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Spontaneous buckling-driven periodic delamination of thin films on soft substrates under large compression

Qiuting Zhang, Jie Yin*

Applied Mechanics of Materials Laboratory, Department of Mechanical Engineering, Temple University, 1947 North 12th Street, Philadelphia, PA 19122, USA

*Corresponding author: jieyin@temple.edu

Abstract: Through a combination of experiments, theoretical modeling, and finite element simulation, we explore the mechanics governing the formation and evolution of periodic buckle-delamination on both micro- and macro-scale by bonding a thin film to an extremely pre-strained soft elastomeric substrate over 400%. We find that upon the large substrate pre-strain release, the deformation in the film follows a three-stage deformation regime, i.e. onset of localized blisters (Stage I), growth through delamination crack propagation to form periodic sinusoidal blisters (Stage II), and transition to post-buckled jig-saw-like blisters under fixed-end compression after crack arrest (Stage III). Related energy-based mechanics models on predicting the evolution and geometry of periodic blisters under moderate and large compression are developed and validated through both experiments and finite element simulation. Finally, we discuss the potential applications of harnessing spontaneous buckle-delamination for interfacial toughness measurement through the metrology of blisters, as well as design of extremely stretchable electronics by achieving an extremely lower value of maximum tensile strain in the buckle-delaminated film.

KEYWORDS: film-substrate system, periodic buckle-delamination, post-buckling, interfacial toughness, stretchability