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Mechanics of confined solid and fluid thin films: Graphene and lipid bilayers

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Many natural and man-made systems consist of a thin elastic sheet coupled to a substrate. As the substrate undergoes compressive deformation, a variety of buckling responses can be observed. In this talk, I will discuss two particular instances of such systems, and how mathematical modeling and computational mechanics can help understand their complex behavior.

Graphene is the ultimate thin elastic sheet, only one atom thick. In applications, it is often supported on a substrate. Wrinkle networks are ubiquitous buckle-induced delaminations in supported graphene, which locally modify the electronic structure and degrade device performance. Through multiscale simulations, we understand how strain anisotropy, adhesion and friction govern spontaneous wrinkling [1]. We propose a strategy to delicately control the location of wrinkles through patterns of weaker adhesion, leading to a variety of network geometries and junction configurations, with the goal of assisting constructive use of strain-engineered wrinkle networks.

Lipid bilayers compartmentalize cells, and mediate in a large number of biochemical and biomechanical processes. They exhibit complex mechanics involving elasticity and hydrodynamics of two tightly coupled monolayers [2]. Bilayers are often confined by the extracellular matrix, the cortex or other membranes. By an integrated experimental and theoretical approach, we investigate the mechanics of confined membranes, including the influence of adhesion, strain, and osmotic pressure [3]. We find that supported lipid bilayers respond to stress by nucleating and evolving spherical and tubular protrusions. In cells, such transformations are generally attributed to proteins, but we show that the mechanics of confinement can explain many cellular structures. Our results offer insights into the mechanics of cell membranes and can further extend the applications of supported bilayers.

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