BACTERICIDAL TiO_2 LAYERS DOPED WITH Cu, Zn, AND ZnO

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Introduction
The constant presence of chemical antimicrobial substances in our environment poses the risk of selecting strains of bacteria that are resistant to the bactericidal agents. At the same time, many research groups point to the need to increase the protection of the antibacterial surface on commonly used materials. Particularly important surfaces appear to be exposed to large numbers of people at places such as public transport or hospital facilities, which may also lead to the spread of pathogenic microorganisms.
One of directions of research is to develop coatings with antibacterial properties based on the action of inorganic compounds such as metal ions or metal oxides. This reduces the use of antibiotics or bacteriostats, reducing the risk of increased resistance to the pharmaceuticals used [1,2].
In this work, coatings produced by anodic oxidation using electrolytes containing ionic germicidal compounds were used.

Materials and Methods
The samples of Ti6Al4V were prepared in the form of discs of 16 mm in diameter and of 3 mm thickness. The surfaces of the samples were prepared according to the standards used for the production of implantable medical devices.
Anodic acid solutions (H_3PO_4, H_2SO_4, HF) and antimicrobial compounds ($CuCl_2$, $ZnSO_4$, ZnO) were used as the working electrolytes for the anode oxidation process.
Doped TiO_2 layers were characterized by measurement of: contact angle and roughness, as well as by analysis with SEM microscopy and EDS spectrometry. Verification of bactericidal potential was carried out using fluorescence microscopy and flow cytometry, as well as the susceptibility test for bacterial colonization of doped TiO_2 layers [3].

Results and Discussion
The efficiency and effectiveness of TiO_2 layers deposition on the titanium surface were assessed by the use of variable operating conditions, i.e. - application time, working electrolyte composition, and current. This allowed us to optimize the proper conditions for obtaining expected continuity and layer thickness on the surface of titanium samples. At the same time, effects of these parameters on bactericidal properties were analyzed - we showed that there are differences in the type of acid used in the electrolyte.
An essential part of this work was testing of antibacterial effect substances introduced into the layer during the anode oxidation process, it means Cu^{2+}, Zn^{2+}, and ZnO in the form of nanopowder. The range of used concentrations was from 0.1 to 1mM in the working electrolyte, and the results show a correlation of antimicrobial protection with the level of added dopants. EDS analysis confirmed the presence of doped substances in the produced layers.

Conclusions
Currently, there is a trend in reducing the level of antibiotics used as protection against the development of undesired bacterial biofilms [4]. The research demonstrates the potential in this respect of technology based on the addition of ionic additives that increase the level of protection against surface colonization and the development of microorganisms.

References
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