Abstract

The laser-based additive manufacturing (AM) has emerged as a transformative fabrication method over conventional manufacturing for processing Titanium (Ti) alloys. However, a high propensity for columnar prior-β-grain growth along the AM-built direction brings anisotropy, limiting the utility of AM-built Ti-alloys. As one of the most feasible ways to address these issues, the present study utilizes various β-alloying strategies for developing novel AM-built Ti-alloys with improved properties. This study investigates the effect of β-eutectoid Fe and Co alloying, and the β-isomorphous Nb alloying, using the work-horse Ti-6Al-4V (Ti64) as the base Ti-alloy. Adopting thermodynamics-guided and theoretical alloy designing, the formulated Ti-alloy compositions were studied via environment-controlled laser pre-placed cladding, and laser directed energy deposition (L-DED) routes. The phase stability, microstructure, and mechanical properties were analyzed along with the evaluation of tribological, electrochemical, and property anisotropy. With an enhanced β-phase stability, the laser-cladded Ti64-5Fe-5Co shows improved hardness compared to its arc-melted condition and the base Ti64 alloy, along with a better dry-sliding wear resistance. In the L-DED bulk fabricated form, this alloy forms fully equiaxed β-grains with 57% grain refinement compared to the Ti64-4Fe alloy, resulting in improved hardness and tensile yield (~1426 MPa), along with a significantly reduced anisotropy. The studied hyper-eutectic Ti64-20Fe-20Co alloy shows evolution of the ordered BCC Ti (Fe, Co) phase, resulting in a hardness value twice that of commercial Ti64, also showing a 60% improvement in wear resistance and good corrosion resistance of the laser-cladded surface. However, the studied alloy system shows brittleness upon bulk laser-AM fabrication. Incorporation of Nb alloying improved β-phase stability for the studied laser-cladded Ti64-4Fe-xNb system, also showing an improved H^3/E^2 ratio, especially at high Nb (>10 wt.%) content. A 41% improvement in wear-resistance was observed at 13 wt.% Nb alloying, along with a good corrosion resistance in a simulated body fluid (SBF). The bulk laser-AM built Ti64-4Fe-13Nb alloy shows a superior toughness with a 25% improved strength compared to L-DED built Ti64, and a 48% improved ductility compared to Ti64-Fe alloy, addressing one of the major challenges observed for the laser-AM built Ti-alloys.

Keywords: Laser-cladding, L-DED, β-Titanium alloys, grain refinement, dry-sliding wear, tensile properties, anisotropy evaluation.