IMPACT OF GAS NITRIDING OF 3D-PRINTED Ti6Al4V ALLOY: MICROSTRUCTURAL EVOLUTION AND CORROSION CHARACTERISTICS

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Gas nitriding of direct metal laser sintered (DMLS) Ti6Al4V alloy was pursue to improve implant performance. Nitrided surfaces showed a positive shift in corrosion potential, though higher current densities were linked to the roughness of 3D-printed samples. Overall, gas nitriding demonstrates potential to enhance corrosion protection and reduce the release of V and Al ions.

Keywords: Ti6Al4V, additive manufacturing, gas nitriding, corrosion resistance

Introduction. The increasing demand for patient-specific spinal implants has driven the development of additive manufacturing technologies based on Ti alloys. Ti6Al4V has become a clinical standard owing to its high strength, corrosion resistance, and satisfactory biocompatibility. Nevertheless, challenges such as insufficient bone integration, local degradation, and risks associated with corrosion processes remain unresolved. One of the promising strategies to overcome these limitations is surface modification through gas nitriding [1].

The aim of this work is to evaluate the influence of gas nitriding on the microstructure and corrosion behaviour of 3D-printed Ti6Al4V alloy fabricated by DMLS.

Materials and experimental procedures. Specimens were produced from medical-grade Ti6Al4V ELI (Ti64ELI) powder via DMLS (ASTM F136, ASTM F3001). Gas nitriding was carried out at 650, 700, 750 and 800 °C for 5 h under N atmosphere.

Microstructural characterization was performed using SEM (JEOL JSM 6610) coupled with EDS. Phase composition was identified by X-ray diffraction (Bruker D8 Advance, Cu Kα radiation). Corrosion behaviour was evaluated in Hank’s solution at 36 °C using a VersaSTAT 3 potentiostat with Ag/AgCl reference and Pt counter electrode.

Results. Microstructural analysis showed a transformation from martensitic to a dual $\alpha+\beta$ structure, accompanied by the development of an α' phase – diffusion zone identified as a solid solution of nitrogen in titanium

(Fig. 1a, b). X-ray diffraction revealed that Ti_2N formation begins at 700 °C, with TiN detected at 800 °C. Even at 800 °C, the nitride layer did not exceed 1 µm in thickness (Fig. 1d). Electrochemical tests demonstrated a positive shift in corrosion potential, although higher corrosion current densities were also observed (Tab. 1). This effect is primarily attributed to the pronounced surface roughness of the as-printed specimens, with R_a =8–11 µm (Fig. 1c).

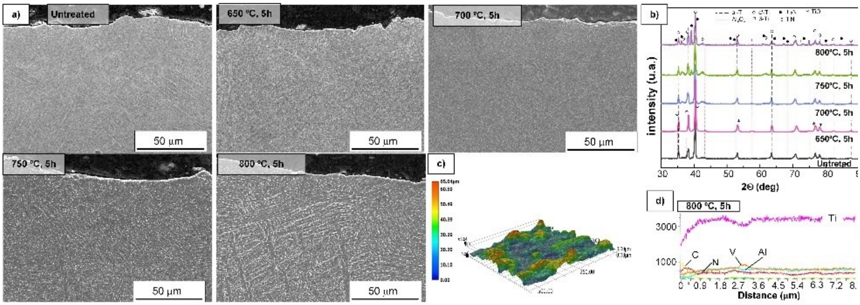

Fig. 1. (a) SEM micrographs of the cross-sections of the nitrided 3D-printed Ti6Al4V alloy, (b) XRD patterns, (c) 3D-colored map of the surface area and (d) EDS line scan result for typical cross-sections of the nitrided at 800 °C Ti6Al4V alloy

Table 1 Electrochemical parameters for nitrited 3D-printed Ti6Al4V in Hank's solution.

Treatment	OCP, V	E_{pas}, V	I_{pas}, $A\cdot cm^{-2}$
Untreated	-0.122	-0.201	$1.207\cdot10^{-7}$
700 °C, 5h	0.055	-0.059	$2.064\cdot10^{-7}$
750 °C, 5h	0.096	0.030	$4.448\cdot10^{-7}$
800 °C, 5h	0.081	0.017	$5.048\cdot10^{-7}$

Conclusions. The gas nitriding in the 650–800 °C range resulted in microstructural refinement through the formation of diffusion layers and nitride phases, while corrosion measurements indicated partial surface improvement. Although the high roughness of 3D-printed surfaces complicates the interpretation of electrochemical results, the observed a shift of corrosion potential toward more noble values was observed, suggesting that gas nitriding may provide beneficial surface modification. Importantly, such a layer may reduce the release of V and Al ions during implant degradation, highlighting the potential of this approach for biomedical applications.

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