THE EFFECT OF SURFACE MODIFICATION ON CORROSION RESISTANCE OF AISI 440B MARTENSITIC STAINLESS STEEL

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Introduction

Issues concerning surface modification techniques are nowadays put in the context of biomaterials development directions. Efficient surface modification of finished products allows to increase their durability, corrosion resistance and improve their frictional properties. Both the diamond-like carbon coatings (DLC) and the low-temperature plasma nitrided (LTN) diffusion layers are mainly known for their good corrosion resistance [1-4] and excellent tribological properties [1,4-7]. However, relatively little attention is paid to matters concerning application of these layers in high-chromium martensitic steels.

Given the above arguments, searching for appropriate methods of surface modification of martensitic stainless steels, which are extensively used in e.g. surgical instruments manufacturing, seems reasonable. The aim of this study was to determine the effect of plasma nitriding and DLC coatings on corrosion characteristics of applied in surgical tools manufacturing PN-EN X90CrMoV18 (AISI 440B) steel.

Materials and methods

The research was made to determine the effect of surface modification on corrosion resistance of high-chromium martensitic steel PN-EN X90CrMoV18 (AISI 440B, DIN 1.4112). Potentiodynamic polarization scans and open-circuit potential tests of metallic materials were carried out on Radiometer analytical PGP201 potentiostat/galvanostat equipped with VoltaMaster 4 software, which comprise as an integral research kit. For the purposes of research the examined steel surface was treated with DLC coating (DLC – series 1). For comparison, analogous tests were carried out for steel plasma nitrided (seres 2) in 380°C (50% H_2 : 50% N_2). The reference sample was conventionally treated steel, tempered at 500°C (series 3).

Each open circuit potential (E_{OCP}) measurement and the potentiodynamic scan was performed in room temperature (21°C) 70 ml 0,9% $NaCl_{aq}$ solution. Using the included in the set software, the corrosion potential (E_{kor}), corrosion current (i_{kor}), polarisation resistance (R_p) and the corrosion rate were determined. All values were determined with respect to a saturated calomel electrode (SCE) as the reference electrode. The three-electrode electro-chemical cell consisted also of platinum auxiliary electrode with a contact area of 128 mm². Working electrode circular area of 50.24 mm² was left to mantain contact with the testing solution. An open circuit potential (E_{OCP}) was studied after two hours of immersion. The initial potentiodynamic polarisation scan potential was E_{OCP}-100 mV.

Once completed corrosion studies, microscopic observations were performed to determine the examined samples surface topography. Observations were carried out on a scanning electron microscope (SEM) Hitachi S-3000N equipped with and X-ray microanalyzer (EDX).

Results and discussion

The analyzed PN-EN X90CrMoV18 steel samples E_{OCP} change in time is presented in FIG. 1. Primarily, it can be noted that the initial potential of diamond-like carbon coated series (FIG. 1, series 1) is significantly more positive than other samples potentials. This implies that only DLC layer application allows refining the analyzed steel surface, making it chemically stable in physiological saline solution. Such properties are attributed to high density and low porosity of diamond-like carbon layers, thus the detail surrounding aqueous solutions and ions therein contained do not penetrate the surface layer [8]. Moreover, series 2 and 3 curves almost coincide, starting the potential drop from 300±20 mV. The observed for all series decrease in corrosion potential is related to the equilibrium processes, in which the corrosive dissolution is prevalent. Potentials stabilize after 80-100 minutes of immersion in physiological saline solution. What is important, approximately after 30 minutes of immersion first corrosion pits were visible on series 2 and 3 samples, whereas no changes were observed for series 1.

Corrosion behaviour of AISI 440B steel prepared samples during anodic polarization is given in FIG. 2. As it is depicted by the family of curves, there are significant differences of E_{kor} and i_{kor} values achieved by each series. Above all, as in open-circuit potential measurement, series 1 curve significantly differs from the others. Both decrease in i_{kor} and corrosion potential shift towards positive values are observed according to series 2 and 3. This means that applying DLC layer allows considerable delay in corrosion processes onset on finished product surface. In case of series 2 and 3, cathodic branches overlapping can be seen; differences between series are noted in anodic course. Course of the third curve is mild, while for series 2 pitting potential (-300 mV) can be noted. The occurrence of pitting potential is in literature attributed to development of corrosion pits on the anodically polarized sample.

