

Unique Formation Characteristics of α' -Martensite in Ti Alloys Processed by Laser Powder Bed Fusion

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1. Introduction

Additive manufacturing (AM) enables complex shaping, material efficiency, and property control in titanium alloys. Among these benefits, direct microstructure tailoring during processing has drawn significant interest. In our previous study, the microstructure of Ti-6246 fabricated Power Bed Fusion using a Laser Beam (PBF-LB) was observed [1]. It was found that fine α' -martensite formed in the high volumetric energy density (VED) condition, while coarse α' -martensite formed in the low VED condition. This is the opposite trend, as generally fine α' -martensite forms in the low VED condition due to a fast cooling rate. The underlying mechanism remains unclear but is considered to relate to melt pool geometry and thermal gradients. In this study, single and multiple bead tests were conducted on various types of bulk titanium alloys to assess the dependence of the melt pool shape and the heat-affected zone on the α' -martensite formation.

2. Experimental procedure

Two titanium alloys, $\alpha+\beta$ Ti-6Al-4V (Ti64) and near- β Ti-6Al-2Sn-4Zr-6Mo (Ti6246) were selected used. Using the EOS M290 PBF-LB equipment (EOS GmbH, Germany), a single scan and 10 scans to X directions were applied to the bulk ingots prepared by cold crucible levitation melting. The laser power was 180 and 360 W, the laser scan speed was from 200 – 1400 mm/s, and the hatch spacing was from 10 to 100 μm . Cross-sectional microstructures were examined using scanning electron microscopy

3. Results

Under single-pass conditions, both alloys exhibited a transition in melt pool shape from keyhole to conduction mode near 1000 mm/s, with similar reductions in pool dimensions as scan speed increased. In both alloys, rapid solidification led to α' -martensite formation within prior β grains, composed of coarse lamellar and fine acicular variants aligned at $\sim 45^\circ$. Ti64 showed a clear trend of decreasing α' size with increasing scan speed, whereas Ti6246 showed minimal morphological change. In consecutive scans, higher energy density and narrower hatch spacing increased remelting, promoting the formation of longer lamellar α' with directional alignment driven by the thermal gradient. Conversely, reduced energy and wider spacing limited remelting, confining α' within a single molten pool. Under high energy density, Ti6246 also exhibited directionally grown α' ; however, at the lowest scan speed (200 mm/s), coarse and ultrafine α' regions appeared separately, likely due to repeated remelting or delayed solidification. These features began to emerge below 600 mm/s, where α' growth became randomly oriented, indicating the loss of thermal guidance. Although the exact mechanism remains unclear, the results suggest that prolonged thermal exposure plays a critical role. Notably, one alloy showed an atypical α' formation behavior: α' structures became finer with increasing energy density, indicating a unique interplay between alloy composition and localized thermal conditions

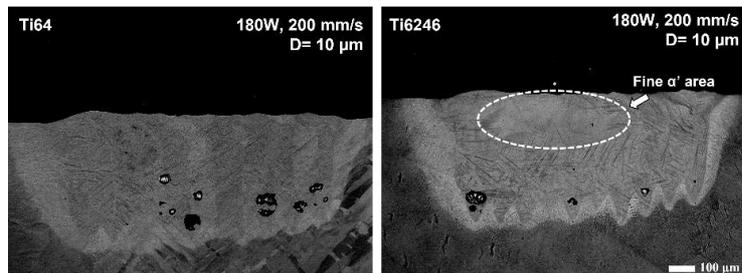


Fig. 1 Cross-sectional SEM images of Ti64 and Ti6246 alloys after multiple laser scans

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