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Determination of corrosion mechanism of NiTi modified by carbon plasma immersion ion implantation(C-PIII) by electrochemical impedance spectroscopy

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Keywords: EIS, NiTi alloys, Corrosion resistance mechanism,Carbon plasma immersionion implantation.

Introduction: To improve implant integration with body tissues and accelerate healing, plasma immersion ion implantation (PIII) is attractive because it can improve the corrosion resistance, hardness, and biocompatibility of materials surface while preserving the favorable characteristics of the bulk materials [1-3]. The technique is especially suitable for biomedical implants with a complex geometry because of its intrinsic non-line-of-sight characteristic [1-3]. NiTi alloys have good biocompatibility [2-4] but the poor corrosion resistance may lead to increased cytotoxicity since Ni may be released from the substrate, causing toxic reactions in humans [3-4]. In this work, carbon plasma immersion ion implantation (C-PIII) is used to modify the surface of NiTi alloys to improve the corrosion behavior and electrochemical impedance spectroscopy (EIS) is employed to investigate the corrosion behavior and the underlying corrosion resistance mechanism.

Materials and Methods: The carbon plasma was generated by a pulsed cathodic arc plasma source and carbon plasma immersion ion implantation (C-PIII) was conducted on NiTi alloys at a low temperature. The phase and morphology of the nanostructured coatings were examined by glancing-angle X-ray diffraction (GIXRD) and field-emission scanning electron microscopy (FE-SEM), respectively. The corrosion resistance mechanism was evaluated by performing electrochemical impedance spectroscopy (EIS) in a cell composed of the working, reference, and auxiliary electrodes in 250 ml of 3.5% NaCl and SBF solutions for different immersion time. The apparatus was the Zennium Electrochemical Workstation potentiostat galvanostat using the ZView analysis software. Inductively-coupled plasma mass spectrometry (ICPMS) was used to monitor the release of Ni release from samples immersed in the 3.5% NaCl and SBF solutions. The concentrations of Ti, Ni, O, and C in the modified surface after immersion for different immersion time were determined by X-ray photoelectron spectroscopy (XPS).

Results and Discussion: The results confirm that the unstable nature oxide form on NiTi can be corroded by aggressive ions leading to delamination from the surface. Carbon plasma immersion ion implantation (C-PIII) enhances the surface stability by forming a smooth and free crack coating with a thickness of 50 nm. EIS demonstrates that C-PIII significantly improves the corrosion resistance and hardness of NiTi alloys while obstructing the release of Ni from the materials. The corrosion resistance mechanism depends on the inactive protection layer and functional carbon film produced on the surface of NiTi alloys.

Conclusion: The corrosion resistance mechanism of NiTi alloys after carbon plasma immersion ion implantation (C-PIII) is related to the inactive protection layer. C-PIII improves the corrosion resistance of NiTi alloys in 3.5%

NaCl and SBF solutions. Some ions in the SBF such as Ca and P producing uniform and homogeneous products on the modified NiTi alloys to obstruct release of Ni from the substrate.

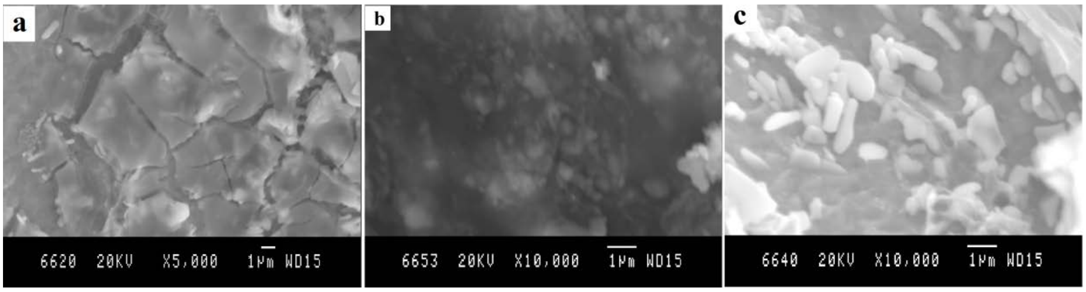

Figure 1FE-SEM images after immersion for 96 h: (a) NiTi alloy in 3.5% NaCl solution, (b) C-PIII coating in 3.5% NaCl solution, and (c) C-PIII coating in SBF.

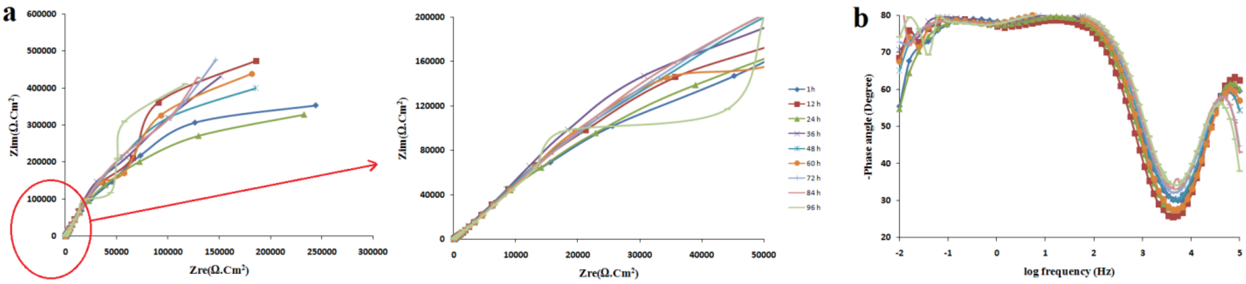

Figure 2 (a) Nyquist plots and (b) Bode plotsof C-PIII samples after immersion in 3.5% NaCl for different time.

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