Ti AND TiO_2 COATINGS FOR IMPLANTS BY GAS FLOW SPUTTERING

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Introduction

Metallic and ceramic coatings are widely used to tune the surface of materials in order to obtain extraordinary properties or to provide special functionalities. Among the variety of coating techniques Physical Vapour Deposition (PVD) can produce thin films with high hardness and excellent tribological properties. This is important for applications were abrasion has to be reduced or if the life time of cutting tools should be prolonged.

In case of medical application hard coatings can defend the articulating surfaces of artificial implants from wear and from release of allergenic ions as well. On the bone side of implants special surface morphologies should improve the osseointegration of the prosthesis. Porous and rough surface textures contribute to a good primary stability and a long-lasting secondary implant stability as well. The favourite surface topology is characterized by a roughness of micron scale which is advantageous for bone cell attachment [1].

Up to now rough and porous bone-side implant surfaces are produced rather by Vacuum Plasma Spraying (VPS) of metal and calcium phosphate powders than by PVD methods. Nevertheless, high rate coating via Gas Flow Sputtering (GFS) [2] allows designing of relative thick metallic and ceramic coatings which show surface features that could be interesting for an accelerated and adherent settlement of cells.

Experimental

Cylindrical ATZ ceramic samples and platelets of stainless steel were ultrasonically cleaned in water containing detergent agents. After mounting within a vacuum chamber the surface was purified by heating and by argon ion bombardment via glow discharge.

The GFS process is illustrated schematically by Fig. 1. The basic part of the GFS source is a pair of target plates mounted parallel to each other and perpendicular to the substrate. In between a hollow cathode glow discharge is sustained driven by a DC magnetron power supply with argon as working gas. At the operating pressure of 0.1…1.0 mbar the target material is sputtered and thermalised near the centre of the hollow cathode. By means of a very high argon flow the sputtered atoms are transported to the substrate. The target atoms diffuse onto the surface and form a coating. Reactive gases like oxygen can be added at the source outlet in order to form ceramic coatings. The film formation is supported by a pulsed DC bias voltage of the substrate (200 kHz).

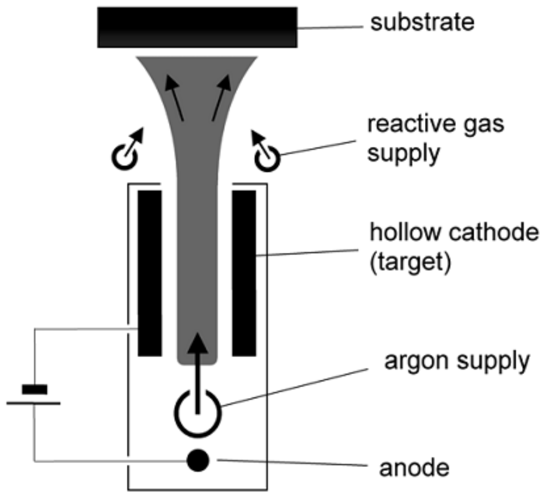

Fig. 1: Sketch of the Gas Flow Sputtering source [3]

The coated samples were fractured. The cross section and the coating surface were studied by a SUPRA-SEM (Zeiss, Germany). In order to avoid any charging of the samples a low beam voltage of 3 kV was used. In addition to the in lens detector (il) an Everhard-Thornley detector (se) was used to ensure high topographic resolution. The surface roughness was analysed by a Hommel tester T-8000 (Hommel-Etamic, Germany).

Results and Discussion

In Fig. 2 the cross section of a pure titanium coating on the as-fired surface of the ATZ ceramic is shown. Obviously, the coating consists of columns showing the typical hexagonal head due to the hcp structure of titanium below 882 °C [4] (Fig. 3). The thickness of the columns increases during growth since different columns merge, whereas length differences of the pillars considerably develop with rising film thickness. As a result, the surface of the coating becomes rough (R_a = 1,4 µm) and structured with lateral distances of some microns between the column heads (Fig. 3) and gap depths in the micron scale, too.

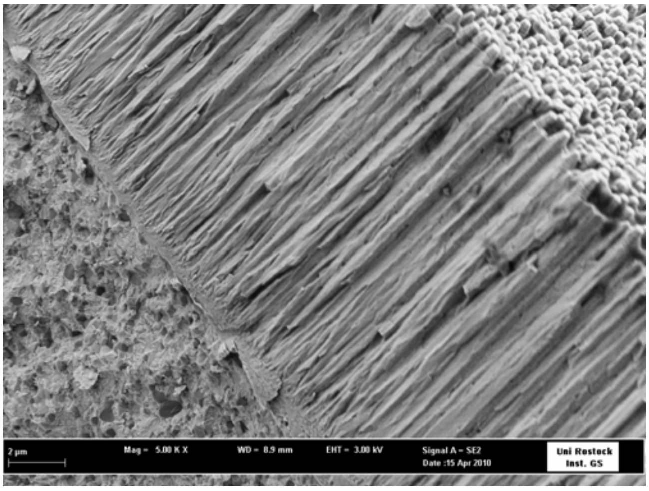

Fig. 2: SEM micrograph of the cross section of the titanium coating on ATZ ceramic (5,000x / 3 kV / se); scale bar: 2 µm

