Mild wear at multi-asperity interfaces: the role of contact pressure

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Plastic deformation, fracture and adhesive wear constitute the main wear mechanisms that have been observed in nanoscale wear experiments. The diversity of length scales covered by such friction induced phenomena make their description largely empirical. Recent experiments established –based on a stress augmented thermal reaction model– that for single asperity Si-on-diamond interfaces the atom removal rate increases exponentially with the local contact stress. Here, we manipulate and quantify the contact pressures at multi-asperity interfaces. An AFM-based wear volume measurement technique is developed to quantify wear volumes at the asperity level for surfaces that were worn in macroscopic friction experiments.

Keywords (from 3 to 5 max): tribology, multi-asperity, wear, contact pressure, mechano-chemistry

1. Introduction

The Archard wear law[1], states that the volume of wear is proportional to the sliding distance and normal force and inversely proportional to the material hardness. However, this law is empirical and a microscopic understanding of its origin, or a prediction of the proportionality constant –which can vary over orders of magnitude- are lacking. An "atom-by-atom" model [2] has been used to explain wear observations at single asperity contacts where the wear rate depends exponentially on the contact pressure. Nonetheless, the relation between contact pressure and mild wear at multi-asperity interfaces remains challenging to quantify. We experimentally establish a link between the local contact pressure and the wear rate at SiN-on-Si multi-asperity interfaces.

2. Methods

We study SiN ball-on-Si flat contacts subjected to non-repeated sliding and focus on the wear behavior of the SiN, which is harder than Si. To link wear of the sphere to the local contact pressure, we perform contact calculations (Boundary element method) that use the surface topographies (Figure 1) and material properties (Table 1) as input.

Table 1: data of the material properties

Properties/Material	SiN rough sphere	SiN pristine sphere
Hardness/Modulus	20/270 GPa	20/ 270 GPa
Roughness (h_{RMS})	431.4 nm	16.4 nm
Mean contact pressure	9.2 GPa	1.9 GPa

2 Results

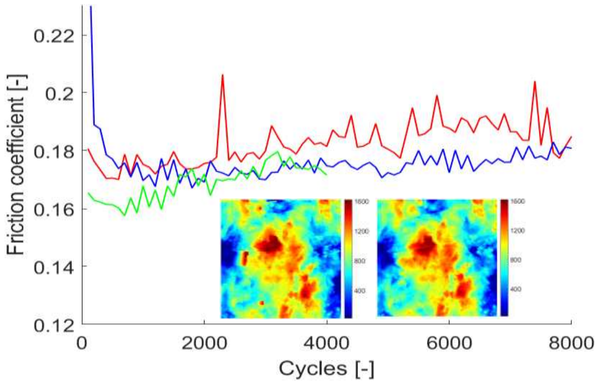

Figure 1: SiC ball-on-Si flat non-repeated friction experiment. The normal force was 100 mN and the stroke length was varied: Green: 0.05 mm, Red: 0.03 mm and blue: 0.015mm. The AFM topographies (23µm x 23 µm) on the left and right were recorded on the surface of a SiN sphere before and after a similar experiment.

3. Discussion

In the non-repeated friction experiments, the friction force increases gradually with the sliding distance. The difference in topography measured before/after the friction experiment is very small, indicating that mild wear and material transfer took place. We found that even though the friction coefficient increases with sliding distance, the wear rate of the ball decreases as the experiment progresses. These preliminary results indicate that thermally activated atomic-scale wear may be the pertinent wear mechanism.

4. References

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