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INVITATION
Mechatronics Seminar on Nanosystems

Nanotribology and Nanomechanics of MEMS/NEMS and BioMEMS/NEMS Materials and Devices

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The Ohio State University, 650 Ackerman Road, Suite 255
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Tuesday, 05.04.2005, in Building ML, D-Floor
Room ML D28 at 4.15 p.m

ETH-Zentrum, Clausiusstrasse/Tannenstrasse, 8092 Zurich

Abstract

MEMS/NEMS and BioMEMS/NEMS include a variety of sensors, actuators, and complex micro/nanodevices for industrial, consumer, defense, and biomedical applications. MEMS/NEMS devices are made from single-crystal silicon, LPCVD polysilicon and other ceramic films, and polymers. BioMEMS/NEMS devices also involve biomaterials. Many devices involve relative motion, and in those cases tribology and mechanics are of importance[1,2]. 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[3-5]. In some devices, high interfacial adhesion is required. Materials used in these devices must exhibit desirable micro/nanoscale tribological and mechanical properties. There is a need to develop lubricants and identify lubrication methods that are suitable for these devices. Measurement and evaluation of mechanical properties of micro/nanoscale structures is also essential to help address reliability issues. Using atomic-force-microscopy-based techniques, we have performed nanotribological and nanomechanics studies of materials and devices and have explored the use of various surface coatings and surface treatments and lubrication approaches, some of which include oxide and diamondlike carbon (DLC) coatings, ion implantation, self-assembled monolayers, and ultrathin bonded perfluoropolyether (PFPE) lubricant films[3-5]. Scaling effects in adhesion, friction, and wear have been measured and a comprehensive model for scale effects in friction and wear due to adhesion/deformation, and meniscus effects has been developed. Methods to

measure static friction (stiction) and adhesion of actual MEMS components have been developed. Surface roughness of MEMS components, a property of tribological interest, has been measured and contact models have been used to develop optimum roughness distributions on a computer. Stiction mechanisms in digital micromirror devices, used for digital projection displays, have been studied and methods to minimize stiction have been proposed. We have carried out adhesion and friction studies on various lubricant films as well as PDMS and PMMA used in BioMEMS/NEMS (micro/nanofluidics). Morphology of silicon based surfaces with and without biomolecules and their adhesion with the substrate govern the performance of various biosensors and other BioMEMS/NEMS. Step by step morphological changes of silicon as well as adhesion during modification have been studied using an AFM. To improve adhesion between biomolecules and the silicon based surfaces, chemical conjugation as well as surface patterning have been used. For cancer treatment, functionalized nanoparticles are being developed for drug delivery. These circulate in the blood stream, detect and attach to diseased cells and kill them. Adhesion between particles and cells is required and is being measured. We have developed a bioadhesion model based on a probabilistic analysis. In the area of biomemics, we have measured surface roughness present on lotus and other leaves and characterized the surface films to understand the mechanisms responsible for high hydrophobicity (high contact angle). We have developed a model for surface-roughness-dependent contact angle and optimum roughness distributions have been developed for superhydrophobic surfaces. We have used AFM Kelvin probe microscopy to measure surface charges present on polymeric microfluidic channels which may affect fluid flow.

In the area of nanomechanics, AFM based techniques have been developed and used for measurements of mechanical properties of nanostructures, made of silicon, silica and polymers, and scaling effects have been studied. A finite element analysis has been used to model deformation of nanostructures to study the effect of surface roughness and scratches on stresses.

[1]Bhushan, B., Israelachvili, J.N., and Landman, U., "Nanotribology: Friction, Wear and Lubrication at the Atomic Scale," *Nature*, Vol. 374, 1995, pp. 607-616.
[2]Bhushan, B., *Handbook of Micro/Nanotribology*, second ed., CRC Press, 1999.
[3]Bhushan, B., *Tribology Issues and Opportunities in MEMS,* Kluwer Academic Publishers, Dordrecht, 1998.
[4]Bhushan, B., *Springer Handbook of Nanotechnology*, Springer-Verlag, Heidelberg, Germany, 2004.
[5]Bhushan, B., Fuchs, H., and Hosaka, S., *Applied Scanning Probe Methods*, Springer-Verlag, Heidelberg, 2004.

Best Regards
Christofer Hierold, 16th March 2005