ME Seminar

Nanotribology, Nanomechanics and Materials Characterization Studies and Applications to Bio/nanotechnology and Biomimetics

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ABSTRACT

At most solid-solid interfaces of technological relevance, contact occurs at numerous asperities. A sharp atomic/friction force microscope (AFM/FFM) tip sliding on a surface simulates just one such contact. However, asperities come in all shapes and sizes that can be simulated using tips of different shapes and sizes. AFM/FFM techniques are commonly used for tribological studies of engineering surfaces at scales ranging from atomic- to microscales. Studies include surface characterization, adhesion, friction, scratching/wear, boundary lubrication, electrical resistance, surface potential, and capacitance mapping [1-4]. AFMs and their modifications are also used for nanomechanical characterization, which includes measurement and analysis of hardness, elastic modulus and viscoelastic properties, and in-situ localized deformation studies. The experimental data exhibit scale effects in adhesion, friction, wear, and mechanical properties. Generally, coefficients of friction and wear rates on micro- and nanoscales are smaller, whereas hardness is greater. Therefore, micro/nanotribological studies may help define the regimes for ultra-low friction and near-zero wear. New lubrication strategies such as the use of self-assembled monolayers promise to be very versatile and effective at these scales.

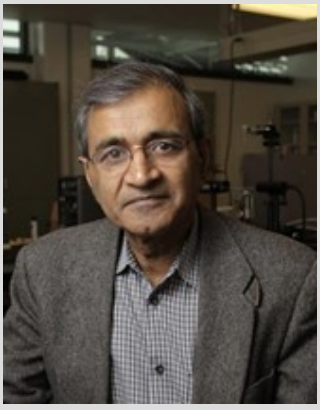
Nanotribology and Nanomechanics of various MEMS/NEMS and BioMEMS/BioNEMS devices which require relative motion is of importance [4]. The scale of operation and large surface-to-volume ratio of the devices result in very high retarding forces such as friction and adhesion that seriously undermine the performance and reliability of the devices. Carbon nanotubes are being used for various nanotechnology applications. The mechanical strength and reliability of many of these devices critically relies on the nanotribology and nanomechanics of the CNTs [5]. There are bioadhesion issues in biosensors and other BioMEMS/BioNEMS which need to be addressed [4].

Biologically inspired design, adaptation, or derivation from nature is referred to as biomimetics [6]. The understanding of the functions provided by objects and processes found in nature can guide us to imitate and produce nanomaterials, nanodevices, and processes [6,7].

These fundamental nanotribological studies provide insight to the molecular origins of interfacial phenomena including adhesion, friction, wear, and lubrication. Friction and wear of lightly loaded micro/nano components are highly dependent on surface interactions within a few atomic layers. Nanotribological and nanomechanics studies are also valuable in the fundamental understanding of interfacial phenomena in macrostructures to provide a bridge between science and engineering. This talk will present an overview of nanotribological and nanomechanics studies and their applications to bio/nanotechnology and biomimetics [3,4,6].

[1] Bhushan, B., Israelachvili, J. N., and Landman, U., "Nanotribology: Friction, Wear and Lubrication at the Atomic Scale," Nature 374, 607-616 (1995).
[2] Bhushan, B., Handbook of Micro/Nanotribology, 2nd ed., CRC Press, 1999.
[3] Bhushan, B., Nanotribology and Nanomechanics: An Introduction, 4th ed., Springer, 2017.
[4] Bhushan, B., Springer Handbook of Nanotechnology, 4th ed., Springer, 2017.
[5] Bhushan, B. "Nanotribology of Carbon Nanotubes", J. Phys.: Condens. Matter 20, 365214 (2008).
[6] Bhushan, B., Biomimetics-Inspired Hierarchical-Structured Surfaces for Green Science and Technology, 3rd ed., Springer, 2018.
[7] Bhushan, B., "Lessons from Nature for Green Science and Technology: An Overview and Superliquiphoboc/philic Surfaces," Phil. Trans. R. Soc. A 377, 20180274 (2019).
[8] Bhushan, B., "Frontiers in Nanotribology: Magnetic Storage, Bio/Nanotechnology, Cosmetics, and Bioinspiration," J. Colloid Interface Sci. 577, 127-162 (2020)

ABOUT THE SPEAKER



Professor Bhushan is currently a Satish Dhawan IoE Visiting Chair Professor at the Indian Institute of Science. He was born in a small town, Jhinjhana, India. He received his B.S. in Mechanical Engineering from the Birla Institute of Technology Science. He received his M.S. in Mechanical Engineering from MIT, an M.S. in Mechanics, a Ph.D. in Mechanical Engineering from the University of Colorado at Boulder, and an MBA from Rensselaer Polytechnic Institute. Prof. Bhushan is an Academy Professor at Ohio State. He has served as an Ohio Eminent Scholar, and The Howard D. Winbigler Professor in the College of Engineering. He has authored 10 scientific books, over 100 book chapters, more than 900 scientific papers and 60 technical reports. As well as receiving more than two dozen awards from professional societies, industry and U.S. Government Agencies, Prof. Bhushan received NASA's 'Certificate of Appreciation' to recognize the critical tasks that he performed in support of President Reagan's Commission investigating the Space Shuttle 'Challenger' Accident.

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