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Diamond-Like Carbon-Based Structures as Functional Layers on Shape-Memory Alloy for Orthopedic Applications

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Abstract : NiTi alloys, possessing unique mechanical properties such as pseudoelasticity and shape memory effect (SME), are suitable for many applications, including implanthology and biomedical devices. Additionally, these alloys have similar values of elastic modulus to those of human bones, what is very important in orthopedics. Unfortunately, the environment of physiological fluids in vivo causes unfavorable release of Ni ions, which in turn may lead to metalosis as well as allergic reactions and toxic effects in the body. For these reasons, the surface properties of NiTi alloys should be improved to increase corrosion resistance, taking into account biological properties, i.e. excellent biocompatibility. The prospective in this respect are layers based on DLC (Diamond-Like Carbon) structures, which are an attractive solution for many applications in implanthology. These coatings (DLC), usually obtained by PVD (Physical Vapour Deposition) and PA CVD (Plasma Activated Chemical Vapour Deposition) methods, can be also modified by doping with other elements like silicon, nitrogen, oxygen, fluorine, titanium and silver. These methods, in combination with a suitably designed structure of the layers, allow the possibility co-decide about physicochemical and biological properties of modified surfaces. Mentioned techniques provide specific physicochemical properties of substrates surface in a single technological process. In this work, the following types of layers based on DLC structures (incl. Si-DLC or Si/N-DLC) were proposed as prospective and attractive approach in surface functionalization of shape memory alloy. Nitinol substrates were modified in plasma conditions, using RF CVD (Radio Frequency Chemical Vapour Deposition). The influence of plasma treatment on the useful properties of modified substrates after deposition DLC layers doped with silica and/or nitrogen atoms, as well as only pre-treated in O2 NH3 plasma atmosphere in a RF reactor was determined. The microstructure and topography of the modified surfaces were characterized using scanning electron microscopy (SEM) and atomic force microscopy (AFM). Furthermore, the atomic structure of coatings was characterized by IR and Raman spectroscopy. The research also included the evaluation of surface wettability, surface energy as well as the characteristics of selected mechanical and biological properties of the layers. In addition, the corrosion properties of alloys after and before modification in the physiological saline were also investigated. In order to determine the corrosion resistance of NiTi in the Ringer solution, the potentiodynamic polarization curves (LSV – Linear Sweep Voltamperometry) were plotted. Furthermore, the evolution of corrosion potential versus immersion time of TiNi alloy in Ringer solution was performed. Based on all carried out research, the usefullness of proposed modifications of nitinol for medical applications was assessed. It was shown, inter alia, that the obtained Si-DLC layers on the surface of NiTi alloy exhibit a characteristic complex microstructure, increased surface development, which is an important aspect in improving the osteointegration of an implant. Furthermore, the modified alloy exhibits biocompatibility, the transfer of the metal (Ni, Ti) to Ringer's solution is clearly limited.

Keywords : bioactive coatings, corrosion resistance, doped DLC structure, NiTi alloy, RF CVD
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