Mechanical & Aerospace Engineering Colloquium Series
Spring 2018 Program

Wednesday, February 21, 2018
3:30 – 4:30 p.m. (refreshments/social hour at 4:30)
Easton Hub Auditorium (in the Fiber Optics Building)

Nanoscale Factors Controlling Friction, Lubrication, and Wear: From 2D Materials to Engine Oil

Professor Robert Carpick

University of Pennsylvania

Abstract: New insights into friction and wear from atomic force microscopy (AFM) and in situ transmission electron microscopy (TEM) are presented. First, nanocontacts with 2-dimensional materials like graphene are discussed, where friction depends on the number of layers. An initial model attributing this to puckering [1] is now enhanced by molecular dynamics (MD) simulations showing a strong role of energy barriers due to interfacial pinning and commensurability [2]. Second, the origins of nanoscale wear using a novel combined TEM-AFM instrument is discussed. Wear of silicon sliding on diamond follows a kinetic model where energy barriers for chemical bonding are strongly affected by stress [3]. Finally, I will discuss very recent results where AFM is used to develop new insights into practical lubrication mechanisms. We study zinc dialkyldithiophosphates (ZDDPs), which are highly effective anti-wear additive molecules used nearly universally in engine oils. We developed a novel AFM-based approach for visualizing and quantifying the formation of ZDDP anti-wear films in situ at the nanoscale. Film growth depends exponentially on temperature and stress, which can explain the known graded-structure of the films. Our findings provide new insights into the mechanisms of formation of ZDDP derived anti-wear films and the control of lubrication in automotive applications [4]. [1] C. Lee *et al. Frictional Characteristics of Atomically-Thin Sheets*. **Science**, 328, 76 (2010). [2] S. Li *et al. The Evolving Quality of Frictional Contact with Graphene*. **Nature** 539, 541 (2016). [3] T.D.B. Jacobs *et al. Nanoscale Wear as a Stress-Assisted Chemical Reaction*. **Nature** Nanotech. 8, 108 (2013). [4] N.N. Gosvami *et al. Mechanisms of Antiwear Tribofilm Growth Revealed in situ by Single Asperity Sliding Contacts*, **Science**, 348, 102 (2015).

Bio: Robert Carpick is John Henry Towne Professor, Dept. of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, where he has served as Department Chair since 2011. 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, the AVS, the Materials Research Society, and the Society of Tribologists and Lubrication Engineers. He holds 5 patents and has authored over 160 peer-reviewed journal publications.

Contact Professor Aaron Mazzeo at aaron.mazzeo@rutgers.edu.
Phone: (848) 445-0504 | Fax: (732) 445-3124