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13. ABSTRACT (Maximum 200 words) The objective of this workshop was to bring together researchers, manufacturers and potential users of MEMS and experts in tribology (including mechanics, mechanical properties and surface modification) so that the MEMS community could better understand the tribology expertise and the tribology community could better understand the major problems on hand and identify critical research issues facing MEMS industry. There were three specific objectives of the workshop. The first was to provide tutorial on MEMS technology and state-of-the-art of tribology for education of tribology and MEMS community, respectively. The second objective was to share whatever tribological understanding of MEMS devices exists. The third objective was to identify tribology research issues and opportunities and general directions for tribology in MEMS research which were accomplished via breakout sessions and a panel discussion. Since the objective of the first part of the workshop was to provide tutorials, we had a large number of lectures of short durations followed by lectures on tribology of MEMS, mechanical property measurements, modification and characterization of surfaces, and breakout sessions and a panel discussion. A side benefit of this workshop was to bring macro- and microtribologists together.					
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# Final Report on Tribology Issues and Opportunities in MEMS Workshop

## PREFACE

Micro Electro Mechanical Systems (MEMS) is already about a billion dollars a year industry and is growing rapidly. So far major emphasis has been placed on the fabrication processes for various devices. There are serious issues related to tribology, mechanics, surface chemistry and materials science in the operation and manufacturing of many MEMS devices and these issues are preventing an even faster commercialization. Very little is understood about tribology and mechanical properties on micro- to nanoscales of the materials used in the construction of MEMS devices. The MEMS community needs to be exposed to the state-of-the-art of tribology and vice versa.

Fundamental understanding of friction/stiction, wear and the role of surface contamination and environmental debris in micro devices is required. There are significant adhesion, friction and wear issues in manufacturing and actual use, facing the MEMS industry. Very little is understood about the tribology of bulk silicon and polysilicon films used in the construction of these microdevices. These issues are based on surface phenomena and cannot be scaled down linearly and these become increasingly important with the small size of the devices. Continuum theory breaks down in the analyses, e.g. in fluid flow of micro-scale devices. Mechanical properties of polysilicon and other films are not well characterized. Roughness optimization can help in tribological improvements. Monolayers of lubricants and other materials need to be developed for ultra-low friction and near zero wear. Hard coatings and ion implantation techniques hold promise.

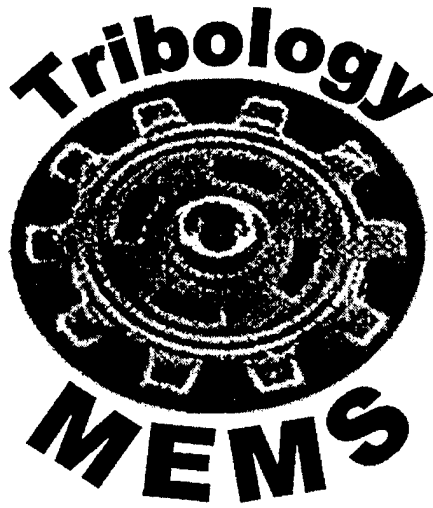
Better tribological understanding of MEMS will advance the state-of-the-art in micromachining and the IC industry, in general. For example, better understanding will contribute to better performance prediction for micromachined pressure sensors, accelerometers and gyro's as well as a better understanding of stiction behavior of micro-mirrors and micromotors and of the influence of roughness on micro-fluids.

The objective of this workshop was to bring together researchers, manufacturers and potential users of MEMS and experts in tribology (including mechanics, mechanical properties and surface modification) so that the MEMS community could better understand the tribology expertise and the tribology community could better understand the major problems on hand and identify critical research issues facing MEMS industry. There were three specific objectives of the workshop. The first was to provide tutorials on MEMS technology and state-of-the-art of tribology for education of tribology and MEMS community, respectively. The second objective was to share whatever tribological understanding of MEMS devices exists. The third objective was to identify tribology research issues and opportunities and general directions for tribology in MEMS research, which were accomplished via breakout sessions and a panel discussion. Since the objective of the first part of the workshop was to provide tutorials, we had a large number of lectures of short durations followed by lectures on tribology of MEMS, mechanical property measurements, modification and characterization of surfaces, and breakout sessions and a panel discussion. A side benefit of this workshop was to bring macro- and microtribologists together.

We assembled individuals who are active in research and manufacturing of MEMS devices or are potential users of this technology. We also invited experts in macro- and microtribology, surface modification and mechanical property measurement arenas from industry, government and academia. The micro/nanotribology community can play a pivotal role. Tribological issues in MEMS are closely related to those faced today by magnetic storage devices community, which were also invited to attend. Furthermore, a special effort was made to attract students and younger researchers from the U.S. and overseas. The response to the course workshop was overwhelming. We had 122 participants from eleven countries including Belarus, Belgium, Germany, India, Japan, Netherlands, Norway, Poland, Switzerland, U.K. and U.S.A. Participants ranged from undergraduate students in engineering to very senior researchers. A total of 46 oral and 27 poster presentations were made at this workshop in addition to four breakout sessions and a panel discussion.

Invited lectures and selected contributed articles have been published in a hard volume by Kluwer Academic Publishers B.V. The workshop proceeding contains 46 articles, 4 breakout session reports, and a panel discussion report.

Professor Bharat Bhushan  
Workshop Director  
Columbus, Ohio, U.S.A.  
June 1998



# **Tribology Issues and Opportunities in MEMS**

**Edited by**

**Bharat Bhushan**

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