Tribocorrosion mechanisms of titanium alloy sliding against a zirconia ball in a Phosphate Buffered Solution

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The tribocorrosion mechanisms of a Ti-Nb-Zr-Ta (TNZT) alloy rubbing against a zirconia ball in a Phosphate Buffered Solution (PBS) were analyzed by considering the mechanical and chemical interactions that lead to the material degradation. The observed peculiar electrochemical response characterized by current transients peaks was found to be linked to the development of third bodies and tribological transformed surfaces. Total wear was therefore determined by those phenomena and two main mechanisms have been proposed: (1) cracking by low-cycle-fatigue in which partial detachment of the tribologically transformed surface (TTS) takes place and (2) depassivation by the continuous removal of small particles.

Keywords (from 3 to 5 max): tribocorrosion, third body, titanium alloys

1. Introduction

Beta titanium alloys composed of non-toxic alloying elements such as Nb, Zr, Ga, Mo, Pd, Se, Sn, Ta, Ge have been developed as an alternative to Ti and Ti-6Al-4V biomedical alloys for biomedical implants in order to improve their mechanical compatibility with the bone (i.e. low elastic modulus). During their typical operating conditions, under the simultaneous action of wear and corrosion, the overall material loss depends on the plastic deformation of the titanium material and the behavior of the generated wear debris within the contact. The later, also depends on the prevailing electrochemical conditions [16]. The aim of this work is to understand the the formation of friction films and their influence on wear of titanium alloys.

2. Methods

Tribocorrosion tests were carried out on a beta titanium alloy Ti35Nb7Yr5Ta (TNZT) with nominal composition in weight 35wt.% Nb, 7wt.% Zr, 5wt.% Ta and Ti bal. (99.995wt.% pure, O < 250 ppm) rubbing against a ZrO_2 ball in a reciprocating tribometer with an integrated three-electrode corrosion cell connected to a potentiostat. Different loads (F_N)and applied potentials (E_{appl})within the passive domain of the TNZT were selected.

2.1. Results

Figure 1 shows an example of the time evolution of the current and the COF before, during and after rubbing in a tribocorrosion test at passive potential. Once rubbing starts, the current and the COF exhibit a sudden increase due to the mechanical detachment of the passive layer followed by an exponential current decrease suggesting a repassivation of the TNZT during sliding. A current transient can be also distinguished simultaneously to a decrease in the coefficient of friction.
In the resulting worn area, three different zones can be distinguished: (1) the bulk material in the bottom of the image, (2) a tribologically transformed surface (TTS) characterized by a grain refinement, with a thickness between 4 to 10 μm; and (3) a third body consisting in a highly oxidized material of 0.1 to 1 μm in thickness. Several cracks with different size and geometries have been observed in the TTS and the third body zones along the sliding direction.

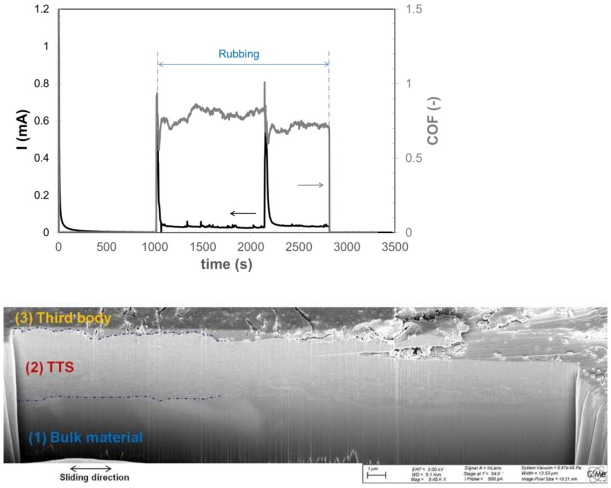

Figure 1: Time evolution of the current and COF before, during and after rubbing and SEM micrograph of the FIB cross-section in the wear track at E_{appl} = 400mV and F_N = 6.7 N.

3. Discussion

Two main wear mechanisms are proposed: (1) cracking by low-cycle-fatigue in which partial detachment of the TTS is produced by single events (transients) and (2) depassivation by the continuous removal of small particles (debris) from the contact. Total wear depends on those cracking events.

4. References

[1] Dalmau Borrás, A, et al. "Chemo-mechanical effects on the tribocorrosion behavior of titanium/ceramic dental implant pairs in artificial saliva" Wear. 426–427, 2019, 162–170.