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Tribofilm growth and wear on nanocrystalline platinum-gold alloys

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Low shear-strength organic tribofilms were grown in-situ on platinum-gold (Pt-Au) surfaces via cyclic sliding in dry N_2 with trace concentrations of ambient hydrocarbons. Steady-state friction coefficients were found to be as low as 0.015 and inversely proportional to pressure. Raman spectroscopy showed an increase in pressure led to an increase in coverage, concentration, and disorder. Atomic force microscopy (AFM) suggested a sublinear increase in tribofilm volume with time, and a transition from growth to wear at a pressure of 1.2 GPa.
Keywords: diamond-like carbon; nanocrystalline alloys; tribochemistry; friction; wear

1. Introduction

The formation of organic tribofilms on catalytic metal films requires at least three conditions: the presence of an organic, a catalytic surface, and interfacial shear. Argibay et al. [1] and Jones et al. [2] recently demonstrated the in-situ growth of diamond-like carbon (DLC) films on Pt-Au, which led to ultra-low friction coefficients (μ<0.02). In this presentation, we report on the effects of pressure, environment, and cycles on the structural and tribological properties of these DLC tribofilms.

2. Methods

Macroscale tribological experiments were performed on Pt-Au-coated steel substrates in dry N_2 with a 3.2-mm-diameter sapphire sphere (bidirectional sliding, 1 mm/s). Nanoscale tribology experiments were conducted on Pt-Au-coated Si substrates in dry N_2 with diamond-coated tips on an Asylum MFP-3D AFM. Raman spectroscopy and imaging were accomplished on a WiTec alpha 300R confocal Raman system with a 532-nm incident laser and 50× magnification and 0.55 numerical aperture objective.

3. Discussion

In the macroscale experiments, the Pt-Au films initially exhibited friction coefficients of $\mu\approx0.35$. However, after run-in, the in-situ formation of DLC tribofilms resulted in steady-state μ as low as $\mu\approx0.015$. The shear strength τ_0 converged to a value of 30 MPa at small inverse contact pressures, in agreement with other DLC films as revealed in Fig. 1. From the Raman spectroscopy, the amount and structure of carbonaceous material were characterized as a function of contact pressure. Averaged Raman spectra were taken from inside and outside wear tracks as shown in Fig. 2, and established an increase in pressure led to an increase in coverage, concentration, and disorder. Finally, the AFM measurements were used to elucidate the stress- and time-dependent tribofilm growth kinetics. The data suggest that the growth kinetics exhibited two regimes as a function of pressure: growth < 1.2 GPa and wear > 1.2 GPa. In addition, the AFM data indicated patchy growth in the contact regions. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

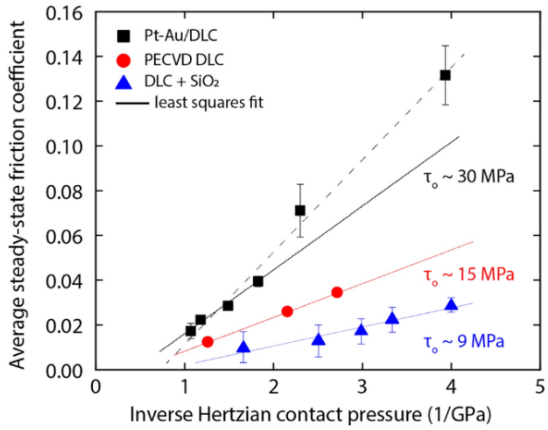

Figure 1: Average steady-state friction coefficient as a function of inverse contact pressure in dry N_2 [2].

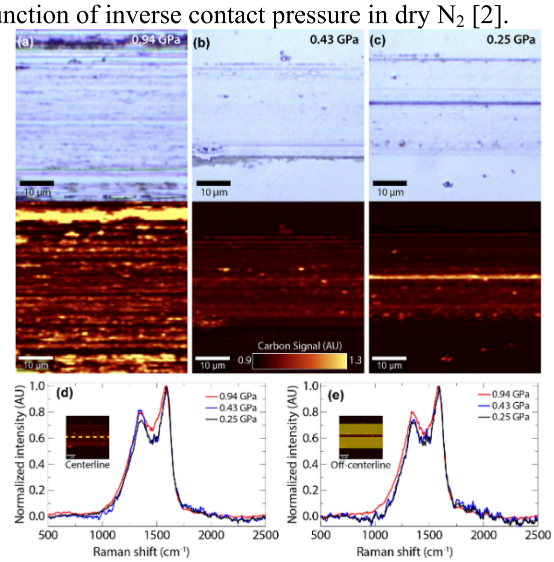

Figure 2: Optical images and Raman maps and spectra for contact pressures of 0.94, 0.43, and 0.25 GPa [2].

4. References

[1] Argibay, N. et al, "In-situ Tribochemical Formation of Self-lubricating Diamond-like Carbon Films," Carbon, 138, 2018, 61-68.

[2] Jones, M.R. et al, "Stress- and Time-Dependent Formation of Self-Lubricating In-situ Carbon (SLIC) Films on Catalytically-Active Noble Alloys," JOM, 2021 (in press).