Kinetic nanoscale friction on van der Waals heterostructures

<u>B. Szczefanowicz</u>[1], Z. Liu[1], J. M. J. Lopes[2], A. George[3], Z. Gan[3], A. Turchanin[3], A. Rothstein[4], C. Stampfer[4], and R. Bennewitz[1]

[1] *INM - Leibniz Institute for New Materials, Saarbrücken, Germany*
[2] *Paul-Drude-Institut für Festkörperelektronik, Leibniz-Institut im Forschungsverbund Berlin e.V., Berlin, Germany*
[3] *Friedrich Schiller University Jena, Institute of Physical Chemistry, Jena, Germany*
[4] *JARA-FIT and 2nd Institute of Physics A, RWTH Aachen University, 52074 Aachen, Germany*

bartosz.szczefanowicz@leibniz-inm.de

2D materials have weak inter-plane and strong in-plane interactions, which lead to their remarkable tribological properties. It was demonstrated by means of friction force microscopy (FFM) that the microscopic processes underlying friction can be tuned by application of high contact pressure [1], electrical field to the contact area [2,3], or by stacking different 2D materials into van der Waals heterostructures [2,4]. Our experimental results illustrate how tribological properties of $MoSe_2$/hBN, graphene/hBN and MoS_2/graphene/SiC(0001) heterostructures vary under increasing contact pressure and applied electrical field.

Heterostructures of $MoSe_2$/hBN and graphene/hBN were fabricated by the exfoliation technique on silicon dices with navigational structures cut by focused ion beam (FIB). The epitaxial graphene prepared by thermal decomposition of SiC(0001) formed an atomically flat and clean surface for following direct growth of MoS_2 flakes by chemical vapor deposition (CVD) technique. The surface evaluation and friction experiments on all heterostructures were conducted in ultra high vacuum at room temperature. Atomic force microscopy (AFM) and Kelvin probe force microscopy (KPFM) were applied to identify position and number of layers of 2D material islands. The influence of normal load and electric field on friction force was determined in FFM experiments. The results will be discussed in terms of bending rigidity of 2D heterostructures, bias-induced electrostatic attraction, and atomic potential corrugation.

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