Antibacterial and osteoinductive multilayer systems involving biopolymer and biologically active nanoparticles deposited on shape memory alloys

Innovative biopolymer – nanoparticles coatings

The research includes intentional surface treatment processes of selected medical alloys (including NiTi with shape memory) for use in bioengineering. Deposition of functional multilayers (hybrid shells) containing biologically active nanoparticles is planned. In contrary to commonly used method, project methodology novel technique of layers fabrication will be used. Instead of creating randomly deposition of nanoparticles in biopolymer matrix, occurred before using immersion in colloid method, coatings will be obtained using spin-coating methods and the Inert Gas Condensation - Magnetron Sputtering technique for deposition of polymer layers (chitosan or silk fibroin) and metal nanoparticles (Cu, Ag, Au). Such as hybrid technology should provide a strategy of creating osteoinductive biopolymer – metal nanoparticles nanosandwich. The presented method allows to obtain a controlled thickness of the area in which nanoparticles are located and to control the release time by applying temporary migration of nanoparticles in a self-assembly biopolymer matrix. This solution should allow us to limit the number of nanoparticles and precisely determine the exposure time. Moreover, the osteoinductive character of natural polymer hastens the reconstruction of bone tissue in the implantation area.

In particular, the implementation of this project will include:

i. preliminary surface preparation,
ii. surface etching/functionalization in acid environments and/or PE RF CVD reactor using various gas mixtures,
iii. selection of technological conditions for hybrid coatings (with specific layer sequences, number of layers, thickness), including biopolymer layers – chitosan or silk fibroin, metal nanoparticles layers – gold, silver or copper using Inert Gas Condensation – Magnetron Sputtering system.

As part of the planned activities, the impact of specific technological parameters for the production of precious metal nanoparticles on the structure and biological activity of selected biopolymer matrixes will be determined, along with the determination of performance parameters. Particular attention will be paid to the number of individual layers, the sequence of their application, the thickness of the outer biopolymer layer, the range of nanoparticles size, and the behavior of different biopolymers within one coating.

Obtained multilayer systems will be examined using research methodology developed to seven areas: mechanical properties, microstructure, chemical composition, atomic structure, surface topography, wettability, corrosion resistance, bioactive nanoparticles release, in vitro biological tests, in vitro antibacterial tests.

Expected results

Firstly, it is expected that the obtained layers on the surface of the shape memory alloy are not will susceptible to delamination and are characterized by the homogeneity of the chemical composition. Moreover, an adaptation of hybrid fabrication based on spin-coating and inert gas deposition – magnetron sputtering technique will provide the “sandwich” composition of the bio-nano composite coating. Secondly, the obtained layer should show biocompatibility with bone tissue in the cytotoxicity test, furthermore, the outer layer should be a suitable environment for osteoblasts cells to proliferation and show osteoinductive propagation for bone tissue. To improve that effect roughness of the outer layer also should be appropriate to fix osteoblast cells. On the other hand, multilayer should be a good anti-corrosion barrier in the simulated human body environment to limit harmful ion diffusion, previous research provides that biopolymers-metal nanoparticles composites possess that properties. Additionally, multilayers system needs to be mechanically durable and adhesion between shape-memory specimen and coating should allow for implementation in surgery conditions. Last, but the most important, implemented system should let to obtain multilayer system that nanoparticle delivery, through self-assembly biopolymer matrix, the system could be flexible to change (thickness of outer biopolymer layer, the thickness of nanoparticles layer and range of nanoparticles size) in order requirements for antibacterial activity against gram-positive and gram-negative bacteria. The first advantage of that kind of tunable system is precisely matched MIC and MBC that properly address the needs of limit potential hazardous impact of overload by nanoparticles. Another advantage of that multilayer system is an easy reconstruction of mentioned concentrations in the case of potential nanoparticles resistant to evaluating living organisms like bacteria, which is observable in drug delivery.