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Obtaining and investigations of biomimetic transition metal oxide thin films

Abstract

The presented dissertation is a description of the research process carried out by the author leading to the assessment of surface biopotential. The main thesis of the work was to optimize the deposition technology of HfO_2 thin layers by the ALD method, enabling the development of a pro-apatite coating of a bone implant. At the same time, the observation and description of the phenomena occurring at the interface between the solid and the biological environment were planned. Physical methods were used to describe the phenomena, in particular X-ray photoelectron spectroscopy (XPS).

The motivation to undertake the research was the social need to functionalize the surface of bone implants dedicated in particular to patients with osteoporosis (OS). Osteoporosis is a systemic disease that drastically reduces bone density. Bone as an element of the skeletal system performs support and locomotion functions. For this reason, bone strength is crucial for the proper functioning of the human body. Reducing the density of bone tissue increases the susceptibility to fractures and hinders the healing process dramatically. Bone tissue has the ability to regenerate if homeostasis between the processes of bone formation and resorption is maintained. Because OS causes excessive activity of cells responsible for bone resorption (osteoblasts), bone regeneration after injury is also impaired. The vast majority of osteoporotic bone fractures require implantological treatment. However, the implantation process is also based on the remodulatory ability of bone tissue. In implantology, the bone connection of the implant surface with the bone tissue is crucial. Only then can the stability of the bone-implant structure be preserved for the patient's motor skills to restore. In addition to the processes of bone formation and resorption, the second stage is important, namely biomineralization of the scar. The mineral component of bone tissue is crystalline calcium phosphate - biological apatite (BA). The main research task in the presented dissertation was to assess whether BA can spontaneously crystallize on the surface of HfO_2.

To assess the functional potential of the HfO_2 coating, a fluid with an ionic concentration similar to human plasma was used. The prepared coatings on quartz substrates were incubated in the prepared solution in conditions close to physiological conditions (temperature 37°C), and then, using physical methods, it was tested whether mineral structures were present on the surface. It turned out that it is possible to prepare the HfO_2 surface that enables the induction of spontaneous deposition of amorphous spherical structures with a developed surface morphology, typical of a hydroxyapatite. Physical methods, in particular XPS and SEM, made it possible to assess the quality and chemical composition of the biomaterial. A model for the formation of structures at the molecular level was also proposed, which resulted from the XPS analysis. Statistical analysis based on the results of SEM observations allowed to determine the optimal technological parameters. In addition, it was shown that the growth process of CaP structures on the HfO2 surface is a self-limiting process, which is important for future medical applications of the coating.

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