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Influence of plasma conditions on the oxidation mechanisms of Ti and its effects on microstructural and mechanical properties

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Abstract

Nowadays, titanium is widely used in biomedical and aeronautical fields due to its attractive mechanical and physicochemical properties. However, its poor tribological performance (high friction coefficient and low wear resistance) remains a critical limitation in these applications. To overcome this issue, surface treatments based on oxidation, such as Oxygen Boost Diffusion, have been proposed [1], [2], [3]. The improvement in surface properties arises from a titanium oxide layer supported by a hardened titanium zone enriched with oxygen in solid solution (Oxygen Diffusion Zone, O.D.Z.). Existing processes generally involve high-temperature steps that may alter the bulk microstructure [2]. The aim of this study is to improve the oxidation process while minimizing its impact on the bulk mechanical properties of the material. To reach this goal, plasma-assisted oxidation is proposed. Plasma technology enhances oxidation kinetics at a moderate temperature (600 °C), thereby reducing the risk of grain growth. Sample heating is achieved through ion bombardment under pulsed bias conditions, with short oxidation durations (6 h). Three different oxidation protocols condition are investigated in order to obtain

oxide layers with various morphologies, while the oxygen penetration depth is also adjusted depending on the protocol. For each protocol, the oxide composition was analyzed by X-ray diffraction (XRD), surface roughness was measured, and cross-sections were examined using EBSD, EDX, SEM imaging, and in situ nanoindentation. These characterizations aim to observe the influence of plasma condition on the oxydation mechanisms and so the changes in oxide thickness and morphology, oxygen penetration depth into the bulk, and microstructural evolution. Variable-load scratch tests were performed on the surface to mechanically characterize the adhesion of the TiO_2 oxide layer. The results show that modifications of the plasma oxidation conditions affect the oxydation mechanisms and not only the morphology and thickness of the oxide layer, but also the oxygen penetration depth, leading to changes in the surface mechanical properties.

Keywords:

titanium plasma oxidation microstructural characterization

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