A STANDARD APPROACH FOR MEASURING ADHESION ENERGIES IN STICTION-FAILED MICRODEVICES

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ABSTRACT

We present results from a new procedure developed to quantify the pull-off force and strain energy release rates associated with stiction-failure in microdevices. The method is analogous to a standard, macro-scale peel test, but carried out using micro-scale devices. Adhesion is initiated by lowering an array of microcantilevers that protrude from a substrate into contact with a separate substrate. Displacement is controlled by a piezo-actuator with sub-nm resolution while alignment is controlled using linear and tilt stages. An interferometric microscope is used to align the array and the substrate and to record deflection profiles and adhesion lengths during peel-off. This geometry is accurately modeled using linear elastic fracture mechanics, creating a robust, reliable, standard method for measuring adhesion energies in stiction-failed microdevices.

INTRODUCTION

Though significant investments have been made to develop new MEMS devices, a host of fabrication issues have limited their development. The dimensions of the highly compliant microstructures essential to MEMS devices result in high surface area to volume ratios. Because the structures are located within several microns of the substrate, are highly compliant, and have high surface area to volume ratios, MEMS devices are particularly susceptible to autoadhesion [1]. Capillary forces present during wet-etching or release of sacrificial layers used to fabricate MEMS devices are known to pull the highly compliant structures into contact with their substrate or their neighbors [1,2]. Once in contact, permanent adhesion between the structures may arise due to van der Waals, electrostatic, or chemical forces [3], generating what is commonly referred to as stiction failure. Stiction continues to be a barrier to full-scale MEMS production and marketing as stiction failures may reduce device yields and operating lifetimes leading to decreased profitability.

Several investigators have studied the stiction phenomenon in MEMS structures. Mastrangelo and Hsu [4]-[6] developed theoretical and experimental methods to place an upper bound on the adhesion energy of stiction-failed microcantilevers by calculating the adhesion energy associated with stiction-failure of the shortest beam in an array. de Boer and Michalske [7] expanded on this approach and developed a rigorous fracture mechanics model to determine the adhesion energy, while Jones et al [8] developed models and experiments to examine the adhesion of microcantilevers subject to mechanical point loading.

A detailed description of a new standard test method for measuring pull-off forces and strain energy release rates for microcantilevers was presented in Reference [9]. Pull-off forces were determined for microcantilevers that were tip-stuck; while adhesion energies were defined for microcantilevers that failed in an “s-shaped” mode (Figure 1).

Figure 1: Schematic representations of experiments on microcantilevers showing key variables: (a) s-shaped beam and (b) arc-shaped beam.