Structure and Properties of Fluorinated Organic Thin Films: Implications for MEMS Devices

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One goal of our research is to determine the factors (structural and chemical) influencing the adhesion and friction between interfaces. As models of lubricated interfaces, we use self-assembled monolayers (SAMs) on gold (see Figure 1) because they allow for precise control of the structure and chemical composition of organic-coated interfaces.[1] In addition, the study of SAMs on flat terraces of gold allows us to evaluate effects due to the roughness of the surface. Our research focuses on fluorinated organic thin films because fluorocarbons impart unique properties to thin films, such as low wettability by water and low coefficients of friction. Our research seeks to define the components needed for producing nanoscale versions of Teflon.

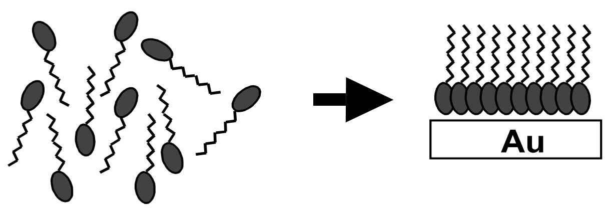

Figure 1. Spontaneous formation of SAMs on Gold

The efficiency of microelectromechanical systems (MEMS) devices is often plagued by surface phenomena, which can be dealt with at the macroscale level using lubricants. However, as the surface-to-volume ratio gets larger, control over the interfacial forces involved in the relative motion of contacting elements becomes critical to maintain them in working condition. To effect the movement of two elements of MEMS with respect to one another, the interfacial "stiction" forces must be overcome.

A few specific sources of stiction can be defined. First, van der Waals and electrostatic interactions between surfaces are attractive forces between the two interfaces. These forces are particularly strong when the two surfaces placed in contact are flat at the nanoscale level (common in MEMS) because they are proportional to the contact area. One strategy to decrease these types of interactions is to increase the roughness of the interface, for example, by coating it with a molecular monolayer or a thin layer of polymer. Another strategy is to use fluorinated materials as coatings because their interactions are inherently weak.[1] Due to the stiffness of the fluorinated chains, the molecules are forced to stand further apart than hydrocarbon chains, thereby minimizing the effective interfacial contact area.[1,2]

Second, capillary forces can bind surfaces together tightly if both surfaces are sufficiently wet by the contacting liquid. To prevent this force from keeping two contacting elements locked in position, the amount of liquid between the elements should be reduced. If the surfaces of the elements are decorated with small structures, the evaporation process can create an additional issue: surface tension increases to compensate for the loss of surface coverage during the evaporation. In this scenario, the strength of the capillary force is increased, which in turn can destroy some structures. Due to its high surface tension and pervasiveness, the most significant liquid that needs to be excluded from contacting surfaces is water. Fluorocarbons are among the most hydrophobic materials known;[2] as a consequence, a solution to reduce capillary forces is to coat the contacting elements with fluorocarbons, preferentially rich in CF_3 groups as described by Zisman and co-workers[3] because these moieties produce the most dramatic reduction in the wettability.

Third, MEMS devices are sensitive to contamination by airborne dust and organic volatile compounds. Hydrophobic surfaces such as fluorinated thin films are less prone to this type of contamination, making them good candidates for coating the surfaces of MEMS devices.

In many current industrial applications, fluorocarbons are commonly used to diminish the interactions between surfaces. At the macroscale, Teflon coatings prevent a variety of bulk elements from sticking together. At the nanoscale, perfluoroethers prevent the scanning head of hard disk drives from scratching the disk, tremendously increasing the lifetime of the device. Similar usage of fluorocarbons is found in MEMS devices. Despite their widespread use, studies of structure-properties relationships remain scarce in the literature. Our research examines the structure of selectively fluorinated SAMs and evaluates the relationships between structure and interfacial properties, such as wettability, adhesion, and friction.

References

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