Reliability of MEMS Devices in Shock Environments

Personnel

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Microsystems can experience shock loading during fabrication, deployment, or operation, and are susceptible to failure by fracture, delamination, and stiction. We have developed a framework to analyze the dynamical reliability of MEMS based on: (i) estimation of the mechanical response and (ii) formulation of appropriate failure criteria. MEMS are modeled as microstructures supported on elastic substrates, and the shock loads are represented as pulses of acceleration applied by the package on the substrate over a finite time duration. The relevant time scales in the response are the acoustic transit time, the time period of normal mode vibrations, and the duration of the shock load. For typical microsystems and loads (durations in the range 50 μs to 10 ms), we find the response of the substrate to be closely approximated by rigid-body motion. For a given microstructure attached to such a substrate, we have obtained time-domain criteria to identify those shock environments in which the stresses in, and deformations of, the microstructures can be estimated using quasi-static analyses. Based on a scaling argument, we have concluded that most cases of MEMS devices subjected to shock loading fall in the quasi-static or resonant-response regimes, and that the quasi-static fracture strength of a structure (or equivalently, the quasi-static fracture toughness of a material) is an adequate failure criterion

In parallel with this study, we have conducted shock tests on the Polychromator (see “The Polychromator: A MEMS Correlation Spectrometer”). The applied shock loads have amplitudes in the range 1500g to 3500g, and durations varying from 0.3 ms to 1 ms. The micromachined polysilicon beams in the device were found to be immune to shock-induced failures, consistent with the predictions of the analytical framework. Based on the shock-load experiments, modifications were made to the die attach and window materials to permit the entire packaged device to survive these conditions. This work is being published in J. Microelectromechanical Systems.

A related study that grew out of the work on vibration analysis was the observation that thermoelastic damping of vibrations in polycrystalline structures may differ from that in single-crystal structures because of the difference between intra-grain and inter-grain thermal conductivities. A paper on this work has been accepted for publication in *J. Microelectromechanical Systems.*

This project has now ended.