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NANOTRIBOLOGY, NANOMECHANICS AND MATERIALS CHARACTERIZATION STUDIES AND APPLICATIONS TO BIO/NANOTECHNOLOGY AND BIOMIMETICS

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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 which 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[1-5]. 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. State-of-the-art contact mechanics models have been developed and are used to analyze dry and wet contacting interfaces. The experimental data exhibit scale effects in adhesion, friction, wear, and mechanical properties, and a comprehensive model for scale effects due to adhesion/deformation and meniscus effects has been developed. 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.

Carbon nanotubes are being used for various nanotechnology applications. The mechanical strength of many of these devices critically relies on the nanotribology and nanomechanics of the CNTs. Various investigations of adhesion, friction, wear, and mechanics of MWNTs, SWNTs and MWNT arrays have been carried out [6]. For bio/nanotechnology applications, to improve adhesion between biomolecules and silicon based surfaces, chemical conjugation as well as surface patterning have been used [5]. Friction and wear studies of biomolecules show that these act as a lubricant but exhibit some wear resistance [5]. In the area of biomimetics [7], surface roughness present on Lotus and other leaves has been measured, and the surface films are characterized to understand the mechanisms responsible for superhydrophobicity (high contact angle), self-cleaning, and low adhesion. A model for surface-roughness-dependent contact angle has been developed, and optimum distributions have been developed for superhydrophobic surfaces [8,9]. Hierarchical structures of interest have been fabricated in the lab [4] using various fabrication techniques, and some of the surfaces show excellent performance superior to that of the Lotus leaf.

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 the surface interactions (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.

REFERENCES

[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, Boca Raton, Florida, 1999.

[3] Bhushan, B. et al.., Applied Scanning Probe Methods, Vol. 1-13, Springer, Heidelberg, Germany, 2004, '06, '07, '08, '09.

[4] Bhushan, B., Nanotribology and Nanomechanics – An Introduction, 2nd ed., Springer, Heidelberg, Germany, 2008.

[5] Bhushan, B., Springer Handbook of Nanotechnology, 2nd ed., Springer, Heidelberg, Germany, 2007.

[6] Bhushan, B. “Nanotribology of Carbon Nanotubes”, J. Phys.: Condens. Matter 20, 365214 (2008).

[7] Bhushan, B., “Biomimetics: Lessons from Nature - An Overview”, Phil. Trans. R. Soc. A 367, 1445-1486 (2009).

[8] Nosonovsky, M. and Bhushan, B., Multiscale Dissipative Mechanisms and Hierarchical Surfaces: Friction, Superhydrophobicity, and Biomimetics, Springer, Heidelberg, Germany, 2008.

[9] Bhushan, B. Jung, Y. C. and Koch, K., “Micro-, Nano-, and Hierarchical Structures for Superhydrophobicity, Self-Cleaning and Low Adhesion”, Phil. Trans. R. Soc. A 367, 1632-1672 (2009)