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Controlled buckling and postbuckling behaviors of thin film devices suspended on an elastomeric substrate with trapezoidal surface relief structures

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Abstract

The wavy structure is a simple, practical, and promising structural design scheme widely used in the field of flexible and stretchable electronics. In the development of the strategies to enable stretchable characteristics in the device, buckling of thin film devices suspended on an elastomeric substrate with surface relief structures provides an alternative tactic for applications that require both high areal coverage and large stretchability without compromising electric performance (e.g., flexible photovoltaics, batteries, supercapacitors, etc.). In this study, we utilize the energy method to reveal the mechanical mechanisms of controlled buckling and postbuckling behaviors of the stiff thin film devices suspended on the elastomeric substrate with trapezoidal surface relief structures (Figure 1). Both two- and three-dimensional models are explored to simulate the buckling behaviors of the thin film devices in the finite element analysis (FEA). Theoretical predictions of the buckling profile and the maximum strain in the thin film devices are compared reasonably well with those obtained from the FEA. The influences of thin film width and the contact width (between the thin film and the structured substrate) on the amplitude and the maximum strain of the buckled thin film devices are discussed. Results show that the amplitude of the buckled thin film device decreases as the contact width increases, whereas the maximum strain in the buckled thin film devices increases with the increasing contact width. The elastic stretchability of the buckled film/substrate system is also discussed. The validated analytic tool provides a powerful basis for further experimental designs.

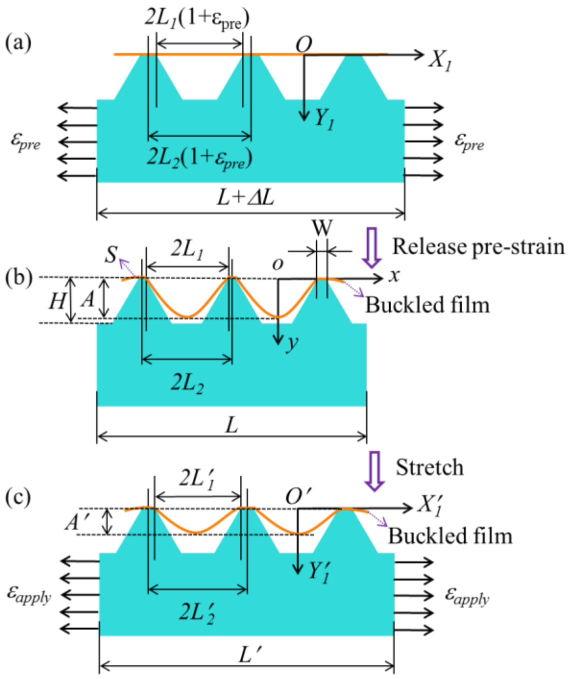

Figure 1: Schematic diagram of the formation process of the buckled stiff thin film suspended on an elastomeric substrate with surface relief structures: (a) The thin film device is first placed on a pre-stretched elastomeric substrate with a strong adhesion at the interface; (b) The release of the pre-strain results in buckling of the thin film device to form a sinusoidal shape; (c) An external applied tensile strain leads to a change in the sinusoidal shape of the thin film device, termed as the postbuckling behavior.