O 6: Tribology

Time: Monday 12:00–13:15 Location: S053

Invited Talk O 6.1 Mon 12:00 S053

The surface science of friction: How molecular films affect sliding and plowing — •Roland Bennewitz — INM - Leibniz Institute for New Materials, Saarbrücken, Germany

Two key mechanisms of friction are sliding and plowing. In sliding, adhesive forces between the contacting surfaces lead to friction, in plowing the plastic deformation of the surface. We have studied the role of the molecular structure at the interface in sliding and plowing by friction force microscopy. Results will be presented for plowing friction in a platinum crystal covered by a graphene layer [1]. Adhesive sliding friction can be controlled by macromolecular functionalization of the surfaces [2]. Finally, we will discuss the dynamic shear properties of liquids which exhibit a molecular layering when confined in the sliding contact [3].

[1] Klemenz, A., et al., Atomic Scale Mechanisms of Friction Reduction and Wear Protection by Graphene. Nano Letters, 2014, 14, 7145-7152.

[2] Blass, J., et al., Dynamic effects in friction and adhesion through cooperative rupture and formation of supramolecular bonds. Nanoscale, 2015, 7, 7674-7681.

[3] Krass, M.-D., et al., Dynamic shear force microscopy of nanometer-confined hexadecane layers. J. Phys.: Condens. Matter, 2016.

O 6.2 Mon 12:30 S053

From Static to Sliding Friction: Universal Ageing Law describes Sliding of Metallic Nanoparticles — Michael Feldmann, •Dirk Dietzel, and Andre Schirmeisen — Institute of Applied Physics, Justus Liebig University, Giessen, Germany

Everyday experience teaches us that static and sliding friction are very distinct phenomena: High forces are usually required to initiate sliding, while maintaining a sliding motion causes much less effort. Theoreticians, however, usually link such dynamic friction effects to a common mechanism referred to as contact ageing. While the existence of contact ageing is widely acknowledged (e.g. within rate and state theories) the fundamental processes on the nanoscale are much less clear. Here we will present nanomanipulation experiments of Sb particles on HOPG that will establish a clear correlation between static friction, sliding friction and contact ageing. By analyzing sliding instabilities (i.e. stick slip motion) it is found, that a universal ageing law based on nanorelaxations at the interface is applicable over 6 magnitudes of time and ultimately makes the distinction between static and sliding friction irrelevant.

O 6.3 Mon 12:45 S053

Investingating the transition between stick-slip and smooth sliding with Intermodulation Friction Force Microscopy — •Per-Anders Thorén[1], Astrid de Wijn[2], Riccardo Borgani[1], Daniel Forchheimer[1], and David Haviland[1] — [1]Nanostructure Physics, Royal Institute of Technology, Stockholm, Sweden — [2]Department of Physics, Stockholm University, Stockholm, Sweden

Friction is a complicated phenomenon involving nonlinear dynamics at different scales. The origin of friction is poorly understood, due in part to a lack of methods measuring the force acting on nanometer-scale asperities sliding at velocity of order cm/s. Dispite enormous advances in experimental technique this combination of small length scale and high velocity remained illusive. We present a technique for measuring the velocity-dependence of frictional forces on a single asperity (an AFM tip) reaching velocities up to several cm/s. The method is based on the measurement and analysis of intermodulation products, or frequency mixing of multiple drive tones near a high Q torsional resonance that arise from the nonlinear frictional force. The method gives the oscillation amplitude dependence of both conservative and dissipative dynamic force quadratures, revealing a transition between stick-slip and smooth sliding that is characteristic of friction at high speeds. We can explain the measurements with a modified Prandtl-Tomlinson model that accounts for the viscous and elastic nature of the asperity. With its high force sensitivity for small sliding amplitude, our method enables rapid and detailed surface mapping of the full velocity-dependence of frictional forces to sub 10 nm spatial resolution.

O 6.4 Mon 13:00 S053

Fundamental Surface-Analytical Investigations in Tribology: the Challenges of Studying Phenomena at Sliding Interfaces — •Filippo Mangolini[1], Nitya N. Gosvami[2], J. Brandon McClimon[3], Medard Koshigan[4], James Hilbert[2], Jason A. Bares[2,6], Dalia G. Yablon[5], Julien Fontaine[4], and Robert W. Carpick[2] — [1]School of Mech. Eng., University of Leeds, UK — [2]Dep. of Mech. Eng. and App. Mech., University of Pennsylvania, USA — [3]Dep. of Mat. Sci. and Eng., University of Pennsylvania, USA — [4]LTDS, Ecole Centrale de Lyon, France — [5]SurfaceChar LLC, USA — [6]BorgWarner Powertrain Technical Center, Auburn Hills, USA

Tribology is the study of interacting surfaces in relative motion and the resulting phenomena of friction, lubrication, and wear. The rational design and synthesis of new, modified, and improved materials and lubricants, which can reduce energy and resource consumption in tribological applications, relies on the understanding of the phenomena occurring at sliding interfaces and controlling the observed tribological performance. A key step in the development of this understanding lies in applying advanced surface-analytical methods to the study of tribological materials and interfaces. In this talk, I will present recent experimental results focusing on fundamental surface-analytical investigations of: a) the thermally-induced structural transformations occurring in the near-surface region of a class of solid lubricants, namely amorphous carbon-based materials; and b) the growth of reaction layers formed by antiwear additives used in automotive engine lubricants, gear oils, and greases.