College of Engineering
Department of
Mechanical & Industrial Engineering

The Sidney E. Fuchs Seminar Series

3:00-4:00pm, Friday, March 31st, 2017
Frank H. Walk Design Presentation Room

Unconventional Approaches to the Development of Hard Coatings and Lubricant Additives

by Yip-Wah Chung*

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This talk will explore unconventional approaches in two areas of tribology. The first is the synthesis of hard coatings. Most hard coatings are based on ceramic materials, which are hard but not tough. An alternative approach to making hard and tough coatings is to start with a metal, which is tough, and attempt to make it harder by forcing the metal to attain nanocrystalline grains. Using this strategy, we have succeeded in synthesizing nanocrystalline metal-based coatings with hardness comparable to sapphire and with thermally stable nanocrystalline grains even after exposure to 1000°C for many hours. In the course of this investigation, we discovered the traditional use of H/E and H3/E2 (H = hardness, E = elastic modulus) as proxies for coating toughness to be incorrect. The second area is the design of lubricant additives to reduce friction in the boundary lubrication regime. This work is driven by the need to improve fuel efficiency in transportation. Inspired by unique lubricants used in computer disk drives, we have developed a series of sulfur- and phosphorus-free oil-soluble alkyl-cyclen-based molecules. Under boundary lubrication conditions, these additives reduce friction by up to 70 % and wear by 95 % from room temperature to 200° C. Molecular dynamics simulations indicate that these cyclen-based molecules adsorb strongly onto oxide surfaces (representative of practical steel surfaces), in an orientation that allows tethered hydrocarbon chains to protect asperities from direct contact in the boundary lubrication regime. The success of this approach suggests opportunities for the design of lubricant additives with functionalities that operate through the entire lubrication regime.

* Yip-Wah Chung obtained his BS (physics and mathematics) and MPhil (physics) degrees from the University of Hong Kong, and PhD (physics) from the University of California at Berkeley. He then joined the Department of Materials Science and Engineering at Northwestern University in 1977. He served as Director of the Center for Engineering Tribology at Northwestern from 1987 to 1992, as Department Chair from 1992 to 1998, and as program officer in surface engineering and materials design at the U.S. National Science Foundation from 2003 to 2005. He has served many years in the Research Grants Council and University Grants Committee of Hong Kong. He has published over 200 papers in surface science, thin films, tribology, and alloy design, two textbooks (Practical Guide to Surface Science and Spectroscopy, Introduction to Materials Science and Engineering), and one monograph (Micro- and Nanoscale Phenomena in Tribology). He co-edited a six-volume Encyclopedia of Tribology (Springer). His current research studies include hard coatings, high-performance steels, and advanced lubricants for improved vehicle efficiency. He was named Fellow, ASM International; Fellow, AVS; and Fellow, Society of Tribologists and Lubrication Engineers. His other awards include Teacher of the Year in Materials Science, Innovative Research Award and Best Paper Awards from the ASME Tribology Division, Technical Achievement Award from the National Storage Industry Consortium, Bronze Bauhinia Star Medal from the Hong Kong SAR Government, Advisory Professor from Fudan University, Visiting Fellow from Japan Society for Promotion of Science, and Visiting Scientist from Austrian Center of Competence in Tribology. He is also a multi-engine instrument-rated commercial pilot and an advanced/instrument ground instructor.