Abstract

Additive Manufacturing (AM) has changed the game for advanced manufacturing of complex high-performance components, and specifically, Laser Powder Bed Fusion (LPBF) is one of the most popular methods of producing near-net-shape metallic parts. Ti6Al4V, among the AM methods using LPBF and other forms, is a widely used alloy for many reasons, including a high strength-to-weight ratio, exceptional corrosion resistance, and high biocompatibility. The challenge with the components manufactured with Ti6Al4V using LPBF typically exhibits some difficulties within the microstructure, such as residual stresses, porosity, and surface roughness, which raise concerns about potential mechanical reliability and biological response to implant applications.

This work explores laser-based post-processing techniques to address these limitations, focusing on laser surface remelting for the in-situ nitriding in a controlled nitrogen environment. The objective is to modify the LPBF-fabricated Ti6Al4V surface microstructure and chemistry to enhance the mechanical integrity, surface hardness, corrosion resistance, and cytocompatibility of LPBF-built Ti6Al4V components. The study involves substrate fabrication using optimised LPBF parameters and their surface modification through controlled laser-nitriding processes.

Various surface characterisation techniques, such as optical and electron microscopy, X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), Electron Backscatter Diffraction (EBSD), nanoindentation, contact angle measurements and in vitro biological evaluations are used to assess the change in surface properties following treatment. The results show that with the nitride phase formation after remelting, this phase ultimately yields improved tribological behaviour along with electrochemical durability. The enhanced cellular viability and bioactivity suggest the potential efficacy of the in-situ nitriding process for biomedical use. To complement experimental nitriding, a non-isothermal molecular dynamics simulation is performed with FEM temperature–time profiles. Results are used to quantify nitrogen penetration and diffusivity.

This work contributes to the growing knowledge on integrated surface engineering in metal additive manufacturing. It proposes a pathway for developing functionally enhanced Ti6Al4V components through tailored laser-matter interactions.

Keywords: Additive Manufacturing, LPBF, Ti6Al4V, In-situ surface nitriding, Cytocompatibility, Molecular Dynamics