Atomic force microscopy study of structural superlubricity and its limitations

Stich, I.[1], Dietzel, D.[2], Brndiar, J.[1] and Schirmeisen, A.[2]

[1] Inst. of Physics, Slovak Academy of Sciences, Slovakia, [2] Inst. Appl. Phys., Justus-Liebig-Universitaet, 3592 Giessen, Germany

Structural superlubricity describes the state of virtually frictionless sliding if two atomically flat interfaces are incommensurate, that is, they share no common periodicity. Despite the exciting prospects of this low friction phenomenon, there are physical limitations to the existence of this state. Theory predicts that the contact size is one fundamental limit, where the critical size threshold mainly depends on the interplay between lateral contact compliance and interface interaction energies [1]. Here we provide experimental evidence for this size threshold by measuring the sliding friction force of differently sized antimony particles on MoS_2 in static AFM apparatus under UHV conditions at room temperature [2], Fig. 1. We find that superlubric sliding with the characteristic linear decrease of shear stress with contact size prevails for small particles with contact areas below 15.000 nm^2. Larger particles, however, show a transition toward constant shear stress behavior. In contrast, Sb particles on graphite show superlubricity over the whole size range. *Ab initio* simulations reveal that the chemical interaction energies for Sb/MoS_2 are much stronger than for Sb/HOPG and can therefore explain the different friction properties as well as the critical size thresholds. These limitations must be considered when designing low friction contacts based on structural superlubricity concepts.

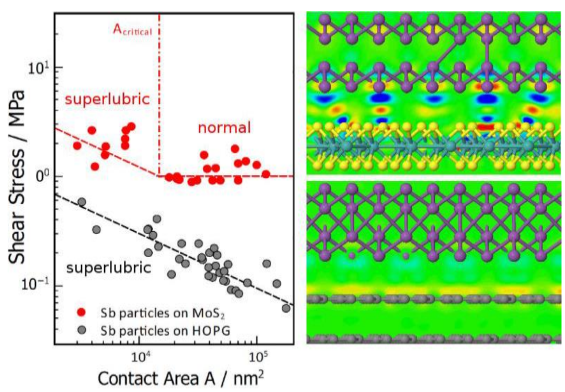

Fig. 1 Contact area dependence of shear stress delimiting superlubric and normal nanoparticle behavior and formation of chemical bonds during nanoparticle sliding on MoS_2 and HOPG substrate.

[1] T.A. Sharp, L. Pastewka, M.O. Robbins, Phys. Rev. **B 93**, 121402 (2016).

[2] D. Dietzel, J. Brndiar, I. Štich, and A. Schirmeisen, ACS Nano **11**, 7642 (2017).

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