Structure and physicochemical properties of surface layers of NiTi alloys used for implants in the cardiovascular system

Abstract

The dissertation is concerned with the surface modification of NiTi alloy for applications in the blood system using occluders dedicated to closing heart defects. The use of this alloy, despite its good biocompatibility and the pseudo-elasticity effect, is associated with the risk of allergies, blood clots or problems occurring during tissue overgrowth. To reduce these negative effects, a surface modification was proposed to modify the surface by applying a tantalum oxide coating by the ALD method to a substrate treated by electrochemical polishing.

The chemical composition of the resulting coating was 30.2% Ta and 69.8% O. Microstructure analysis of the sample cross-section revealed two areas in the coating: on the substrate side, a layered arrangement of structures consisting of titanium and tantalum was identified. The other region contained an uniform structure containing mainly tantalum. The thickness measurements of the coating were made using ellipsometry; the thickness of the passive layer was 2.7 nm and the Ta_2O_5 coating was 13.8 nm. The formed coating also showed great adhesion to the substrate and improved the friction coefficient of nitinol. Moreover, the coating effectively reduced the penetration of nickel ions into the PBS solution and improved resistance to crevice and pitting corrosion, even after deformation.

To complement physicochemical studies, biological tests were performed, including bacterial adhesion to the substrate, cytotoxicity, cell proliferation, thrombogenicity, hemolysis, and pro-inflammatory cytokine levels studies. The results of the mentioned studies showed a beneficial effect of the coating on the properties of the test material; bacterial adhesion, cytotoxicity, thrombogenicity, and cytokine levels were reduced, while proliferation was promoted. Nonhemolyzing properties were confirmed for the substrate and the coated substrate.