Research project objectives

With the increased life span more and more people are suffering from diseases of the skeleton, such as joint diseases or osteoporosis. Statistics show that the number of total knee and hip arthroplasties will grow up. The surgical placement of implants into the body is associated with the risk of the post-operative complications, such as bacterial infections or the lack of tissue integration between bone and implant. Among the implantable materials, titanium and its alloys have been widely investigated. They possess good biocompatibility, but the process of osteointegration is long-lasting. One of the solution to reduce the time of osteointegration is formation of the nanoporous TiO_2 layer on Ti substrate via electrochemical anodization. Nanoporous and nanotubular titanium dioxide layers have drawn scientists' attention as a potential material for cell growth and drug delivery. There are several approaches to improve their biological properties: (1) change of the pore diameter and length, (2) surface functionalization of the pores and (3) coating the pores with a polymer layer.

The main aim of this project is to modify the surface of the nanoporous titanium dioxide (TiO_2) layers with silane and/or phosphonate derivatives and explore them as drug delivery systems (DDSs) and scaffolds for osteoblasts-like cells culturing. In addition, the anodic TiO_2 layers (ATO) will be coated with a polymer (chitosan) layer in order to improve their biological properties. The apatite-forming ability of modified nanoporous anodic titanium dioxide layers will be examined in simulated body fluid (SBF).

Research project methodology

Before the anodization process titanium samples will be electrochemically and chemically polished. Nanoporous titanium dioxide layers will be synthesized in the ethylene glycol-based electrolyte with fluoride ions and water at the constant potential. Different potentials and times of the anodization process will be applied in order to obtain nanostructures with different parameters. Two approaches for modification will be applied. The first method will include modification of the TiO_2 surface with silane and/or phosphonate derivatives. The second approach will include coating of the ATO samples with the polymer layer. For both cases the modification conditions, such as time and solution concentrations, and annealing conditions will be examined. Modified ATO layers will be characterized by a field-emission scanning electron microscopy (FE-SEM), energy dispersive X-ray spectroscopy (EDS) and X-ray photoelectron spectroscopy (XPS). The contact angle measurements will be also performed. Modified TiO_2 layers will be examined as possible drug delivery systems (DDSs) and scaffolds for osteoblasts-liks cells culturing. The drug release studies will be performed in a phosphate buffer solution (PBS, pH = 7.2) at the temperature of 37 °C. The impact of all modifications on the drug release characteristics will be examined. The proposed drug release model will be fitted to the experimental profiles. The fitted model parameters will be calculated and analysed in detail. The biological properties of modified ATO samples will be examined. The osteoblast-like cell line MG-63 will be used in the studies. The survival rates, cell adhesion, cell proliferation and morphology of the cells will be examined using MTT assay, a fluorescent microscope and a field-emission scanning electron microscope (FE-SEM). The statistical analyses will be performed. In addition, the apatite-forming ability of modified and non-modified samples will be examined by the immersion in the stimulated body fluid (SBF) for different time periods. The samples will be characterized using a field-emission scanning electron microscope (FE-SEM), energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD).

Expected impact of the research project on the development of science, civilization and society

The concept of modification of the nanoporous TiO_2 layers with silane and phosphonate derivatives has not been thoroughly examined so far. It is expected that chemical surface functionalization of ATO layers with silane and/or phosphonate derivatives may have a significant impact on the increase in the control of drug release process. In addition, the silanation reaction can be used to form the chemical bond between the chitosan and anodic titanium dioxide layers. This method has not been studied so far. It is expected that TiO_2 layers are capable of forming the chemical bond between the biomaterial surface and chitosan coating. In addition, it is expected that the silane-modified and/or phosphonate-modified ATO layers will affect the morphology of obtained apatite. Therefore, modification with silane and/or phosphonate derivative and coating ATO layers with chitosan is believed to improve the drug delivery process, osseointegration and apatite-forming ability. Functionalization of ATO layers with different functional groups will improve biological properties of the nanoporous TiO_2 layers (cell behaviours, such as adhesion, migration, and differentiation). The basic research coming from this project will benefit in the future development of novel functional, biocompatible material suitable for implantable applications. This project will provide insights into how chemical modifications affect the biocompatibility of nanoporous TiO_2 layers.