Corrosion characterization of stainless steels for application as biomaterials by electrochemical methods

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Abstract

The metallic materials used in implants or prostheses are generally passive materials and therefore are subject to localized corrosion when in contact with body fluids. The conductivity properties of the passive film are of great importance to their protective character against corrosion. The production processes involved in implants manufacturing, mainly those that influence the surface finishing, affect the properties of the passive films and, consequently, their corrosion resistance. Pitting and crevice corrosion are among the most common types of localized corrosion observed in metallic implants. In this study, the resistance to pitting of two types of stainless steels (SS) used as biomaterials for orthopedic or dentistry applications, specifically, the ASTM F139 austenitic and the AISI 444 ferritic SS was investigated by electrochemical methods in a saline buffered solution (PBS) at 37 ^{o}C. Although ferritic SS are not used for fabrication of permanent implants their ferromagnetic properties are useful for some specific applications, such as for fixing dental prostheses by using magnetic attachments. The effects of cold deformation on pitting and crevice corrosion were also investigated by Electrochemical Impedance Spectroscopy (EIS), polarization methods and Mott-Schottky approach. Besides, the influence of surface marking for identification and traceability of implants was evaluated by Scanning Vibrating Electrode Technique (SVET). EIS and polarization methods were also used to investigate the effect of protein, specifically albumin, on the localized corrosion resistance of ASTM F139 SS. Cold deformation was carried out by cold rolling reducing the thickness of the SS plate to 30%, 50% and 70% of its initial thickness. The EIS and polarization results indicated the decrease in localized corrosion resistance with the increase of deformation up to 50% of thickness reduction, and the increase of this resistance for 70% reduction. The results were supported by Mott-Schottky approach. The oxide film on samples with 70% reduction in thickness was associated to an increased number of n-type defects in the passive film. The results suggested a more protective film on the stainless steel with 70% deformation compared to the material without deformation. This indicates a more protective property of the passive film and, consequently, increased pitting corrosion resistance associated to the highly deformed material. For the laser marked samples of ASTM F139 SS, all the electrochemical methods used indicated the deleterious effect of this marking process in comparison to the mechanical one, leading to increased susceptibility to pitting of the laser affected areas. It was proposed that the decreased pitting corrosion resistance of these areas was due to the increased amount of oxide inclusions at the laser marked zones. The corrosive attack of the SS matrix around these inclusions led to micro crevices that favor pit growth. Despite of the controversy in the literature concerning the effects of proteins on the corrosion resistance of SS, the results of the present study showed a beneficial effect of albumin at concentrations typical of that found in body fluids (10 g/L) on the pitting corrosion resistance of the ASTM F139 SS. The pitting resistance of the AISI 444 was also investigated and it was equivalent to the ASTM F139 SS and superior to that of a commercial ferromagnetic keeper of dental prostheses indicating that the AISI 444 studied is a potential candidate for replacement of commercial ferromagnetic alloys used in dental prosthesis.