Chapter 2
Bioinspired Solutions for MEMS Tribology

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ABSTRACT

Micro-electro mechanical systems (MEMS) are miniaturized devices that operate at a small scale. Actuators-based MEMS have not been commercially realized yet, owing to the manifestation of high surface forces such as adhesion and friction between their moving elements. In recent years, inspiration from "Lotus Effect" has opened a new direction in the field of micro/nano-tribology to manipulate/control surface forces at small scale. The underlying principle discovered from the super-hydrophobic nature of the leaves of water-repellent plants has led to the design and development of various biomimetic tribological surfaces that exhibit remarkable reduction in surface forces under tribological contact. This chapter presents the tribological issues in MEMS devices, examples of conventional solutions for the tribological issues, and unique bioinspired solutions that have great capability to mitigate surface forces at micro/nano-scales.

INTRODUCTION

Micro-Electro-Mechanical Systems (MEMS) are miniaturized devices that perform intelligent functions. They can be classified as: (i) sensors based, which have sensing elements and (ii) actuators based, which have elements that undergo mechanical motion. Micro-motors/engines, micro-gears and micro-shutters are examples of actuators based devices. Figure 1 shows a micro-gear made from silicon (http://www.sandia.gov/mstc/_assets/images/mems/gallery/gears/1.jpg). In these devices, tribological issues such as adhesion, friction and wear strongly manifest, which undermine the mechanical motion of MEMS elements (Kim, Asay, & Dugger, 2007). Therefore, it is imperative to solve these tribological issues in order to realize smooth operation and increased operating lifetimes of actuators based MEMS. Convention-

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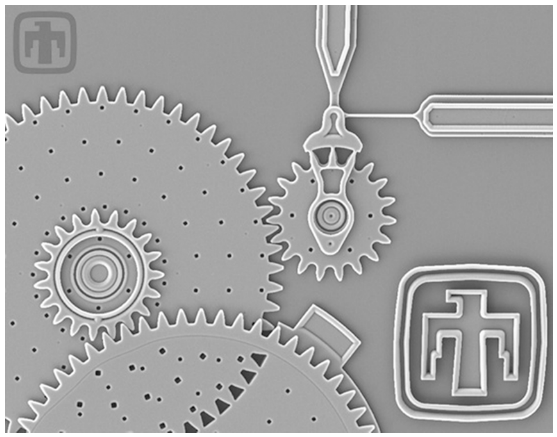
Figure 1. MEMS micro-gear made from silicon. (http://www.sandia.gov/mstc/_assets/images/mems/gallery/gears/1.jpg). In MEMS devices, tribological issues such as adhesion, friction and wear strongly manifest and undermine the mechanical motion



ally, thin films/coatings have been researched for their application to MEMS as solutions to mitigate the tribological issues. Examples include self-assembled monolayers (SAMs), diamond-like carbon (DLC) coatings, polymers and perfluoropolyether films (PFPE) (Bhushan, 2001). In recent years, bioinspired approaches have attracted attention as better alternative solutions for MEMS. This chapter highlights bioinspired approaches that are promising tribological solutions for actuators based MEMS devices.

BACKGROUND

MEMS are built at micro/nano-scale. At these scales, the ratio of surface area to volume is high. Hence, body forces such as inertia and gravity become insignificant. In contrast, surface forces such as capillary, van der Waals, electrostatic, and chemical bonding dominate. These surface forces cause adhesion at the interface of contacting MEMS elements. Amongst these forces, the capillary force that arises due to the condensation of water from the environment is the strongest. Further, adhesion strongly influences friction at micro/nano-scale (Maboudian & Howe, 1997). The magnitude of these surface forces is comparable with those that drive the motion of MEMS elements, thereby rendering the elements completely inoperable. MEMS are traditionally made from silicon due to availability of the process knowledge developed for the material in semiconductor industries. However, silicon does not have good tribological properties (Bhushan, 2001). Silicon due to its inherent hydrophilic nature experiences high surface forces, and because of its brittle nature it undergoes severe wear. Thus, the improvement of tribological performance of silicon is the key to realize the smooth operation of actuators based MEMS. Williams and Le have presented an excellent review on the tribological issues in MEMS devices (Williams & Le, 2006).

Tribological properties of materials at micro/nano-scale are evaluated using atomic force microscopes (AFM) and micro-tribo testers. With these instruments, contact conditions similar to those in MEMS can be easily simulated (loads ~nN to μN-mN; area ~few hundreds of nm^2).

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