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Exploiting Elasticity with Thin Polymer Films

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Soft matter is often dominated by long-ranging mechanical distortion and is thus intimately linked to elastic theory. The detailed understanding provided by theory has allowed remarkable technological achievements to be made with polymers and other soft systems. However, as technology pushes lengthscales downward many challenges have arisen and even basic problems such as measuring Young's modulus become difficult. To move forward, many polymer thin-film researchers have been attracted to the simple repetitive buckling pattern known as wrinkling because the instability provides a convenient tool to measure mechanical properties. As with all technology the wrinkle system does have physical limits on its applicability, several of which may not be obvious and may have implications for extreme measurement. Here we highlight some of our recent work examining the limits of this elastic pattern and the implications for thin polymer films. We first show how the morphology of ultra-thin wrinkled polystyrene and polystyrene-block-poly(2-vinylpyridine) films show signs of localization effects - a clear deviation from linear elasticity. We go on to show how roughness, in certain cases, can induce similar morphologies, even in the limits of vanishing applied stress. As random roughness influences a film's elastic behaviour it is natural to examine periodic roughness as means to control localization and create more complex morphologies. Colloidal polystyrene is an excellent test material as it can easily be assembled in highly ordered crystalline monolayers. Remarkably, this "discrete" polymer film shows the same wrinkled morphology as does a continuum film. We show how a completely different type of elasticity is necessary to explain the effect, that of a granular material. More disordered "glassy" colloidal monolayers provide a means to push our understanding of the granular elastic theory, and suggest an interesting, albeit highly speculative limit for extreme continuum behaviour.