Bioactivity of titanium surfaces after oxygen and water plasma treatments

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Abstract

Titanium oxides play a fundamental role in the biocompatibility of Ti and Ti alloys. In oxidant environments, a thin titania (TiO2) layer of few nanometers is naturally formed on the metal surface. The corrosion potential of such coatings (2.4 V) is above the potential of body fluids (0.4 V), and the passivation time (_˜50 ms) is much lower than that for other metallic biomaterials (CoCr: > 6000 ms) [1]. These features make the titanium a bioinert material, which is indifferent to the vital functions of the body. Moreover, titanium oxides are also related to the metal bioactivity. Surface treatments, such the electrochemical oxidation, produce the TiO2 allotropic forms rutile and/or anatase, with proper chemical conditions for the calcium phosphate precipitation on the surface in the presence of body fluids [2]. Concerning an effective oxidation, one could consider the plasma-based methods, in which active species diffuse through the material's surface. The aim of the present study was to investigate the bioactivity and physical and chemical features of titanium oxides produced on Ti by DC plasma treatments (glow discharge). Two different oxidant atmospheres were used: (i) 100% O2; (ii) water (distilled and deionized). The samples were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS). Hardness and elastic modulus were obtained by instrumented indentation at nanoscale. The samples bioactivity was evaluated by in vitro assays using simulated body fluid (SBF) solution, in periods from 7 to 30 days. The 100% O2 samples presented a stratified oxide layer comprising TiO2 (rutile and anatase), Ti2O3 and TiO. Elastic modulus values increased by 60%, and the modified layer presented severe embrittlement under normal loading. On the other hand, a bluish film was produced by the water plasma treatment, marked by spurious phases corresponding to non-equilibrium oxides. In both situations, none bioactivity was observed in the in vitro tests. Irrespective to the plenty and diversity of oxide phases, such result can be attributed to the lack of other favourable chemical conditions for the Ca-P precipitation at the surface, in the SBF solution. Conspicuous is the small density of chemical radicals, which trigger the osseointegration, in the composition of oxide layers grown by low energy plasma processes.

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