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Thin -film adhesion measurement by laser -induced stress waves

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Abstract

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Thin films are crucial components in a wide range of multilayer microelectronic and optical 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 research is to develop the use of laser generated stress waves to characterize intrinsic interfacial strength of thin films under mixed-mode conditions.

A rigorous theoretical analysis of stress wave generation, propagation and attenuation is carried out followed by a systematic experimental study of tensile spallation. Theoretical analysis provides meaningful insight into the nature of the wave propagation, while the experimental 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 generation of fast fall times 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 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, mixed-mode loading of the thin film interface is realized. Film failure under mixed-mode conditions is observed and the mixed-mode interfacial strength is measured and compared with the tensile case.

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