Effect of Proteins and Normal Load on the Tribocorrosion Behavior of Hip Joint Implant Material (CoCrMo Alloy)

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Statement of Purpose:

CoCrMo alloys are extensively used for hip replacements due to their wear and corrosion resistance [1]. A protective oxide film is formed at the surface which inhibits corrosion [2]. However, implanted metallic materials are subjected to combined mechanical and electrochemical stresses in the joint. This raises concerns about the tribological and chemical effects on material degradation [3]. Previous studies have shown that adsorbed proteins at the metal surface influence the electrochemical behavior, acting on the dissolution mechanism of the alloy [4]. The effect of proteins in presence of additional mechanical stress on the release of metal ions and wear is still unknown.

The purpose of this study was to evaluate the tribocorrosion behavior of CoCrMo alloy in two different testing systems commonly used in laboratories under different fluid and different loading conditions. It was hypothesized that the specific test condition influences the wear and corrosion resistance of this alloy.

Methods:

Tribocorrosion tests were conducted in two different wear testing configurations using a three-electrode electrochemical cell. The first used a conventional tribometer in which a 10mm diameter alumina ball sliding against the CoCrMo alloy (Surgival, Spain) immersed in a phosphate buffer solution (PBS). The second used a special made tribosystem that emulated a hip joint. Here, a 28mm diameter alumina ball oscillated against a CoCrMo alloy (ATI Allvac, USA) pin in bovine calf serum (BCS) solution. The reference electrode was a saturated calomel electrode (SCE); the counter electrode was a platinum wire and a graphite rod, and the working electrode the metallic alloy. Tests were performed under potentiostatic conditions with an applied potential of -0.345V, with sliding duration of 1800 cycles and frequency of 1Hz. The normal load applied was 1N for the first configuration and 64N for the second one, corresponding to 380MPa and 757MPa initial Hertzian contact stress, respectively. Electrochemical impedance spectroscopy (EIS) measurements were carried out before and after sliding test, in a frequency range from 63kHz to 0.001Hz with 10 frequency/decade. This was done to investigate kinetic and mechanistic processes that occur at the passive film/electrolyte interface. Surface characterization was performed using optical microscopy and scanning electron microscopy (SEM). The material loss was estimated from wear scars using profilometry.

Results:

The corrosion behavior of CoCrMo was inferior in BCS compared with PBS as can be seen in Bode plots (Fig. 1) by the lower absolute impedance |Z| values, as well as the narrow shape of BCS phase angle curve. However, proteins seem to have a protective effect on the surface when subjected to mechanical articulation, as suggested by an increasing polarization resistance (Rp before sliding=403Ohms.cm^2, Rp after sliding=522Ohms.cm^2).

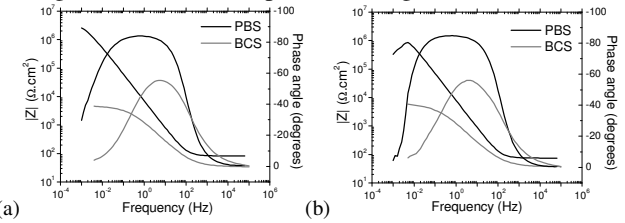

Fig. 1- Bode diagram from EIS measurements (a) before sliding for 1N and (b) after sliding for 64N, in two different solutions.

Wear scar of the two tests are shown in Fig. 2. Material loss was 7.09±0.35µg/cm^2 for Test 1 (1N) and 19.40±0.97µg/cm^2 for Test 2 (64N).

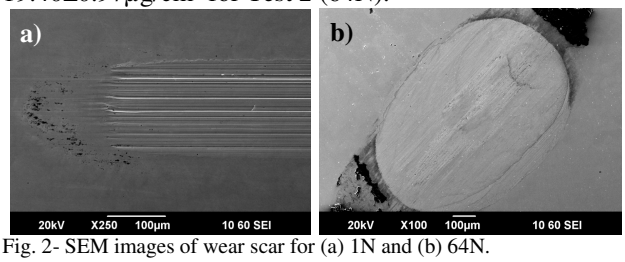

Fig. 2- SEM images of wear scar for (a) 1N and (b) 64N.

Discussion:

As expected, the results of this study were affected by the specific test set-up. In fact, it was shown that proteins and normal load influence significantly the tribocorrosion behavior of CoCrMo alloy. Interestingly, it was found that the presence of proteins decreased the corrosion resistance without mechanical articulation, but in the presence of tribological stresses, proteins improved the corrosion resistance of the alloy. This suggests the formation of a protective tribofilm [5]. Obviously, normal load is a sensitive variable in this respect since it can promote or destroy the tribofilm. Since only two discrete values were tested, more research has to follow to elucidate the exact behavior.

References:

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