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SPEAKER

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101 DAVIS HALL



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NANOSCALE FACTORS CONTROLLING FRICTION AND  
LUBRICATION: FROM 2D MATERIALS TO  
ENGINE OIL

ABSTRACT

New insights into friction and lubrication from atomic force microscopy (AFM) 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]. I will then discuss very recent results where AFM is used to develop new insights into practical lubrication mechanisms. We study zinc dialkyl-dithiophosphates (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 [3].

[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] N.N. Gosvami et al. Mechanisms of Antiwear Tribofilm Growth Revealed in situ by Single Asperity Sliding Contacts, *Science*, 348, 102 (2015).

BIO SKETCH

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 6 patents and has authored over 170 peer-reviewed journal publications.



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