel finer twins with thickness hundreds nanometers in