LASER-INDUCED DELAMINATION PATTERNED THIN FILMS: EXPERIMENTS AND SPECTRAL ANALYSIS

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Over the past few years, laser-induced spallation has proven to be one of the most successful experimental techniques to extract interfacial failure properties in thin film structures. In this non-contact approach, the film/substrate interface is loaded dynamically through a substrate wave generated by subjecting an energy absorbing layer located on the back side of the substrate to a short-duration laser pulse. The resulting compressive wave propagates through the substrate, reflects as a tensile wave from the film surface and leads to the failure of the film/substrate interface. Originally limited to tensile loading, this method has recently been extended to allow for shear loading of the film and has allowed for the extraction of the tensile and shear failure strengths of the film.

The key objective of this collaborative experimental and numerical project is to extend this method to extract the fracture properties of patterned thin films, with special emphasis of the failure process taking place in the vicinity of the corners present in the pattern. At the experimental level, this extension involves primarily modifying the interferometric techniques used to measure the motion of the film surface. On the numerical side, the extraction of failure properties necessitates the development of new computational tools able to capture the multidimensional transient nature of the stress field as the loading wave interacts with the thin film patterns.

As a first step in that direction, we have developed and implemented a spectral scheme to simulate the delamination of thin films subjected to dynamic anti-plane shear loading conditions. The numerical scheme is based on an exact spectral representation of the elastodynamic relations between the interface traction stress, the interface displacement and the transient traction applied along the surface of the thin film. The formulation incorporates the contribution from all the wave reflections taking place in the film and the effect of the material mismatch between the film and the substrate, both of which are assumed to be linearly elastic. Its implementation involves an explicit time stepping scheme with, for each time step, the use of Fast Fourier Transform to link the spatial and spectral domains, and the computation of a convolution over the past displacement and stresses history. We apply the developed scheme to thin film delamination problems involving non-propagating and propagating interface cracks. In the non-propagating case, special focus is placed on extracting the time-dependent stress intensity factor and on relating its evolution to the complex wave reflection events taking place in the thin film. In the propagating crack problem, we investigate the effect of the wave reflections off the film surface on the subsonic and intersonic crack motion, and the inertial effect of the film in crack arrest scenarios.