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

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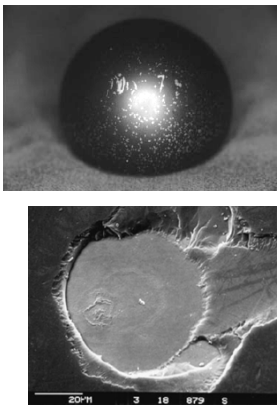
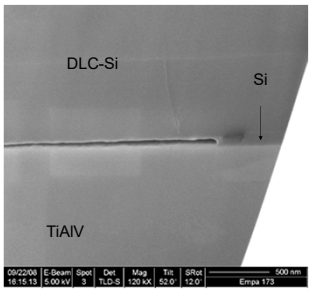
Motivation

Coatings present an interface with the substrate where a few nanometer reactively formed material is generated with different properties compared to those of the coating itself 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. Additionally, stable interlayers materials may not be stable anymore when exposed to an aggressive crevice chemistry. The same problem has to be considered for interfaces generated in 3D printing of metals.





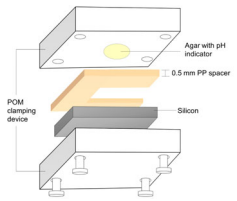
Simulator test
In-vivo

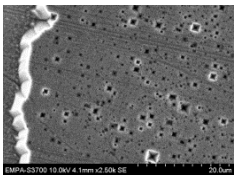
Fig. 1: *Failed DLC coated femoral head explant. FIB cut shows local absence of Si adhesion interlayer in crevice*

Objective and Methods

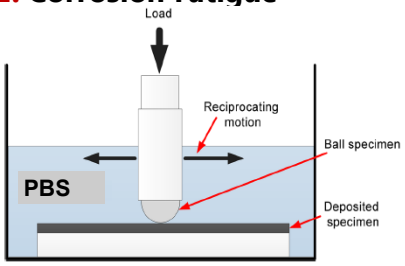
The aim of this work is to develop methodologies to separately accelerate and to gain a better understanding of the different corrosion mechanisms responsible for delayed delamination at an interface or interlayer, by addressing crevice corrosion (CC,) corrosion fatigue (CF) and stress corrosion cracking (SCC).

1. CC

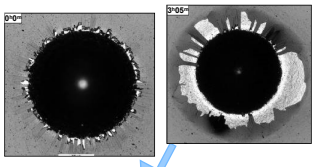




2. Corrosion Fatigue



3. SCC



Goal: achieve a lifetime prediction with separated accelerated tests of the different corrosion mechanisms

Results

1. CC experiments

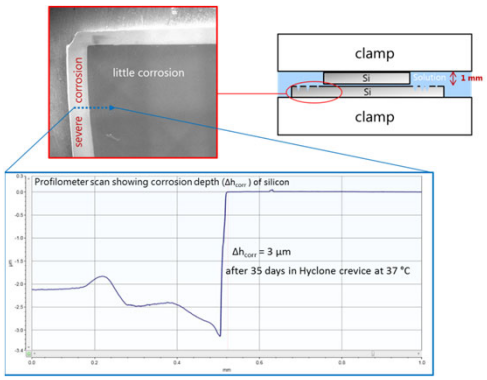


Fig. 2: *Crevice/confined space experimental setup: Profilometer scan shows significant corrosion depth of 3 µm in the confined space outside of a Si crevice, after 35 days immersion in HyClone® Wear Testing Fluid at 37 °C*

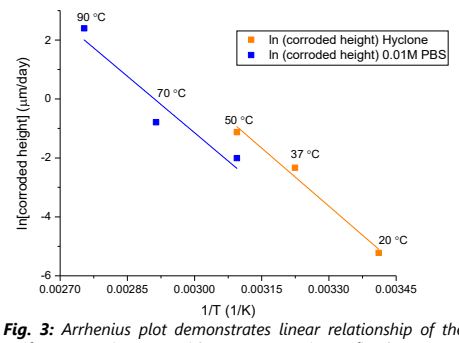


Fig. 3: *Arrhenius plot demonstrates linear relationship of the Si uniform corrosion rate with temperature in confined space, when immersed in 0.01 M PBS and HyClone Wear Testing Fluid*

2. Corrosion fatigue related experiment

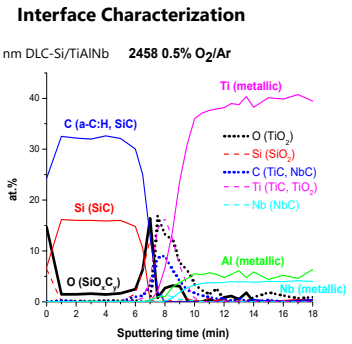


Fig. 4: *XPS depth profile separated into components*

3. SCC

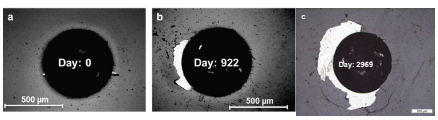


Fig. 5: *Rockwell indentation based adhesion test for a 4µm DLC/Si-DLC (2% O_2 contamination in Plasma)/ CoCrMo layer system immersed in PBS at 37°. After initiation, delamination follows a SCC behavior for some years and thereafter shows a CC behavior*

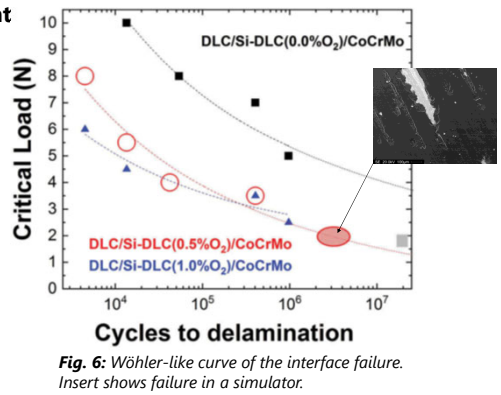


Fig. 6: *Wöhler-like curve of the interface failure. Insert shows failure in a simulator.*

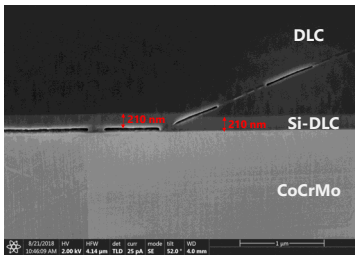


Fig. 7: *FIB cut near the interface: plastic deformations and delaminated areas are visible*

Conclusions

- Silicon interlayers are susceptible to crevice/confined space corrosion.
- Small O_2 contamination in the plasma deposition process can result in a altered interface material with reduced corrosion resistance.
- CC and fatigue corrosion susceptibility should be addressed in separate dedicated accelerated tests experiments to achieve reliable assessment of lifetime prediction.

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