Pre-sliding friction: the role of wear

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The onset of frictional slip between stiff materials involves only a few dozen nanometers of interfacial displacement and crucially depends on the area of real contact and the interfacial stiffness. A newly designed tribometer enables the measurement of this nanometric interfacial displacement during non-repeated reciprocated sliding. We show that mild wear during pre-slip leads to a smoother surface topography that increases the interfacial stiffness and strongly impacts the onset of slip.

Keywords: tribology, pre-slide, interfacial stiffness

1. Introduction

The dynamics of the onset of frictional slip have proven to be complex yet highly relevant, for instance in the context of earthquakes or stick-slip actuators. Experimental work on interfaces between plastics, glass and elastomers has indicated that the area of real contact can shrink or slip locally when a tangential force is built up at a stationary interface [1]. Numerical calculations have confirmed that this type of 'pre-slip' also occurs at interfaces between stiffer materials such as between silicon and diamond-like carbon (DLC) [2]. While pre-slip constitutes a dissipative response of the interface, elasticity also plays an important role at the onset of slip. The tangential stiffness of multi-asperity interfaces has been described numerically and depends on the surface topography where smoother surfaces lead to higher stiffness [3]. In general the length scales associated with pre-slip behavior are small, particularly for interfaces between stiff materials. This makes experimental observation and measurement of pre-sliding behavior at macroscopic contacts challenging. This study aims to elucidate the pre-sliding friction behavior at multi-asperity interfaces between stiff materials using a customized tribometer which is able to measure the friction force and relative displacement at the nm scale.

2. Methods

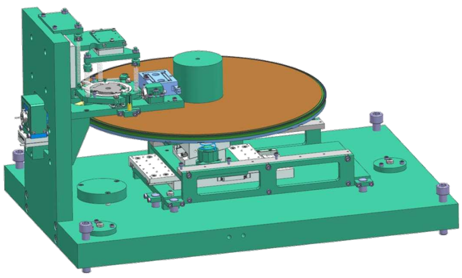

Figure 1: Schematic representation of the pre-slip tribometer

The newly designed tribometer (Figure 1), imposes disk-on-disk contact between three cylindrical pillars on the slider and a silicon wafer. The tribometer can be operated both in ambient and in high vacuum conditions. Special care is taken to optimize the alignment between the flat pillar surfaces on the slider and the counter surface. An interferometer is used to measure the relative displacement between the slider and the substrate with sub-nanometer precision. Piezostages and compliant springs enable precise control over the normal and tangential force exerted at the interface. Furthermore, the tribometer is designed to measure pre-sliding friction behavior as a function of wear in a non-repeated fashion, with the slider contacting previously untouched counter surface in each cycle which consists of a forward and a backward stroke.
To characterize the topography evolution of the contact area, atomic force microscopy (AFM) in tapping mode is used for ex-situ surface roughness measurements before and after tribotests. The wear of the cylindrical pillars is measured by a laser scanning confocal profilometer. The contact surfaces are also measured using scanning electron microscopy (SEM) and its integrated energy dispersive X-ray (EDX) measurements. Furthermore, raman spectra of the slider surface are measured ex-situ before and after the tests to characterize compositional and structural changes.

3. Results & Discussions

Preliminary results indicate that the tangential stiffness increases as the slider surface becomes smoother as a result of mild wear during the sliding cycles. The increased tangential stiffness can be ascribed to an increase in the slider-on-substrate contact area due both to increased adhesion and reduced contact pressure.

4. References

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