O 120: Tribology: Surfaces and nanostructures

Time: Friday 11:30–13:00 Location: MA 144

O 120.1 Fri 11:30 MA 144

The Prandtl-Tomlinson model with time-varying interaction potential: Analytical predictions and experimental results — •Enrico Gnecco[1], Andre Schirmeisen[2], and Juan J. Mazo[3] — [1]Friedrich Schiller University Jena, Germany — [2]Justus Liebig University Giessen, Germany — [3]University of Zaragoza, Spain

The nonlinear Prandtl-Tomlinson (PT) model is possibly the simplest mechanism explaining the stick-slip motion of a sharp tip elastically pulled on a solid surface. In its basic version the PT model assumes uniform tip-surface interaction. Here we will assume that this is not the case and discuss the influence of contact oscillations and of a growing interaction strength due to "contact ageing" on the model results. In the former case the friction force is expected to decrease almost linearly with the oscillation amplitude until the stick-slip is replaced by steady sliding [1,2]. In the latter contact ageing results in a characteristic velocity weakening of friction which, in specific parameter ranges, can supersede the velocity strengthening caused by thermally activated stick-slip [3]. Interestingly, a similar approach can be used to reproduce the patterning process of compliant amorphous surfaces indented by a tip sliding on them [4]. The main predictions of the extended PT models are supported by experimental results on alkali halide and polymer surfaces in UHV and ambient conditions.

[1] R. Roth et al., App. Phys. Lett. 104, 083103 (2014). [2] O.Y. Fajardo et al., Phys. Rev. B 89, 075423 (2014). [3] J.J. Mazo et al., Phys. Rev. Lett. 118, 246101 (2017). [4] E. Gnecco et al., New J. Phys. 17, 032001 (2015).

O 120.2 Fri 11:45 MA 144

Temperature dependent Contact Ageing Dynamics of Silica Nano-Junctions — •Matthias Vorholzer[1], Guilherme Vilhena[2], Dirk Dietzel[1], Ruben Perez[2], Enrico Gnecco[3], and Andre Schirmeisen[1] — [1]Institute of Applied Physics, Justus-Liebig-University, Giessen, Germany — [2]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [3]Department for Mechanics of Functional Materials, Friedrich-Schiller-University, Jena, Germany

Contact ageing is a fundamental part of rate and state friction laws, which are commonly used to describe macroscale friction. Here, ageing is typically linked to changes of the contact area. Recent nanoscale experiments showed similar ageing for silica nano-junctions, but the effects were attributed to interfacial bond formation [1, 2]. Now, we are probing the temperature dependence of ageing to pinpoint further details about the intrinsic process. We present results for single-asperity slide-hold-slide [1] experiments under UHV conditions for temperatures ranging from 200 K to 300 K for a silica-silica interface. Key for our analysis is measuring the pre-rupture contact stiffness instead of static friction. Our results show logarithmic contact ageing at all temperatures with the expected temperature dependent slope. Additional MD simulations were conducted, which show a striking agreement to the experiments, thereby confirming thermally activated formation of chemical bonds as the governing process for ageing.

[1] Q. Li et al., Nature 480, 233 (2011)
[2] K. Tian et al., PRL 118, 076103 (2017)

O 120.3 Fri 12:00 MA 144

Influence of phase transitions on nanoscale friction in the charge density wave material 1T-TaS_2 — Torben Marx[1], •Dirk Dietzel[1], Emanuele Panizon[2], Franco Pellegrini[2], Giuseppe E. Santoro[2,3,4], Erio Tosatti[2,3,4], and Andre Schirmeisen[1] — [1]Institute of Applied Physics, Justus-Liebig-University Giessen, Giessen, Germany — [2]International School for Advanced Studies (SISSA), Trieste, Italy — [3]CNR-IOM Democritos National Laboratory, Trieste, Italy — [4]The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy

In recent years, analyzing the temperature dependence of nanoscale friction has proven to be an instructive tool to pinpoint internal relaxation modes for materials like polymers [1] or self-assembled monolayers (SAM) [2]. Now, we will show, that friction force microscopy can also be applied to characterize phase transitions by detecting the accompanying mechanical anomalies. To do so, the lateral force signal was constantly monitored during a continuous change of the sample temperature. As a model system, we analyzed the charge density wave material 1T-TaS2 and found, that e.g. the first order phase transition between the NC-CDW and the C-CDW phase was accompanied by distinct friction peaks. This behavior can be explained by a theoretical model, where small mechanical perturbations by the AFM tip are assumed to preemptively trigger the spinodal transformation, if the free energy barrier preventing this transformation becomes small enough.

