

Stellingen

behorende bij het proefschrift

Atomic-Scale friction: Thermal Effects and Capillary Condensation

door

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1. Friction in the limit of zero velocity is reduced to zero at nonzero temperatures. [*Phys. Rev. E* **71**, 65101(R) (2006) and Chapter 4 of this PhD thesis].
2. When granted enough time, a sliding nanocontact will explore higher-energy two-dimensional trajectories to reach the next energy minimum in front, even if there is a direct, low-energy one-dimensional path. This significantly lowers the friction force at low velocities. [Chapter 4 of this PhD thesis].
3. Exciting a contact externally at its lateral resonance frequency can be a very efficient tool to ‘lubricate’ sliding motion, which might be very useful in MEMS and NEMS technology. [Chapter 5 of this PhD thesis].
4. Water condensing inside nanometer sized clefts can freeze at room temperature, which makes water a glue rather than a lubricant at the nanoscale. [*Phys. Rev. Lett.* **96**, 166103 (2006) and Chapters 6 – 8 of this PhD thesis].
5. Nucleation of multiple capillary bridges between the tip and the surface has been claimed to introduce a velocity dependence in nano-scale friction in a humid atmosphere [*Phys. Rev. Lett.* **88**, 185505 (2002)]. However, it is very unlikely that multiple capillary bridges would remain separated within the nanometer sized tip-sample gap.
6. Friction can be effectively reduced by resonating the nanocontact either in a direction normal to the surface or in the lateral direction [A. Socoliuc *et al.*, *Science* **313**, 207 (2006)], but the physics underlying this effect is entirely different in these two cases.

7. Nature lubricates biological machines with water-based lubricants, whereas manmade lubricants are mostly oil-based [M. Urbakh *et al.*, *Nature* **430**, 525 (2004)]. Nature might be achieving this by addition of special molecules that prevent confinement-induced crystallization of water in biological nanopores.
8. Oxides formed at ambient pressure and elevated temperatures on various palladium surfaces have a higher reactivity in oxidation catalysis in this pressure regime than the original metallic surfaces. [S.C. Bobaru *et al.*, *unpublished*].
9. Rice husk ash (RHA) can be used as a partial substitute for cement. This reduces the environmental issues of cement manufacture and usage, by introducing an environment-friendly material. [D.G. Nair *et al.*, *unpublished*].
10. It has been estimated that friction and wear alone cost a whopping 1.6 percent of the annual gross national product of western countries, which amounted to \$116 billion for the USA in 1995 [J. Krim, *Scientific American*, October issue 1996, page 48]. In this light, it is surprising that western society is investing such a small fraction of its R&D budget on tribology.
11. The origin of this Universe is so mysterious that only God knows all about it; perhaps even God himself doesn't know. [Rigveda, **X**, 129 Creation Hymn].