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8. Surface characterization, adhesion measurements and modeling of microelectromechanical systems

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Abstract

Adhesion, also referred to as stiction, is a common failure mechanism occurring in microelectromechanical systems (MEMS) during device fabrication and operation and has become the main barrier to the advancement and wide commercialization of MEMS and miniature devices. To investigate the adhesion behavior of MEMS devices, experimentally and theoretically, different small scale interfacial experiments and continuum-based models have been developed and applied with varying success to explain such phenomena. In this work, a beam-peel-based MEMS experimental setup was designed and built to measure the adhesion energy between MEMS microcantilevers and a substrate at different humidity levels. The microcantilever arrays were separated from the substrate and their fixed ends were directly attached to a piezoactuator to control the beam displacement with sub-nanometer accuracy. The experimental setup was sealed in a chamber with precise humidity control. An in-situ interferometer was used to measure the beam deflection and crack length during the peel test. To examine the effects of surface roughness and relative humidity on adhesion energy, different surface pairs were measured at humidity levels ranging from 40% to 92%. Before testing, the microcantilevers and substrates were scanned using an Atomic Force Microscope (AFM). Surface roughness parameters and the exact probability density function of the asperity heights were extracted and directly entered into a statistical-based roughness model. An Extended-Maugis-Dugdale (EMD) single-asperity meniscus model considering both asperity deformation and solid surface interaction was coupled with the Pearson surface statistical model to develop an improved elastic asymmetrical surface meniscus model. The model compared favorably with the experimental data.