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Structural and surface properties of semitransparent and antibacterial (Cu,Ti,Nb)Ox coating

D. Wojcieszak[a,*], M. Mazur[a], D. Kaczmarek[a], B. Szponar[b], M. Grobelny[c], M. Kalisz[c], A. Pelczarska[d], I. Szczygiel[d], A. Poniedzialek[a], M. Osekowska[e]

[a] Faculty of Microsystem Electronics and Photonics, Wroclaw University of Technology, Janiszewskiego 11/17, Wroclaw, 50-372, Poland
[b] Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, Rudolfa Weigla 12, Wroclaw, 53-114, Poland
[c] Motor Transport Institute, Jagiellońska 80, Warsaw, 03-301, Poland
[d] Wrocław University of Economics, Faculty of Chemistry and Food Technology, Komandorska 118/120, Wroclaw, 53-345, Poland
[e] Department for Experimental Surgery and Biomaterials Research, Wroclaw Medical University, Poniatowskiego 2, Wroclaw, 50-326, Poland

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ABSTRACT

In this work structural and surface properties of oxide thin-film coating based on Cu, Ti and Nb prepared by reactive magnetron sputtering have been described. During the deposition process metallic Cu, Ti and Nb targets were sputtered in oxygen plasma. Structural characterization of the film microstructure has revealed that as-prepared coating was amorphous. Due to such structure and the content of Ti and Nb the hardness of the oxide film was about 3.6 GPa, which is 40% higher as compared to metallic Cu film. Moreover, the surface roughness was below 1 nm, what resulted in receiving of hydrophobic properties. The multioxide film was transparent at the level of 40%, but due to high Cu-content its optical absorption edge was about 450 nm and had bright orange color. Optical investigation has revealed that the energy band-gap of this film was 1.41 eV, which indicates on the presence of CuO form. Moreover, the studies of antimicrobial activity showed that as-prepared film had a strong bactericidal effect for *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus subtilis* and *Enterococcus hirae*, while fungicidal effect for *Candida albicans* was not observed. The biological activity was related to the amount of copper ions released from the surface of (Cu,Ti Nb)Ox coating, which was equal to 0.041 ppm per day.

1. Introduction

Medical devices and objects of common use that exhibit biological activity are often produced based on cheap materials as a carrier, whose surface is covered by bioactive material in the form of e.g. thin film [1–3]. It is a consequence of final product price and weight reduction by the use of cheaper or lighter substrates (e.g. polymers), respectively [4,5]. Deposition of thin-film coatings based on metals and their oxides is a good way of biologically active surface fabrication. Such coatings can be prepared by various methods, but PVD and CVD are most often used in the industry. Particularly, sputtering and evaporation are frequently used in mass production due to high deposition rates and possibility of covering substrates with different shapes [6–9].

In the case of bioactive materials the lead takes copper [10–14], which is the most biologically active element. It has a very strong antimicrobial effect. Copper ions in contact with microorganisms inhibit their growth or lead to their death. Therefore, Cu is commonly used e.g. in hospitals for covering door handles, window and bed frames and other elements where the growth of bacteria may endanger human life and health [15]. However, copper has several disadvantages limiting its field of application in everyday life. Cu endures poorly contact with the environment and its surface rapidly oxidizes [10]. Moreover, it has sensitizing properties - even in a form of alloy with other metals, but usually this fact applies to high concentrations of Cu [16,17]. Therefore, it is important to develop new copper base materials that are bactericidal and harmless to the human body (non-cytotoxic) [17]. A slightly lower activity than copper has silver and gold, but their price is much higher. Similarly, high activity is also exhibited by Pd, Ni, Co and Cr elements, but they often cause allergies, which limits their application area [18,19].

As mentioned, a major disadvantage of Cu or other bioactive elements is low resistance to environmental factors [10,16,17,20]. One way to solve this problem is manufacturing of such coatings in the form of multi-component oxides. It results in linking of high

* Corresponding author. Tel.: +48 71 320 39 03.
E-mail address: damian.wojcieszak@pwr.edu.pl (D. Wojcieszak).

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