Creating patterned microchannels by swelling

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Abstract

We study the effect of inflation on the swelling-induced wrinkling of thin elastic membranes in a set-up that is commonly used to create microchannels in lab-on-chip applications. Using a combination of experiments, mathematical analysis and associated numerical simulations, we demonstrate that the out-of-plane deformation of the inflated membrane and the resulting anisotropic stress lead to two distinct instabilities as the swelling progresses.
The membrane first develops small-amplitude wrinkles that retain the cross-channel symmetry. Their wavelength depends on the pressure and is set in a process similar to the axisymmetric buckling of pressurised, uni-axially compressed cylindrical shells. As swelling increases, the membrane undergoes a secondary instability during which the wrinkles coarsen into large-amplitude folds whose morphology can be controlled by the degree of pre-inflation. At modest levels of inflation, a secondary (symmetry-breaking, wavelength-doubling) bifurcation results in the formation of worm-like patterns, reminiscent of those occurring in blister delamination processes. At even greater levels of inflation, the symmetric initial wrinkling pattern undergoes a different secondary bifurcation that no longer breaks the cross-channel symmetry but leads to the formation of symmetric large-amplitude folds that are separated by random (but integer) multiples of the initial wrinkling wavelength. We elucidate the fundamental mechanisms responsible for this behaviour to explain how inflation can be used as a control mechanism in the manufacture of microchannels.

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