O 31: Tribology

Time: Tuesday 14:00–15:45 Location: MA 144

O 31.1 Tue 14:00 MA 144

Influence of Temperature on Contact Ageing of Nano-Asperities — •Matthias Vorholzer, Dirk Dietzel, Michael Feldmann, and André Schirmeisen — Institute of Applied Physics, University of Giessen, Germany

In recent years research in nanotribology has advanced at an increasing pace. But although a lot of fundamental insight into various tribological processes has been gained, the problem of nanoscale contact ageing still remains largely unexplored. Recently, single-asperity slide-hold-slide experiments have been conducted with an AFM at room temperature under ambient conditions to directly investigate the evolution of static friction with time [1]. The results were explained based on a model that describes the formation of chemical bonds between the surfaces [2]. Thermal activation should thus play a major role in the temperature dependence of the ageing processes, which have been analyzed in this work under UHV conditions for temperatures ranging from 15K to 350K.

Our results confirm logarithmic increase of static friction over time for all temperatures. However, the distinct temperature dependence cannot be explained by purely thermally activated processes, which suggests that additional processes like viscoelastic contact area variations need to be considered.

[1] Li et al., Nature 480, 233-235 (2012) [2] Liu et al. PRL 109, 186102 (2012)

O 31.2 Tue 14:15 MA 144

Stochastic stick-slip friction on oxide thin films — •Andra D. Craciun, Jean-Louis Gallani, and Mircea V. Rastei — Institut de Physique et Chimie des Matériaux de Strasbourg, CNRS, Université de Strasbourg, F-67034 Strasbourg, France

Most of sliding surfaces in micro- and nano-mechanical devices are covered by native oxides [1]. Little is known however about nanoscale friction on these surfaces [2,3]. Here, we report on lateral forces needed to move a nanoscale asperity on various oxide thin films, as studied by an atomic force microscope operating in vacuum and at different temperatures. Force-distance traces unveil erratic stick-slip movements separated by several nanometers. The variations of friction force with normal load demonstrate dispersive adhesive interactions at interface. We modeled our findings by considering a Lennard-Jones-like interaction potential, which accounts for changes in the effective contact area. The model captures the formation and fluctuation of stick-slip phases and provides guidelines for predicting transitions from stick-slip to continuous sliding.

[1] See proceedings of IEEE 27th annual international conference on MEMS San Francisco, California (2014). [2] A. Schirmeisen, L. Jansen, H. Holscher, H. Fuchs, Appl. Phys. Lett. 88, 123108 (2006). [3] M. Lessel, P. Loskill, F. Hausen, N. Gosvami, R. Bennewitz, K. Jacobs, Phys. Rev. Lett. 111, 035502 (2013).

O 31.3 Tue 14:30 MA 144

Impact of temperature variation on nanoscale adhesion forces — •Mircea. V. Rastei, Maxime Kein-Wierez, and Alexandre Pinon — Institut de Physique et Chimie des Matériaux de Strasbourg, CNRS, Université de Strasbourg, F-67034 Strasbourg, France

Nanoscale adhesion is a key parameter in formation and stability of many nanomaterials. Without forming chemical bonds, van der Waals interactions induce an attractive potential which establish an equilibrium bond distance between two close contacting bodies. Here, we present a combined atomic force microscopy and theoretical study on how temperature influences the adhesion force triggered by van de Waals interactions. Similar to the case of atomic-scale lateral friction forces [1,2], we found that adhesion follows a distribution whose density function is an asymmetric bell-shaped curve. By increasing temperature the asymmetry increases whereas the most probable adhesion force value decreases. We checked various forms of interaction potentials within the reaction rate theory and evaluate several parameters governing adhesion at the nanoscale. [1] Y. Sang, M. Dubé, and M. Grant, Phys. Rev. Lett. 87, 174301 (2001). [2] A. Schirmeisen, L. Jansen, and H. Fuchs, Phys. Rev. B 71, 245403 (2005).

O 31.4 Tue 14:45 MA 144

Dynamic shear force microscopy of liquids in nanometer confinement — •Marc-Dominik Krass[1,2], Nitya Nand Gosvami[3], Om Prakash Khatri[4], Robert W. Carpick[3], and Roland Bennewitz[1,2] — [1]INM-Leibniz Institute for New Materials, Nanotribology Group, Saarbrücken, Germany — [2]Department of Physics, Saarland University, Saarbrücken, Germany — [3]Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia 19104, USA — [4]CSIR-Indian Institute of Petroleum, Chemical Science Division, Mohkampur Dehradun 248005, India

We present a new method to measure shear forces of liquids in nanometer confinement. A torsionally oscillating atomic force microscope probe (AFM) is approached to the surface. Direct torsional actuation is achieved by a micrometer-scale magnetic bead attached to the back side of the cantilever which experiences a torque by an alternating magnetic field generated by an integrated solenoid.

