360b High Temperature in-Use Stiction of Cantilever Beams Coated with Perfluorinated Alkysiloxane Monolayers

Joelle Frechette, Carlo Carraro, and Roya Maboudian

Stiction, or unwanted surface adhesion, has been a major reliability concern for the MEMS (microelectro-mechanical systems) industry. Various alkylsiloxane monolayer coatings have been used successfully to limit the importance of stiction. Most surface coatings, however, have not been tested for conditions other than room temperature. MEMS structures are highly likely to be exposed, during packaging or in-use, to high temperature or harsh environmental conditions. Perfluorinated alkylsiloxane monolayers are promising surface coatings for high temperature applications. Investigation of the impact of annealing (for temperatures up to 300oC) on the stiction of two perfluorinated alkylsiloxane monolayers: 1H,1H,2H,2H, perfluorodecyltrichlorosilane (FDTS) and 1H,1H,2H,2H, perfluorodecyldimethylchlorosilane (FDDMCS), both deposited via liquid and vapor phase was accomplished.

Adhesion measurements show a consistent increase in the detachment length (reduced adhesion) upon annealing. Both monolayers can sustain a wide temperature range but FDTS is more stable (regardless of the deposition method), probably due to the highly crosslinked nature of the monolayer. The increase in detachment length with temperature could not have been directly predicted by contact angle measurements (showing a slight decrease in the hydrophobic nature of both monolayers with annealing) or AFM imaging (no significant change in surface roughness measured for the studied temperature range). This underscores the importance of conducting micromachine stiction measurements rather than relying solely on techniques such as AFM or contact angle.

Annealings in vacuum (up to 450oC) were performed with Si(100) test chips to measure the XPS spectra. XPS analysis shows that FDDMCS starts to desorb even for annealing at 100oC. FDTS monolayers have a better temperature stability than FDDMCS monolayers. A mechanism for the thermal decomposition of perfluorinated alkyl silane monolayers can be extracted from the XPS measurements. FDTS and FDDMCS loose the fluorine during annealing by a loss of the entire monolayer chain, which is drastically different than annealing of alkyl siloxane monolayers (they decompose by “shaving” methyl groups from the surface). This mode of desorption does not seem to affect stiction because the film is not left with a reactive group at the surface and the chains are able to tilt to maintain a hydrophobic surface of comparable surface energy. Understanding the mechanism of thermal decomposition of perfluorinated alkylsiloxanes gives a direct insight in the root of the high temperature stability of those monolayers compared to alkyl monolayers such as OTS (octadecyltrichlorosilane).