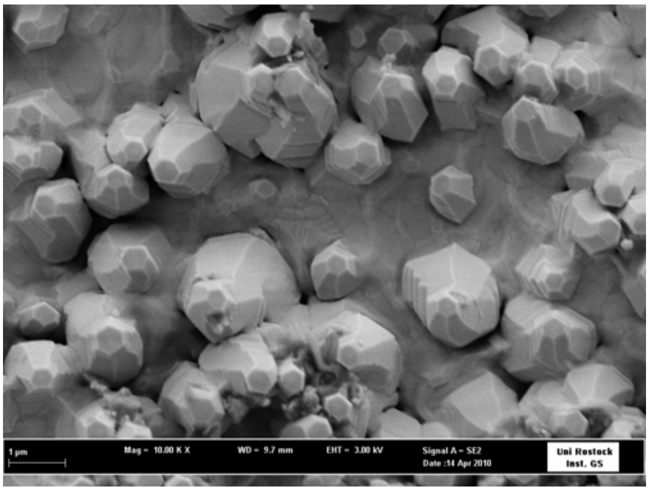

Fig. 3: Top view of the coating of Fig. 2 (10,000x / 3 kV / se); scale bar: 1 µm

In case of titania coatings on stainless steel substrates the variability of the coating structure is illustrated by the examples in Figs. 4 and 5.

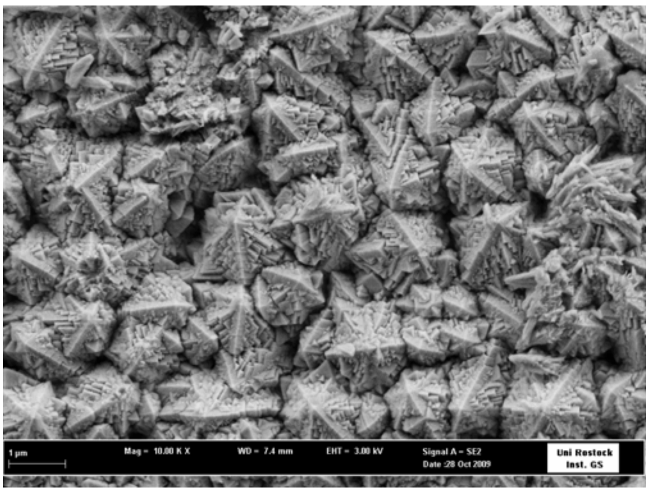

Fig. 4: Top view of a TiO_2 coating on stainless steel, U_{Bias} = 5 V, sample distance 40 mm; (10,000x / 3 kV / se)

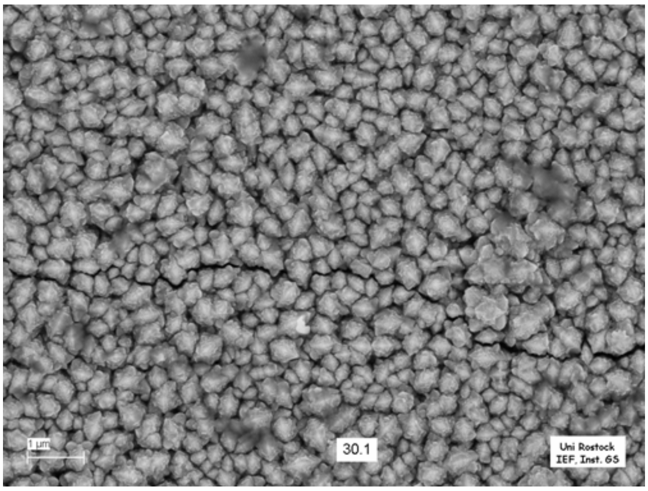

Fig. 5: TiO_2 coating on stainless steel, U_{Bias} = 30 V, sample distance 40 mm; (10,000x / 3 kV / se + il)

The coating processes differed according to the bias voltages, only. The findings can be discussed in terms of the Thornton model of structure zones [5]: At low mobility of the film forming species due to small bias voltage and low coating temperature large porous and rough structures develop corresponding to zone 1 (Fig. 4). With higher bias voltage the mobility increases and densely packed fibrous columns are formed (zone T, Fig. 5). Similar structure coarsening like via bias reduction can be obtained by increasing the distance between GFS source and sample. This causes more aggregation of particles on their pathway to the substrate and, therefore, larger structure elements with lower mobility during film formation.

Conclusions

The results presented show that metallic and ceramic GFS coatings can provide surface topology in the micron scale. Therefore, the coatings offer a potential of structuring the bone side of implants with adherent, biocompatible and microscopically rough layers which could improve the osseointegration of implants.

References

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