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Interactions between the bovine calf serum and the metallic surface of hip implant taper junctions

Saskia Heermant[1)], Adrian Wittrock[1)], Christian Beckmann[1)], Markus A. Wimmer[2)], Alfons Fischer[3)], Jörg Debus[1)*]

[1)]Experimental Physics 2, TU Dortmund University, Otto-Hahn-Str. 4a, 44227 Dortmund, Germany
[2)]Department of Orthopedic Surgery, Rush University Medical Center, 1611 W. Harrison St., Chicago, Il 60612, USA
[3)]Department Microstructure Physics and Alloy Design, Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Str. 1, 40237 Düsseldorf, Germany

*Corresponding author: joerg.debus@tu-dortmund.de

Structural and chemical changes in the system of metals interacting with the human body fluid in biomedical taper junctions are of particular interest. Insight into these interactions is gained by label-free and non-destructive Raman spectroscopy. Specimens made from a low-carbon CoCrMo alloy and a high-Nitrogen FeCrMnMoN steel are worn in fretting tests in bovine calf serum under different numbers of cycles. Changes in the absorption of differently long-chained molecules as well as conformation variations of the amide I band are observed. The proteins from the bovine calf serum become denaturized independent of the number of fretting cycles. Instead of lipids, only sp2-hybridized amorphous carbon is detected on worn sample surfaces.

Keywords (from 3 to 5 max): taper joint, fretting, metal-serum interaction, Raman scattering

1. Introduction

Nowadays an artificial hip joint is a common, promising and widely used treatment for patients with osteoarthritis or rheumatism. The modular design of the metal-on-metal bearings allows for recreating the natural hip joint as close as possible, and it allows for preserving bone during revision surgery. This study aims at investigating structural and chemical changes within the fretting contact area of such modular head-neck junctions by means of Raman scattering spectroscopy.

2. Materials and Methods

2.1. Fretting test

The fretting experiments were performed in 30 g/l bovine calf serum (BCS, 588 ml newborn calf serum, 3.7 g NaCl, 82.4 mg EDTA, 11.12 g Trisaminomethan, 412 ml deionized water, 7.6 pH) by two metal pins pressed against a metal cylinder that moved with an amplitude of 50 µm at 37°C.

2.2. Metals

The material of the two pins (∅ 12 mm x 7 mm) is either a high-Nitrogen FeCrMnMoN steel (1.4452) or a low-carbon (LC) CoCrMo-alloy (ISO5832-12). The pins' surfaces were grinded and polished. They were run against fine-machined TiAl6V4 cylinders (∅ 13 mm, ISO5832-3).

2.3. Raman Spectroscopy

The pins and cylinders were investigated at room temperature with confocal Raman scattering spectroscopy. The optical excitation was established by a 532 nm laser. Its output power was set to low values so that laser-induced changes/damages were prevented.

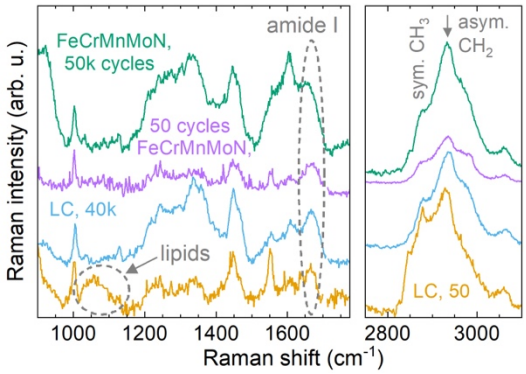

Figure 1: Raman spectra of accumulated wear debris of LC-CoCrMo and FeCrMnMoN pins measured after different numbers of cycles.

3. Results and Discussion

The Raman spectra shown in Fig. 1 demonstrate that the intensities of the symmetric CH_3 and asymmetric CH_2 modes strongly change with the number of fretting cycles (50 vs. 40k/50k). From their intensity ratio, it is possible to determine the proportion between chain ends (CH_3) and chain links (CH_2). The changes in the ratio suggest that short-chained molecules adsorb on the LC pins before long-chained molecules are adsorbed. Such a dynamic is not observed for the FeCrMnMoN pins, where the intensity ratio remains constant.

The analysis of the protein backbone, based on the amide I band, indicates a shift from about 1655 cm^{-1} to about 1665 cm^{-1}. It suggests that once a protein is bound to the surface, its conformation changes from an α-helix to a random or β-sheet structure. Thus, a general denaturation of proteins is observed during the entire duration of the fretting experiment. Still, lipids also present within the BCS are hardly detectable after 5,000 and 40,000 cycles. In contrast to this, sp^2-hybridized amorphous carbon is detected the more pronounced by the increasing number of cycles, suggesting that wear is associated with the formation of amorphous carbons.