Structural and tribo-mechanical characterization of nitrogen plasma treated titanium for bone implants

Gelson De Souza*†[1], Giovanne Steudel[1], Bruno Da Silva[1], Carlos Foerster*[1], and Carlos Lepienski[2]

[1]Universidade Estadual de Ponta Grossa (UEPG) – Brazil
[2]Universidade Federal do Paraná (UFPR) – Brazil

Abstract

Synthetic replacements for bone and teeth are expected to match the mechanical features (notably elastic modulus) of the surrounding bone, allowing a better transfer of functional loads with the bone and then avoiding resorption. Ti and Ti alloys present several physicochemical requirements for use in prosthesis, and they are usually modified by surface treatments in order to induce osseointegration. However, results in the recent literature have shown that such modified layers or films may not be mechanically stable and/or attend to the elastic modulus matching. The surface tailoring by ion nitriding can eventually improve adhesion and mechanical properties of such bioactive layers on Ti. In the present study, commercially pure Ti was plasma nitriding by glow discharge in different conditions of temperature (673 K and 873 K) and time (1 h and 3 h). The modified surfaces were characterized by grazing incidence X-ray diffraction (GIXRD) with the fixed incidence angle from 1° to 5°, scanning electron microscopy (SEM), atomic force microscopy (AFM), instrumented indentation and nanoscratch tests. The roughness effects on the mechanical properties measured by instrumented indentation were corrected by the analytical method based on the contact stiffness analysis. The surface roughness was directly dependent on the sputtering rate during the plasma treatment. The nitrogen solid solution [Ti(N) phase] prevailed in the lower temperature, whereas Ti2N was produced by treatments in 873 K and its amount increased in depth with treatment time. In the whole hardness and elastic modulus profiles obtained up to 3000 nm, values did not significantly changed after nitriding in the lower conditions (673 K 1 and 3 h), and the scratch behaviors in these samples were similar as well. On the other hand, at 200 nm depth, the treatment condition 873 K 3 h presented hardness which was four times and elastic modulus twice higher than the pristine surface. The specific wear rate in scratch tests varied from 0.09 mm3/N.m (reference Ti) to 0.01 mm3/N.m (nitrided in 873 K 3h). In conclusion, the load bearing capacity of Ti surfaces can be properly improved to be applied in osseous implants, in synergy with deposited bioactive layers.

Keywords: Titanium, plasma nitriding, biomaterial, mechanical properties

*Speaker
†Corresponding author: gelbsou@yahoo.com.br