Accelerated tests for lifetime prediction of interfaces and interlayers with respect to crevice and fatigue corrosion in body fluid

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INTRODUCTION: Coatings have an interface with the substrate where a few nanometer reactively formed material is generated with different properties compared to those of the coating or the substrate. Depending on the processing conditions, contaminations in the range of one atomic layer may be present, which can result in altered corrosion and fatigue behavior of this particular interfaces.

METHODS: To measure the chemical composition and reactivity of the nm-thick interface material, the coated sample was polished by an ion beam at an ultralow angle. Then, Auger Electron Spectroscopy (AES) measurements locally characterized the composition and microcapillary electro-chemical measurements determined the local reactivity [1]. Crevice corrosion, which is not accelerated in a physiological implant simulator, was accelerated in a dedicated crevice/confined space setup [2]. Corrosion fatigue testing of an interface in articulating simulator testing only lead to a good/bad result. By reciprocal sliding over a coating in media, an alternating load was generated at the interface. This test methodology did generate the Wöhler curve and the corresponding endurance limit of a particular interface [3].

RESULTS:

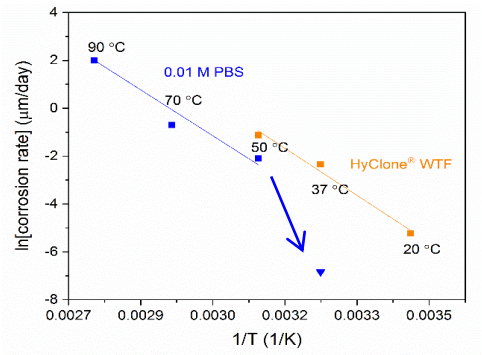

Fig.1: Arrhenius plot of Si in a crevice/confined space arrangement. Corrosion rate measured in the confined area at different temperatures, from [2].

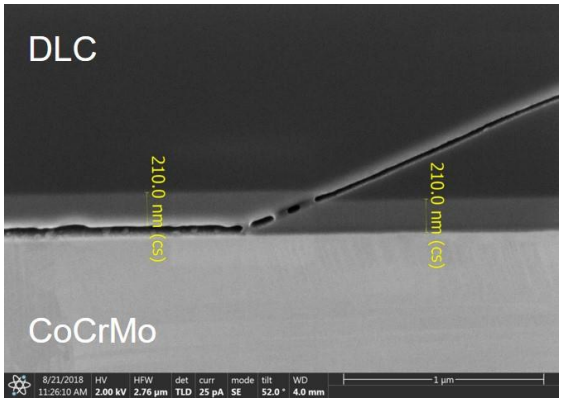

Fig. 2: FIB cross section of a growing crack in 4 µm DLC/Si-DLC (1.0 % O_2 contamination)/ CoCrMo after 13500 cycles in PBS. Plastic deformations of the Si-DLC are visible [3].

DISCUSSION & CONCLUSIONS: The temperature dependent corrosion rates yielded a linear Arrhenius relation, indicating a single rate limiting process step, with the activation energies (Ea) of 106 kJ/mol in 0.01 M PBS, and 109 kJ/mol in Hyclone®. The corrosion rate at 37 °C in PBS is lower than expected, leading to false lifetime expectations. This may be because conditions are not harsh enough, so passivation of Si is still effective and crevice conditions could not (yet) build up. Corrosion was most prevalent at the edge of the crevices, and pH indicators showed a pH increase, potentially due to oxygen reduction inducing OH^- release. Concerning corrosion fatigue at the interface, Wöhler curves for different interfaces are generated, showing the deteriorating influence of small interface contaminations. The induced plastic deformations are visible in figure 2, and result in a slowly ongoing local weakening of the material strengths.

REFERENCES: [1]E. Ilic et al., Surface & Coatings Technology, 375 (2019) 402-413. [2]E. Ilic, et al., Journal of the Electrochemical Society, 166 (2019) C125-C133. [3]A. Pardo, et al., Science and Technology of Advanced Materials, 20 (2019) 173-186.