SUITABILITY OF GRADIENT COATINGS OF TiO_2/SiO_2 IN IMPROVING HEAMOCOMPATIBILITY OF AISI 316LVM BASE

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Introduction

Many years of biotolerance studies AISI 316LVM allowed to establish certain qualitative and quantitative criteria ensuring the safety of its use and assemble it to the standards. This applies above all to the chemical and phase composition and mechanical properties. Suitable amounts of dopant elements provide paramagnetic structure and corrosion resistance in tissue environment. Nevertheless solutions don't solve existing problems concerning with steel implants attributed to the formation of physico-chemical properties of the surface layer. The main aim of the surface layer is to prevent adverse phenomenon generated by the implant in the blood environment [1-3]. The essence of the problem in the proposed study was to evaluate the coating of TiO_2/SiO_2 for improving heamocompatibility of AISI 316LVM used among others for blood-contacting implants.

Materials and Methods

The coating for steel substrate (after electrochemical polishing and chemical passivation) were coated by ALD method (SiO_2: precursors - $C_6H_{19}N_3Si$ and O_3, T = 340°C, L = 600 cycles; TiO_2: precursors - $TiCl_4$ and H_2O, T = 200°C, L = 50 cycles). The application of this type of surface treatment did not affect for the structure and mechanical properties of the base material. Surface topography was performed by atomic force microscope (AFM). The mechanical properties of the surface layer with TiO_2/SiO_2 layer determined on the basis of nanometer hardness (nH) and Young's modulus (Ym).

In turn, adhesion tests and other symptoms of mechanical damage of layer were performed by scratch test method used by open platform equipped with CSM Micro-Combi-Tester. Pitting corrosion resistance (DC-ET) was evaluated by recording of polarization curves potentiodynamic method using the AutoLab PGSTAT 302N in a three-electrode system. In addition, our research was using supplemented electrochemical impedance spectroscopy (EIS) was carried out. The measurement was performed using the same set of measurement as in the potentiodynamic tests equipped with a FRA2 module (Frequency Response Analyser). All the electrochemical tests were performed in artificial plasma solution (T = 37 ±1°C, pH = 6.8 ±0.2).

Results and Discussion

Studies carried out with the use of atomic force microscopy showed no significant differences in surface topography. The morphological characteristics of the SiO_2/TiO_2 layers showed a tendency to inherit the stereometric parameters of the steel base surface formed by treatments preceding its application. The surface roughness expressed by the Ra parameter for the base and the layer was in the range of 7 ±1 nm. The hardness of the layer was measured at a depth of 30 nm from its surface was H_{IT} = 11947 MPa and was higher than the hardness of the steel base - H_{IT} = 4478 MPa. In other hand, the value of the critical force determined in the Scratch –test caused total delamination was L_{c2} = 4.22 N. During the test, no cracks or chipping were observed. There was also no sound signal. This indicates a low binding energy between the layer and the base. In turn, the obtained polarization curves in potentiodynamic studies were the basis for determining the characteristic electrical properties describing the resistance to pitting corrosion – TABLE 1. The presented results unequivocally demonstrated that, the layer with Ti and Si causes increase corrosion potential, polarization resistance and transpassivation potential, which is a favorable phenomenon.

TABLE 1. Results of potentiodynamic test.

Sample	E_{corr}, mV	E_{tr}, mV	Rp, kΩcm^2
AISI 316LVM	-288	+1203	2820
AISI 316LVM + TiO_2/SiO_2	-148	+1622	28524

Increase of corrosion resistance by the presence of the layer was also confirmed in EIS studies. Impedance spectra for the TiO_2/SiO_2 layer were interpreted by comparing them to equivalent circuit, which indicates the appearance of two sublayers: internal compacted and external porous (R_s – artificial plasma resistance, R_{pore} – pore layer resistance, CPE_{pore} – the capacity of double layer (porous, surface), R_{ct} and CPE_{dl} – resistance and capacity of TiO_2/SiO_2 layer) [4] – TABLE 2.

TABLE 2. Results of EIS.

Sample	R_s, Ωcm^2	R_{pore}, Ωcm^2	CPE_{pore}		R_{ct}, kΩcm^2	CPE_{dl}	
			Y_0, $Ω^{-1}cm^{-2}s^{-n}$	n		Y_0, $Ω^{-1}cm^{-2}s^{-n}$	n
AISI 316LVM	17	-	-	-	2517	0.1887E-4	0.87
AISI 316LVM + TiO_2/SiO_2	16	19	0.6597E-4	0.85	32105	0.6685E-4	0.87

Conclusions

The passive layer made on AISI 316 LVM base during surface pretreatment (mechanical and electrochemical) and deposition the gradient TiO_2/SiO_2 layer by ALD method, improves corrosion resistance. Correct selection of parameters for applying the layer also resulted in adequate adhesion to the base, which effectively minimizes the migration of ions of the elements Fe, Cr, Ni or Mo.

References

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