

# PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF TITANIUM DIOXIDE FILMS PREPARED BY TWO DIFFERENT PHYSICAL VAPOUR DEPOSITION TECHNIQUES

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## Introduction

Preserving hospital sterility constitutes one of the major challenges of today's health care institutions. Unfortunately, it still often happens that a patient gets infected in a hospital. To prevent that, hospital space should be protected with bactericidal coatings. Such protection, among others, can be successfully provided by thin TiO<sub>2</sub> films [1]. Titanium dioxide belongs to the most frequently investigated transition metal oxides. Thanks to its physicochemical properties, for many years it has been focusing attention of the scientific community [1,2]. Its most abundant functions comprise a white pigment, an optical filter material and a photocatalyst, not to speak of numerous biomedical applications.

As a result of its illumination with light of appropriate wavelength, active forms of oxygen are formed on titanium dioxide surface, which then acquires a strong bactericidal character against various strains of bacteria [2,3]. Additionally, such a coating responds to light excitation by changing its character from hydrophobic to strongly hydrophilic. That phenomenon is known as superhydrophilic affect and it, to a large extent, prevents TiO<sub>2</sub> surface contamination with solid particles [1-3].

There is a number of different synthetic routes leading to a deposition of titanium dioxide films described in the literature. The most frequently used techniques comprise sol-gel and anodizing methods as well as thermal spraying and reactive magnetron sputter deposition [3]. For a number of years, there has been an interesting novel modification of the latter technique developed in Poland [4]. This method, known as gas impulse magnetron sputtering (GIMS), consists in a repeated application of working gas pressure impulses of a magnitude enabling initiation of a glow discharge. The aim of the present work is to report a structure as well as water wetting and bactericidal properties of titanium dioxide coatings synthesized with both conventional reactive magnetron sputtering (RMS) and novel GIMS methods.

## Materials and Methods

In both instances, the reactive sputtering of a titanium target in oxygen atmosphere was carried out. For the RMS processes, pressure and flow rate of oxygen were kept constant, thus allowing for the maintenance of a continuous discharge on magnetrons. In the case of the GIMS technique, on the other hand, oxygen was introduced in rapid pressure pulses which caused a pulsed discharge on the magnetrons. In both techniques the same rectangular planar magnetron and medium frequency power source were used. Both RMS and GIMS processes were carried out with an applied power of 0.8 kW and 1.5 kW.

Elemental composition and chemical structure of the films were investigated with the help of X-ray photoelectron spectroscopy (XPS), using a Kratos AXIS Ultra XPS spectrometer equipped with a monochromatic Al K $\alpha$  X-ray source. In addition, chemical bonding of the films was studied with the use of Thermo Scientific model Nicolet iS50 Fourier transform infrared (FTIR) spectrometer. The phase composition of the coatings was investigated using a low angle grazing incidence X-ray diffraction (GIXRD) technique. For that purpose, a PANalytical Empyrean diffractometer with a goniometer diameter of 240 mm, working in the Bragg-Brentano geometry and utilizing filtered Cu K $\alpha$ X-ray radiation, was applied. Surface morphology of the coatings was studied with the help of scanning electron microscopy (SEM), using JEOL JSM-6610LV microscope. Water wetting angles were measured by means of Kruss, EasyDrop apparatus. Changes of water wettability under the effect of UV-B light illumination were followed in five minutes long steps. The bactericidal effect of the illuminated coatings was studied using *E. Coli* bacterial strain.

## Results and Discussion

Elemental composition studies of the coatings show that they are predominantly built of titanium and oxygen atoms, with their Ti:O ratio being close to stoichiometric TiO<sub>2</sub>. Apart from that, also oxygen bound carbon atoms are present at their surface, which constitutes a likely result of photocatalytic effect typical for that material. FTIR analysis of the films RMS deposited at the higher power level reveals the presence of a distinct sharp absorption band at 440 cm<sup>-1</sup>. This band, corresponding to stretching vibrations of Ti-O bonds in anatase crystalline environment, in the case of GIMS synthesized samples appears already at the lower discharge power of 0.8 kW. As opposed to that, an application of the lower power level in the RMS process results in a broad, weakly separated band present in that region and revealing an amorphous character of the film. All the above results of the coatings phase composition were confirmed with the XRD data. SEM studies have shown a smooth and homogeneous surface of the films. Water wettability measurements under the influence of UV-B light revealed a strong hydrophilic effect in the case of RMS samples deposited at 1.5 kW of discharge power as well as in that of GIMS synthesized films deposited at 0.8 kW. In all cases, microbiological studies showed a substantial bactericidal effect, ranging from 21% to 50%.

## Conclusions

The results acquired in the present work show that high quality homogeneous TiO<sub>2</sub> coatings can be produced with both RMS and GIMS methods. All the samples exhibit photocatalytic as well as photowetting effect. In the case of films synthesized with the GIMS technique, the strongest effect is observed for samples deposited at 0.8 kW of magnetron discharge power, while a double of that magnitude is needed to attain a similar level of photoactivity of the coatings produced with the help of RMS method.

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