Examining tribocorrosion of passivating steels – new materials and methods

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Mitigating wear and corrosion risk during operation in seawater environments typically requires the use of metals with passivating surface oxides, expensive alloying elements, and complex microstructure. Materials that may perform well under corrosive or wear conditions separately can experience significant damage from synergistic processes collectively termed 'tribocorrosion.' Here we review our recent work to examine fundamental processes linking material loss and electrochemical response to local microstructure in passivating alloys. The nature of the wear and electrochemical response will be discussed in light of both surface analysis of the microstructure (conductivity, work function etc.) and models incorporating oxide dissolution and regrowth.

Keywords: tribocorrosion, duplex stainless steel, wear, AFM, additive manufacturing

1. Introduction

In order to address the complex problem of the linkage between tribology and corrosion, new approaches are required to develop the science enabling us to explain and predict "tribocorrosion" behavior. We approached the problem by assembling an interdisciplinary research team with expertise in tribology and corrosion science and backgrounds in surface science, materials science, electrochemistry, and modeling. A significant scientific challenge remains in determining how the interaction between tribology and corrosion influences material removal and surface oxide degradation. Our approach involved several key aspects to address the science: (1) make measurements local to the active wear and repassivation process, and (2) determine how local materials interfaces, microstructures, and applied stresses contribute to tribocorrosion processes.

2. Methods

We have performed sliding wear experiments on model stainless steels including UNS S32205, UNS S32750 and UNS S31603 (wrought and additively manufactured, (AM)). Experiments were performed using both macroscopic methods and at the single asperity level (Figure 1), as described previously [1,2]. The majority of the experiments were performed under anodic potentiostatic conditions in 0.6 M NaCl. Some experiments were performed in Na_2SO_4 solutions to explore the effect of anion chemistry.

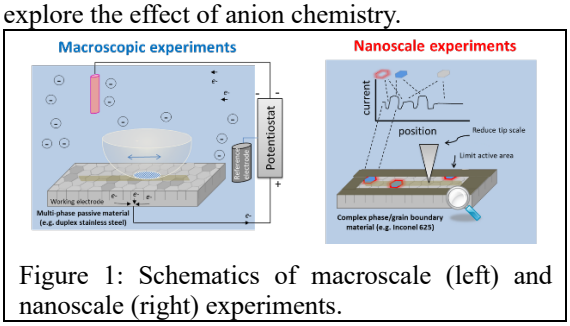

Figure 1: Schematics of macroscale (left) and nanoscale (right) experiments.

Surfaces were analyzed by scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDS), optical profilometry, and optical microscopy.

3. Results and Discussion

Our macroscopic experiments reveal that damage in a given alloy was localized to identifiable phases, but not always those which are most obvious or predicted based on composition and nobility. The sliding wear damage to aged S32750 and as-received S32205 steels was associated with sliding above a threshold potential and resulted in localized pitting. In Na_2SO_4, sliding damage to S32205 steel wear tracks did not initiate pitting, implicating Cl^- in the pitting process. Performance of a S31603 AM steel relative to its wrought counterpart revealed non-uniform wear resistance.

By scaling the experiments down to a single asperity with atomic force microscopy, we were able to spatially resolve both wear and corrosion current, and correlate the electrochemical response to sliding as a function of contact pressure and microstructure. A model for the single asperity was developed using an interfacial film growth kinetics approach. The simulated currents from the model of stainless-steel passive film formation were compared with corrosion currents obtained from contact-AFM measurements.

4. References

[1] Shockley, J.M. et al., "Effect of aging of 2507 super duplex stainless steel on sliding tribocorrosion in chloride solution," Wear 380-381, 2017, 251-259.
[2] Shockley, J.M. et al., "Direct Observation of Corrosive Wear by *In Situ* Scanning Probe Microscopy," ACS Appl. Mat. Inter. 12, 2020, 23543-23553.