O 88: Symposium Nanotribology

Time: Friday 10:15–13:15 Location: H1

Invited Talk O 88.1 Fri 10:15 H1
Atomic friction under ultrahigh vacuum conditions — •Ernst Meyer[1], Enrico Gnecco[1], Pascal Steiner[1], Gregor Fessler[1], Sascha Koch[1], Thilo Glatzel[1], Alexis Baratoff[1], Mircin Kisiel[1], Urs Gysin[1], Akshata Rao[1], Shigeki Kawai[1], and Sabine Maier[2] — [1]Department of Physics, University of Basel, Switzerland — [2]Lawrence Berkeley National Labs, USA

It will be shown that atomic-scale stick-slip is relatively well understood, where the dependence on velocity and normal force is experimentally investigated and interpreted in terms of an extended Tomlinson model. It is essential to include thermal actuation to understand the observed phenomena. The transition from atomic-scale stick slip to continuous sliding will be described. The detailed analysis yields the energy corrugation and the lateral contact stiffness as a function of load. Very low lateral contact stiffness values of the order a few N/m are found. Experiments will be shown to determine the normal contact stiffness, simultaneously. Slip distances are related to the atomic lattice, where mostly single but also multiple slips are observed. An important parameter is the damping coefficient of the contact, which can be estimated from histograms of slip distances. Friction can be reduced with rather high accuracy by electrostatic actuation. An essential prerequisite are the high intrinsic resonance frequencies of the nanometer-sized contacts, which gives the opportunity to move in nearly continuous way without instabilities. Therefore, average friction values become negligible and small objects can be moved without extremely small dissipation.

Invited Talk O 88.2 Fri 10:45 H1
Layering and Squeeze-out Damping in Confined Liquid Films — •Frieder Mugele — University of Twente, Physics of Complex Fluids, Enschede (The Netherlands)

Liquid films confined between solid surfaces play a crucial role as lubricants reducing friction and wear in a wide range of tribological contacts ranging from biological joints to engineering bearings. For separations between the solid surfaces of just a few nanometers, the properties of the fluid deviate substantially from their macroscopic behaviour. Due to the presence of the solid surfaces the liquid arranges itself in well-defined molecular layers, which gives rise to pronounced forces between the solid surfaces, oscillating between attractive and repulsive as a function of the distance between the surfaces. The structural reorganization also affects the dissipation during flow. Compared to the oscillatory conservative forces, however, the effect of confinement on the dissipation has been much more challenging to quantify. Recent experiments using both laterally wide slit pores with atomically smooth surfaces in a surface forces apparatus (SFA) as well as atomic force microscopy (AFM) experiments with nanoscale single asperity contacts indicate that the effect of the structural reorganization is relatively small. Except for the molecular layers in direct contact with the solid surfaces, the effective viscosity of confined liquids remains close to its bulk value within approximately one order of magnitude.

Invited Talk O 88.3 Fri 11:15 H1
Wear on the nanoscale: mechanisms and materials — •Bernd Gotsmann[1], Mark A. Lantz[1], Harish Bhskaran[1], Abu Sebastian[1], Ute Drechsler[1], Michel Despont[1], Yun Chen[2], Kumar Sridharan[2], Papot Jaroenapibal[3], and Robert Carpick[3] — [1]IBM Research - Zurich, Switzerland — [2]University of Wisconsin-Madison, Madison, WI, USA — [3]University of Pennsylvania, Philadelphia, USA

Endurance requirements in emerging probe technologies, such as probe based data storage and lithography, are extremely demanding. Tip lifetime has been viewed as an unsolved critical issue in this context.

We show, that on the nanoscale the complexity of wear can be simplified to a thermally activated bond breaking process in which the energy barrier is reduced by the frictional shear stress. The resulting atom-by-atom wear deviates strongly from macroscopic wear behavior. Model predictions agree well with wear data obtained using sharp tips sliding in contact with various surfaces at sliding distances up to hundreds of meters.

As an application alternative tip materials are studied: We fabricated a nanoscale silicon-doped Diamond-Like-Carbon tips using a plasma immersion ion implantation and deposition process in conjunction with a molding technique. Silicon carbide (SiC) is another interesting material, in particular for thermo-mechancial applications. Tips were made by a combination of carbon ion implantation and an anneal step.

For both, Si-DLC and SiC tips, we demonstrate an improvement over silicon of several orders of magnitude.

Invited Talk O 88.4 Fri 11:45 H1
Friction at the Nanoscale: Insights from Atomistic Simulations — •Izabela Szlufarska, Yifei Mo, Yun Liu, and Maneesh Mishra — Department of Materials Science & Engineering, University of Wisconsin, Madison, WI 53706

Controlling tribological properties requires understanding a bewildering array of interrelated mechanisms, including elastic instabilities, plastic deformation, fracture, and chemical reactions. Large scale atomistic simulations have been used to unravel some of these mechanisms. Tribological studies are typically divided into a wearless regime, where deformation is primarily elastic, and a wear regime where permanent deformation occurs. For wearless contacts, I will use the example of H-terminated diamond surface to illustrate the breakdown of continuum mechanics at the nanoscale and to demonstrate that nanoscale contacts can be described using macroscale roughness theories. This discovery lays a foundation for unified friction laws across all length scales. I will also discuss effects of surface chemistry on friction, such as frictional dissipation in the presence of trace moisture. In the wear regime I will focus on the origins of recently observed ductile wear in nominally brittle SiC. Although this ductile wear holds potential for greatly enhancing the ease of machining of high-performance ceramics, its origin is still an open question. I will evaluate potential mechanisms for ductile wear, including the possibility of transformation to more ductile phases, dislocation mediated plasticity, and nanoindentation-induced amorphization.

Invited Talk O 88.5 Fri 12:15 H1
The friction of wrinkles — •Martin H. Müser[1] and Hamid Mohammadi[2] — [1]Universität des Saarlandes, Saarbrücken, Germany — [2]University of Western Ontario, London, Ontario, Canada

When in contact with an adhering particle, elastic sheets possess competing mechanically stable, wrinkled geometries if their thickness is below a critical value. Using molecular dynamics simulations, we show that adhering particles moving laterally over a wrinkled elastic sheet induce instability transitions of the wrinkles. These dynamics produce a frictional force between the particles and the sheet that can be well described with the Coulomb law of friction for solids. Analytical models for buckled rods are presented that allow one to rationalize the frictional response of wrinkles. We will also discuss the implications of our results for tribological experiments of graphite sheets that are only a few layers thick.

Invited Talk O 88.6 Fri 12:45 H1
Influence of humidity on nano- and micromechanical contact adhesion — •Hans-Jürgen Butt — Planck Institute for Polymer Research, Mainz, Germany

The interaction between hydrophilic surfaces or particles in air is often dominated by capillary forces. In this case capillary forces are caused by liquid menisci forming in the gap between the surfaces by capillary condensation. Significant progress has been made during the last decade in understanding capillary forces. In particular the influence of surface roughness is now better understood. After giving an introduction into the subject recent results are presented. To analyse capillary forces we measured the adhesion forces between atomic force microscope (AFM) tips or particles attached to AFM cantilevers and different solid samples. Humidity was adjusted relatively fast to minimize tip wear during one experiment. It is demonstrated that the results can be interpreted with simple continuum theory of the meniscus force. The capillary force between two fine particles or between the AFM tip and a sample depends on the precise geometry of the contact region on the 1 nm length scale. We demonstrate that vice versa from a measurement of the adhesion force versus humidity one can calculate the shape of the AFM tip. Finally, a simple, approximate formalism is described to calculate capillary forces between solid surfaces analytically.