VACUUM ARC DEPOSITED NANOSTRUCTURED TI COATINGS

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ABSTRACT: Ti coatings on silicate glass substrates have been produced using a nonfiltered vacuum arc deposition technique. The dependence of the deposition rate on the distance from the cathode both in lateral and transversal directions was investigated. The average roughness, R_a , decreases with the distance, showing a transition area between the microparticle-containing and microparticle-free Ti films. A linear dependence of R_a depends strongly on the number of microparticles. A linear dependence of R_a on the discharge current was obtained only for substrates far enough from the cathode. For substrates close to the cathode the dependence is governed by the microparticle density. Transmission electron microscopy (TEM) reveals dense structure with nanograins.

Key words: Average roughness; Deposition rate; Grain size; Ti; Vacuum arc deposition

1. INTRODUCTION

Titanium coatings are mainly attractive due to their biocompatibility which make them reliable for the design of medical instruments or implants in the human body. The control of the surface roughness is an important factor for the implants [1]. Vacuum arc deposition of titanium offers a wide range of microstructural and morphological properties for coatings [2]. High deposition rates and a wide intervall of roughness can be achieved with an excellent coating uniformity. The following study presents the main coating characteristics of vacuum arc deposited titanium on silicate glass depending on the deposition parameters.

2. EXPERIMENTAL SETUP AND CHARACTERIZATION OF THE SAMPLES

The vacuum arc apparatus used in this work is described elsewhere [3]. Ti was deposited on a 450×470×4 mm silicate glass plate. The glass plate was positioned horizontally, at the middle of the round 180 mm cathode, perpendicular to the cathode surface plane, and 50 mm away from it. Before coating, a grid was drawn on the glass surface with the aid of an overhead pen. The grid also acted as a mask and its removal after deposition made it possible to determine the film thickness. The vacuum arc source voltage was maintained constant at U = 22 V while the discharge current I varied (I = 110, 140, 160, 175 and 220 A). No bias was applied to the substrate and no magnetic filtering was used. The coating time t were the same for all samples (t = 420 s) except for I = 160 A (t = 240 s). The microstructure and surface morphology was observed using transmisison electron microscopy (TEM) JEOL FX 2000 and atomic force microscope (AFM) *Autoprobe CP AFM* (Park Scientific Instruments). The thickness of the coatings, d, and average roughness, R_a, was measured with the aid of both Taylor-Hobson *Polystep* profilometer and AFM. The AFM was operated in the contact mode, using sharpened gold-coated microlevers with a nominal radius of the tip curvature less than 20 nm. For the film thickness measurements 50×50 μm scans were positioned in such a way that the border between coated and uncoated glass was approximately in the middle of the scanned area (Fig. 1).

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figures 1 and 2 display the microstructure of the Ti coatings. During vacuum arc deposition, the flux of material coming from the cathode to the substrate contains multiply charged ions and microdroplets [4]. The microdroplets are ejected from the liquid pool of the cathode (created by the arc impact) and accelerated by the ionic flux towards the target. In our case, the microdroplets fly almost parallel to the substrate plane. Their resulting shape is thus ellipsoidal and can be characterized by their aspect ratio. The surface morphology of the coating is driven mainly by the microparticle density. Close to the cathode, the Ti film has a very rough surface made of overlapping microparticles. Further away from the cathode, both droplets and a homogeneous film formed by the deposition of individual ions can be clearly seen. The microdroplets are still of various size but their shape is more uniform. In the AFM image taken at low magnification (Fig. 1) the „tail“ of a large microdroplet is visible together with some smaller particles on the rather smooth surface of a film formed by the flux of individual ions. High-magnification AFM pictures show the smooth film between the droplets (Fig. 2a) and the surface morphology of the microdroplets (Fig. 2b). The average roughness, R_a, measured profilometrically on the length of 80 µm, includes both big and small droplets and a smooth surface among them and, therefore, is rather high (about 350 nm on the sample shown in Figs. 1 and 2). R_a measured microscopically is much lower (3.7 nm for the location shown in Fig. 1a and 6.2 nm for Fig. 2b). If the deposition time t is high, the

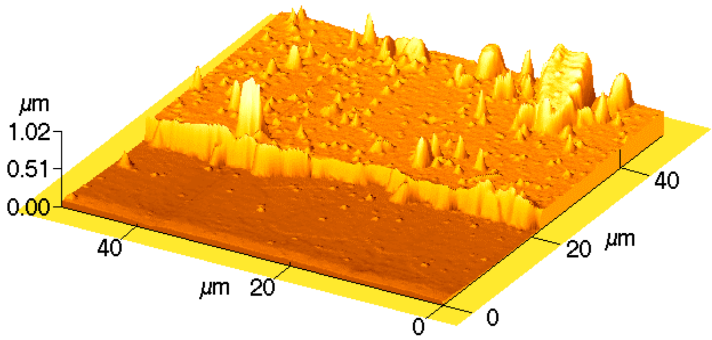
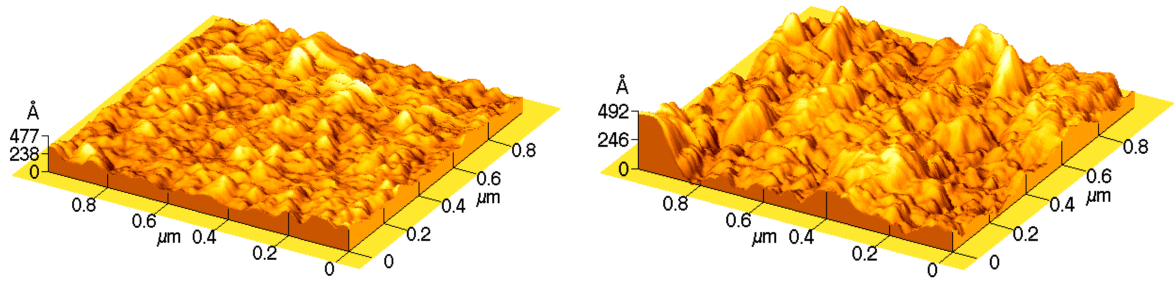


Fig. 1. AFM low magnification micrograph of a vacuum arc deposited Ti coating on the silicate glass substrate (L = 80 mm, I = 160 A, t = 240 s), showing the step between the masked and coated part. Small droplets and the smooth film formed from the ionic flux can be seen.



(a) (b)

Fig. 2. AFM high magnification micrograph of vacuum arc deposited Ti coating on the silicate glass substrate (L = 80 mm, I = 160 A, t = 240 s). The topography of a film between droplets (a) and the surface topography of a large droplet (b).

microdroplets become an integral part of the coating. At the largest distance from the cathode, the microdroplets density is very low and the coating consists of a homogeneous film formed by deposition of individual ions and which can be considered as microparticle free. The AFM measurements reveal that the film between the particles is atomically smooth (R_a = 1 nm) at L > 200 mm. Figure 3 displays the dark-field TEM micrograph of Ti coating. The film contains uniform grains having size from 3 to 10 nm.