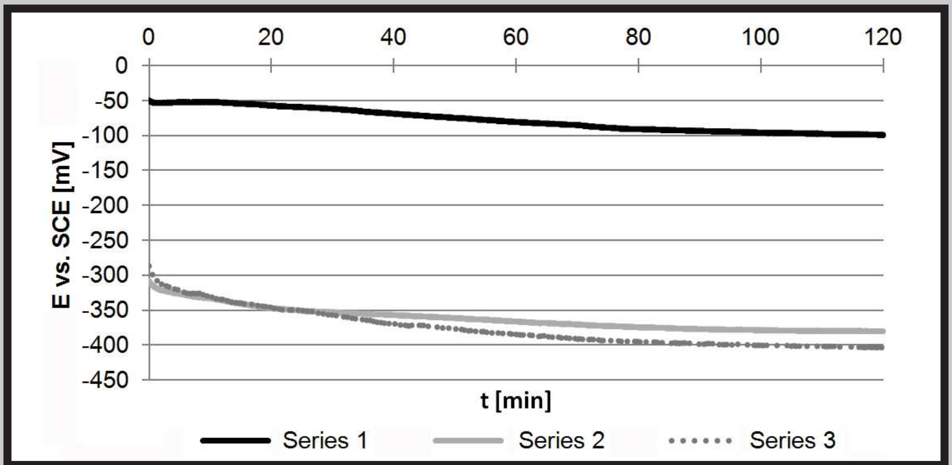

FIG. 1. An open-circuit potential of PN-EN X90CrMoV18 steel; 0,9% $NaCl_{aq}$ solution.

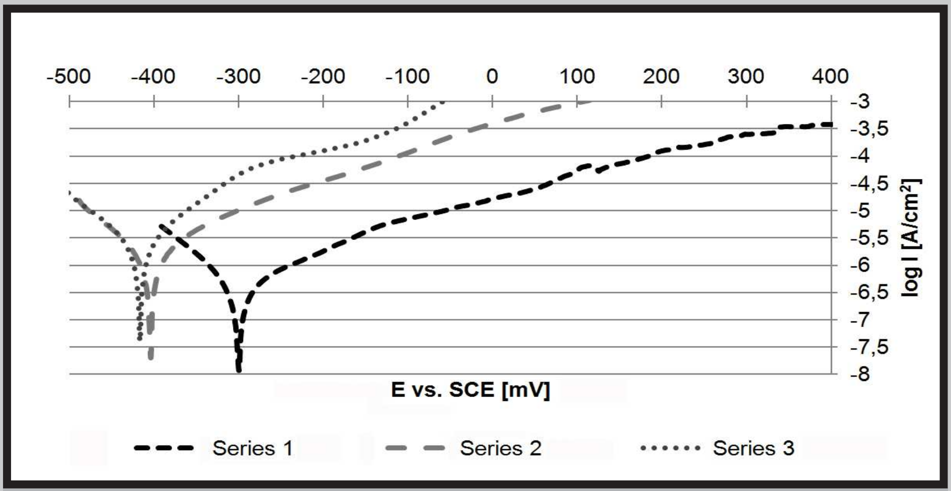

FIG. 2. Potentiodynamic curves of PN-EN X90CrMoV steel in 0,9% $NaCl_{aq}$ solution.

Conclusion

The obtained results suggest that DLC layers are promising coatings for use in manufacturing cutting surgical tools made of high-chromium martensitic stainless steel PN-EN X90CrMoV18. Unlike the low-temperature plasma nitriding, applying protective diamond-like carbon layer effects in increase of surface passivity, and thus – delays corrosive dissolution development. According to the authors, further analyses of suggested layer are needed, paying special attention to its friction properties and wear resistance in cutting tools applications.

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