PURDUE MECHANICAL ENGINEERING

MIDWEST MECHANICS SEMINAR

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Friction and Wear: New Insights from Atomic-Scale Measurements

Abstract:
Although friction and wear are common phenomena, we lack well-grounded scientific theories to explain them. Such understanding would allow the development of rational strategies for reducing energy dissipation and increasing reliability at all length scales, and would help enable applications for which friction and wear are primary limitations such as micro-/nano-electromechanical systems (MEMS/NEMS). I will discuss recent studies of nanoscale friction and wear that reveal surprising new behavior and insights obtained using atomic force microscopy and *in-situ* transmission electron microscopy methods.

First, the behavior of nanoscale contacts with 2-dimensional materials will be discussed. For nanoscale contacts to graphene, the friction force exhibits a significant dependence on the number of 2-D layers, which we attribute to a "puckering" mechanism arising from the increased tendency of thinner materials to adhere to the sliding tip. An even stronger effect occurs when graphene is fluorinated, where experiments and molecular dynamics simulations consistently show that friction between nanoscale tips and fluorinated graphene (FGr) monolayers exceeds that for pristine graphene by an order of magnitude. The results can be interpreted in the context of the Prandtl-Tomlinson model of stick-slip friction, where static friction arises from the high electronic roughness of fluorinated graphene.

I will then discuss new insights into the origins of nanoscale wear. We have demonstrated the ability to characterize single-asperity wear with a high degree of precision by performing in-situ wear tests inside of a transmission electron microscope. For silicon probes slid against a flat diamond substrate, the shape evolution and volume loss due to wear are well described by kinetic model based on stress-assisted chemical bonding mechanisms. This allows new insights to be gained about the kinetics of atomic-scale wear.

Presenter Bio:
Robert Carpick is John Henry Towne Professor and Chair, Dept. of Mechanical Engineering and Applied Mechanics, University of Pennsylvania. Previously, he was a faculty member at the University of Wisconsin-Madison (2000-2007). He received his B.Sc. from the University of Toronto (1991), and his Ph.D. from the University of California at Berkeley (1997), both in Physics, and was a postdoc at Sandia National Laboratory (1998-1999). He studies nanotribology, nanomechanics, and scanning probes. He is the recipient of a NSF CAREER award (2001), the ASEE Outstanding New Mechanics Educator award (2003), the ASME Newkirk award (2009), an R&D 100 Award (2009), and is a Fellow of the American Physical Society and the AVS. He holds 3 patents and has authored over 100 peer-reviewed journal publications.