[1] Jansen et al., PRL 102, 236101 (2009)
[2] Marx et al., Langmuir 33, 6005 (2017)

O 120.4 Fri 12:15 MA 144

Electrostatic Friction on Bi2Te3 (0001) — •Dilek Yildiz[1,2], Marcin Kisiel[1,2], Urs Gysin[1], Oguzhan Gürlü[3], and Ernst Meyer[1] — [1]Universität Basel, Basel, Switzerland — [2]Swiss Nanoscience Institute, Basel, Switzerland — [3]Istanbul Technical University, Department of Physics, Istanbul, Turkey

Bi2Te3 belonging into the class of topological insulators, has a bandgap in the bulk that makes the crystal semiconductor, whereas its surface is protected from backscattering. While protected topological systems are promising to observe exotic physical phenomena like Majorana fermion bounded state or magnetic monopoles, their frictional responses remain to be studied. Although in general 2D electronic systems are expected to strongly enhance the electrostatic friction, there is still lack of experimental evidence of it. Here we study electronic nature of Bi2Te3 surface and its effect on frictional response of the crystal by means of combined pendulum AFM/STM. While quantized image potential states which are above vacuum level were observed with STM, huge energy dissipation peaks were observed few nanometers above the surface with pendulum AFM. Energy dissipation peaks are localized at relatively large voltages as expected for image states and observed to be shifted to even higher voltages as tip-sample distance increase. Their relation was investigated in more detail by simultaneously operating STM and AFM. In this study, we observed that dissipation peaks are mainly due to electrostatic friction and closely related to image potential states.

O 120.5 Fri 12:30 MA 144

Pendulum AFM dissipation peaks and surface oxygen vacancies on SrTiO3 — Marcin Kisiel[1], Oleg Brovko[2], Dilek Yildiz[1], Remy Pawlak[1], Urs Gysin[1], Erio Tosatti[2], and •Ernst Meyer[1] — [1]Department of Physics, University of Basel,Klingelbergstr. 82, 4056 Basel, Switzerland — [2]International Centre for Theoretical Physics (ICTP), P.O.Box 586, I-34151 Trieste, Italy

Bodies in relative motion separated by few nanometer gap experiences a tiny friction force, whose nature is not understood. This non-contact form of friction can be successfully measured by highly sensitive cantilever oscillating like a tiny pendulum over the surface [1].

Recently it was reported that the critical fluctuations at the phase transition in a bulk SrTiO3 may affect the dissipation of mechanical probes even if completely external to the crystal surface [2]. Here we report on striking singlets or multiplets of dissipation peaks above SrTiO3 surface present at low temperatures (T=5K) and after sample annealing to high temperatures (T> 1000oC) which leads to oxygen deficient sample. The observed dissipation peaks are explained as arise due to a tip induced change of valency of the single quantum dot formed by oxygen vacancy (singlet), or groups of vacancies (multiplet). Moreover the results show strong dependence of dissipation peaks on the external magnetic field.

[1] - M. Kisiel et.al., Nature Materials10 (2011), 119-122. [2] - M. Kisiel,et.al., Phys. Rev. Lett.115 (2015), 046101.

O 120.6 Fri 12:45 MA 144

Friction at the Au/graphene interface: A density functional theory investigation — •Duygu Gizem Şentürk[1], Daniele Toffoli[2], and Hande Toffoli[1] — [1]Department of Physics, Middle East Technical University, 06800, Ankara, Turkey — [2]Dipartimento di Scienze Chimiche e Farmaceutiche, Universita degli Studi di Trieste, Via L. Giorgieri 1, I-34127, Trieste, Italy

As the confines of materials science extend to the nanoscale, the tribological behavior of materials diverges significantly from their macroscale counterparts as the classical Amontons-Coulomb laws no longer apply to interfaces since the quantum mechanical nature of the

materials dominates. It is then of great importance to develop a new picture of friction at this scale, especially due to its increasing industrial importance. Friction Force Microscopy(FFM), has opened new frontiers in the study of these challenging interfaces. In particular, metal-coated tips have been used in FFM experiments to uncover the fascinating behavior of two-dimensional systems such as graphene, h-BN and MoS2. In this work, for the first time to the best of our knowledge, we will present a detailed density functional theory investigation of the direction-dependent friction forces that arise as a result of relative motion at the interface between graphene and low-index surfaces of Au. We will highlight the differences in the behavior of the (100), (110) and (111) surfaces and detail the results of our attempts to understand the source of these differences.This work is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) within the 1001 program, Grant No: 115F493.