

Thin films are crucial components in a wide range of multilayer microelectronic and optical devices. ~~They are also desirable candidates for micro-actuators in micro-electro-mechanical devices.~~ The size scales and dissimilar nature of the constituents present great challenges regarding thermomechanical integrity and reliability. Interfacial adhesion is a critical parameter governing the mechanical behavior and reliability of a thin film on a substrate. Laser-spallation techniques have been developed to investigate the intrinsic strength of planar interfaces using laser-generated stress waves. In all of the laser-spallation experiments reported in the literature, only normal pressure pulses were applied to the films. Consequently, the interfaces were subjected to only tensile (mode I) loading. In most commercial applications, however, thin-film interfaces fail under mixed-mode conditions. The goal of this ~~dissertation~~ research is to develop the use of laser-generated stress waves to characterize intrinsic interfacial strength of thin films under mixed-mode conditions.

~~With a view towards optimal design for the mixed-mode loading experiment, a~~ rigorous theoretical analysis of stress-wave generation, propagation, and attenuation is carried out followed by a systematic experimental study of tensile spallation. ~~The spallation behavior of aluminum thin films is investigated as a function of substrate thickness, film thickness, laser energy, and various parameters governing the source. Two different substrate materials—single crystal silicon (100) and fused silica—are considered.~~ Theoretical analysis provides meaningful insight into the nature of the wave propagation, while the experimental ~~para~~ metric study reveals important design variables for improving the tensile spallation test and developing the mixed-mode loading experiments. Of particular importance is that fused-silica substrates, with their negative nonlinear elasticity, cause the compressive stress wave generated by the pulsing laser to evolve a decompression shock, which is critical for genera

~~tion~~generation of ~~the~~ fast fall ~~tim~~-estimates needed for significant loading of thin-film interfaces.

Based on the theoretical and experimental parametric study results, the planar tensile sample geometry is modified to a triangular prism so that a high-strain-rate shear wave is generated (~~by mode conversion at an oblique surface~~) and then allowed to impinge upon the test film. By allowing the initial longitudinal wave to mode-convert to a shear wave and a secondary longitudinal wave at the oblique surface, ~~m ixed-m-ode~~mixed-mode loading of the thin

film interface is realized. ~~T he film~~Film failure ~~patterns observed under~~ ~~m ixed-m-ode~~mixed-mode conditions

~~are quite different from those is~~ observed ~~in and~~ the ~~tensile case~~. By measuring the out-of-plane displacement of the test film using an interferometer, mixed-mode interfacial strength ~~under mixed-mode~~

~~conditions~~ is ~~obtained~~measured and compared with the tensile ~~values~~. ~~The shear strength under mixed case~~.

~~mode conditions is slightly higher than the tensile strength for the same aluminum /fused silica interface. The m ixed-m-ode loading experiment developed in this dissertation provides a new tool to explore a range of thin-film interfacial failure modes as well as the role of such extrinsic effects as residual stress, surface roughness, and imperfections.~~