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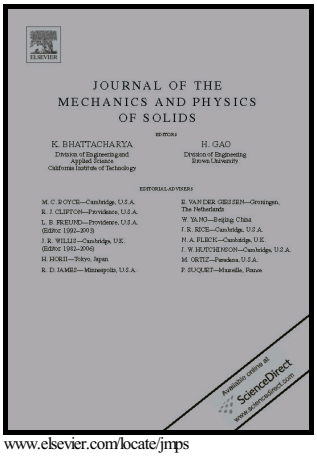

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Effects of tension–compression asymmetry on the surface wrinkling of film–substrate systems

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Abstract

Many soft materials and biological tissues are featured with the tension–compression asymmetry of constitutive relations. The surface wrinkling of a stiff thin film lying on a compliant substrate is investigated through theoretical analysis and numerical simulations. It is found that the tension–compression asymmetry of the soft substrate not only affects the critical strain of buckling but, more importantly, may also dictate the wrinkling pattern that occurs in the film–substrate system under specified loading conditions. Due to this mechanism, the thin film subjected to equi-biaxial compression will first buckle into a hexagonal array of dimples or bulges, rather than the checkerboard pattern theoretically predicted in previous studies, and consequently evolve into labyrinths with further loading. Under non-equi-biaxial compression, the system may buckle either into a parallel bead-chain pattern or a stripe pattern, depending on the substrate nonlinearity and the loading biaxiality. Phase diagrams are established for the wrinkling patterns in a wide range of geometric and mechanical parameters, which facilitate the design of surface patterns with desired properties and functions.

Keywords: Film–substrate system; Tension–compression asymmetry; Wrinkling; Biaxial compression; Morphological evolution

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