

Friction: Big Challenges at Small Scales

By

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<http://www.me.gatech.edu/SMSS>

ABSTRACT

The emergence of micro- and nano-engineered materials and devices has highlighted the need to characterize and control surfaces and interfaces. Friction, adhesion, and wear are particularly critical factors in micro- and nano-electromechanical systems (MEMS/NEMS), and these are yet to be well-understood or controlled. The pathway to addressing these challenges involves tailoring surfaces to reduce friction and wear. Two prominent examples are self-assembled monolayers (SAMs) and ultrastrong diamond-based thin films. We use quantitative atomic force microscopy (AFM) to determine the atomic-scale tribological behavior of these materials.

In the case of SAMs, we study interfaces that replicate the size, shape, and composition of coated asperities found in actual MEMS devices. It has been known for some time that these hydrocarbon layers are extremely effective in reducing friction and adhesion. Here, we quantify the reduction as a function of whether or not each surface is coated. Furthermore, we show that sliding appears not only to be controlled by interfacial friction, but also by an additional contribution that we propose arises from energy dissipation due to molecular plowing.

For novel forms of ultrahard carbon, including ultrananocrystalline diamond (UNCD), characterization of the atomic bonding configuration at the surface (including the hybridization state of the carbon atoms) is crucial. We determine this using synchrotron-based X-ray absorption spectroscopy. In conjunction with AFM, these experiments show that the nanotribological behavior is directly affected by the nature of these bonds. Exposure to atomic hydrogen terminates the surface with a hydrogen monolayer, maximizes the diamond bonding character, and correspondingly reduces friction and adhesion to the van der Waals limit. Furthermore, chemical changes that occur due to wear are imaged at the sub-micron scale using photoelectron emission microscopy (PEEM). The ability to spatially resolve these changes at high resolution is harnessed to determine new insights into the atomic origins and environmental limits of these materials' ultralow-friction performance.

BIOGRAPHY

Robert W. Carpick is an Associate Professor in the Department of Mechanical Engineering and Applied Mechanics at the University of Pennsylvania. He also holds a secondary appointment in the Department of Materials Science and Engineering.

Prof. Carpick works at the intersection of mechanics, materials, and physics to conduct research into nanotribology (atomic-scale friction, adhesion, and wear), nanomechanics, nanostructured materials, and scanning probe microscopy (SPM).

His primary focus is on using SPM and other surface science techniques to probe the fundamental nature of materials in contact, and to apply the results to nanotechnology applications. Recently he has focused extensively on the science and technology of carbon-based materials, including diamond.

He was the recipient of a CAREER award from the National Science Foundation in 2001. He has taught several invited short courses on nanomechanics and scanning probe microscopy, and is the author of over 50 peer-reviewed publications.

If you are interested in meeting Dr. Carpick, please contact Ting Zhu at ting.zhu@me.gatech.edu or Cecelia Jones at cecelia.jones@me.gatech.edu