Biomedical Properties of TiO₂ Films Synthesized by Dual Plasma Deposition

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Titanium metal and titanium alloys are among the most widely used materials in biomedical devices because of their relatively high corrosion resistance and good biocompatibility. It has been suggested that the physiochemical and dielectric properties of the surface native oxide play a crucial role in the biocompatibility. There is increasing evidence that titanium may be releases extensively in vivo, and under certain conditions, accumulated in adjacent tissues or transported to distant organs. Therefore, it is necessary to synthesize thicker and denser TiO₂ films on titanium to enhance its biomechanical properties. In this paper, we discuss our fabrication technique utilizing dual plasma generated by metal vacuum arc and radio frequency. By controlling the oxygen inlet rate, titanium oxide films with different Ti to O atomic ratios can be fabricated. The samples are then annealed at 750°C for 40 minutes at 2 x 10⁵ Pa. The film characteristics are studied using x-ray photoelectron spectroscopy (XPS), x-ray diffraction (XRD), atomic force microscopy (AFM), scanning electron microscopy (SEM), as well as microhardness and nano-scratch tests. XRD results reveal that the main phase of the titanium oxide film is of the rutile type. The preferred orientation varies with the oxygen density and changes after annealing. The highest microhardness measured in our experiments is 19 GPa whereas that of the film adhesion strength is 22 mN.

P-22

Calculation and Measurement of Thin Film Characteristics

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Thin film characteristics such as adhesion, hardness, porosity, roughness, and micro-stress were calculated theoretically and checked in experiment. In the model presented, some new concepts were used: firstly, the nuclei distribution function (DF) as a key point determining the film structure was calculated on the base of modeling the adatoms' diffusion field treated by a real ensemble of nuclei. It is shown that the mean surface concentration used in theories of nucleation provides the excessive rate of growth and the incorrect DF. Secondly, the local irregularities of the surface electrical field can radically change the behaviour of nuclei DF and then the final properties of a film. So, the surface electrical charge can be used as a key parameter for the film properties control. Thirdly, the hypothesis about decreasing the small nuclei melting point and presence of a quasi-liquid layer was destructively used for explanation of the experimental data on a quasi-liquid behaviour of small nuclei during the nucleation process.

The surface diffusion fields, surface electrical fields, nuclei distribution functions and film properties are calculated and shown. The experimental check was performed proving the theoretical predictions. Films were deposited using the ion beam-assisted deposition process and it was shown that the adhesion risers with surface electrical potential rising, porosity depends on a rate of deposition and decreases with a rate rising up to 20 μm/hour; this fact is completely predicted by the diffusion field calculations. Besides, the porosity value was found to decrease with voltage increasing, that fact is explained in theory using the distribution function concept; and finally the film hardness-roughness ratio with a maximum in 1000 V was explained using new concept of small particle nucleation. The model proposed can be regarded to as fruitful and experimentally justified.

- 70 -