Dynamic measurements are conducted in a simple liquid (hexadecane) as well as in halogen-free ionic liquids ([trioctylhexylammonium][bis(salicylato)borate]). The experimental data shows changes in the dynamic signals which correlate with jumps in normal force reflecting molecular layering of the liquid. The changes in amplitude and phase of the lateral tip oscillation indicate respective changes of shear dissipation in the confined liquids.

O 31.5 Tue 15:00 MA 144

Puckering stick-slip friction induced by a sliding nanoscale contact on graphite — •Mircea V. Rastei, Benoit Heinrich, Pedro Guzman, and Jean-Louis Gallani — Institut de Physique et Chimie des Matériaux de Strasbourg, CNRS, Université de Strasbourg, F-67034 Strasbourg, France

We report on the experimental observation of puckering-induced nanoscale friction at a graphite surface [1,2]. Using an atomic force microscope operating in vacuum, we show that puckering effect induces nanoscale stick-slip processes originating from periodic deformations of the contact region followed by thermally activated relaxations. These processes are found to depend on the stiffness difference between the crystal axes, and on other tunable parameters such as sliding velocity. The angle between the sliding direction and the stiff crystallographic axis determines the periodicity of the slip events defining domains of various friction properties. We show that each domain presents a particular logarithmic dependence of friction with speed, indicating thermally assisted sliding regimes implying different potential barriers. The difference is proposed to arise from the way the tip interacts with the ridge of the puckered region, which in turn depends on local structural defects. The experimental data are interpreted using the rate theory, with specific potential barriers for each frictional domain. [1] M.V. Rastei, B. Heinrich and J.L. Gallani, Phys. Rev. Lett. 111, 084301 (2013) [2] M.V. Rastei, P. Guzman, J.L Gallani, Phys. Rev. B 90, 041409(R) (2014)

O 31.6 Tue 15:15 MA 144

Contact Ageing observed during Stick Slip Movement of Antimony Nanoparticles — Michael Feldmann, •Dirk Dietzel, and Andre Schirmeisen — Justus Liebig University, Giessen, Germany

Contact ageing is an essential process to understand macro-scale friction dynamics and is typically related to an increasing contact area of asperities. It is less clear, however, if nanoscale asperities of constant size are also capable of ageing. Only recently, such contact ageing was demonstrated for antimony nanoparticles sliding on HOPG [1]. From temperature and velocity dependent measurements, a thermally activated contact ageing of the interface was deduced, while, at the same time, an increase of contact area can be ruled out. Additional measurements with a high data acquisition rate have now revealed that particle movement follows a stick slip pattern as it is common in friction force microscopy. By regarding the slip events as recurring contact renewal, the age of the contact can directly be related to the stick phases. This allows for a very direct assessment of contact ageing and a logarithmic increase of friction with the age of contact is found.

[1] Feldmann, Dietzel, Fuchs, Schirmeisen, Phys. Rev. Lett. 112, 155503 (2014)

O 31.7 Tue 15:30 MA 144

Friction boosted by spontaneous epitaxial rotations —

•Davide Mandelli[1], Andrea Vanossi[1,2], Nicola Manini[1,2,3], and Erio Tosatti[1,2,4] — [1]SISSA, Trieste, Italy — [2]CNR-IOM Democritos, Trieste, Italy — [3]Universita degli Studi di Milano, Milano, Italy — [4]ICTP, Trieste, Italy

It is well known in surface science that incommensurate adsorbed monolayers undergo a spontaneous, energy-lowering epitaxial rotation from aligned to misaligned relative to a periodic substrate. We show first of all that a model 2D colloidal monolayer in an optical lattice, of recent importance as a frictional model, also develops in full equilibrium a small rotation angle, easy to detect in the Moire pattern. The colloidal monolayer misalignment is then shown by extensive sliding simulations to increase the dynamic friction by a considerable factor over the aligned case. More generally, this example suggests that spontaneous rotations are rather ubiquitous and should not be ignored in all tribological phenomena between mismatched lattices.

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