

Constrained Buckling in Thin Films and Nanostructures

Rui Huang

Dept. Aerospace Engineering & Engineering Mechanics, University of Texas, Austin, TX 78712

Buckling of thin films has been observed in various material systems. Typically, subject to compression, a film bonded to a substrate can buckle under one of the two conditions. On a stiff substrate, the film can buckle when it partly delaminates from the substrate, resulting in localized buckle patterns such as telephone cord blisters. Alternatively, when the substrate is soft, the film may buckle without delamination, leading to wrinkles all over the film area. Recent experiments have also observed co-existing of both and transition from wrinkling to buckle-delamination. We construct a phase diagram showing the two buckling modes and mode transition as material properties, interface defect size and stress vary.

We then focus on wrinkling of thin films on soft substrates. As an application, a buckle-based metrology was developed for measurement of elastic properties of thin films. We show that, for ultrathin polymer films ($h < 40$ nm), the measured effective modulus exhibits a thickness dependence. We develop a bilayer model to account for the effect of surface properties, which successfully predicts the buckling wavelength and amplitude of ultrathin films. Next, we develop a kinetic model of wrinkling for an elastic film on a viscoelastic substrate. The dynamics of wrinkle growth and coarsening is elucidated by a scaling analysis. Following the exponential growth at the initial stage, a power-law coarsening is predicted. Under various stress states, our numerical simulations show a variety of wrinkle patterns and suggest potential means for the control and making of ordered wrinkle patterns.

The last part of this seminar will be devoted to our recent efforts in the study of buckling nanostructures. Experiments have observed buckling of silicon nanolines under indentation and swell-induced buckling of polymer nanolines. I will discuss our understanding of the experimental results and share some preliminary results from buckling analysis.