Solid structures generated by capillary instability in thin liquid films

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Patterns are ubiquitous in nature, ranging across myriad examples such as the hexagons in dry mud cracks, the arrangement of seeds in plants, the ripples forming on dirt roads, and our fingerprints [1]. Patterns have fascinated generations of scientists from mathematicians to biologists, who have studied the genesis of their shape and arrangement [2,3]. In particular, it has been shown that instabilities are a robust road to pattern formation [1,4]. An instability typically has a range of unstable periodical modes, yet the most unstable mode is often the only one observed in experiments. Its growth surpasses all other modes, thereby enforcing the regularity of the outcome of the instability. Here we take
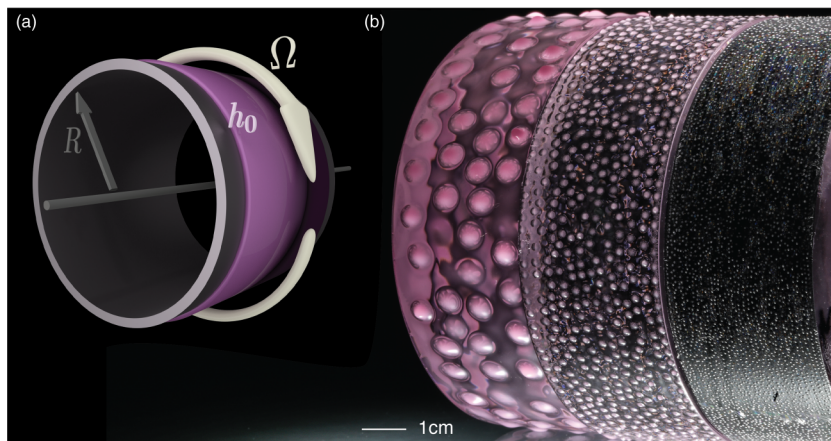

FIG. 1. (a) A thin polymeric film is coated on the outside of a cylinder with radius R, which is subsequently rotated at speed Ω. (b) The coating destabilizes to the Rayleigh-Taylor instability and yields drops, whose size decreases with ΩR^2 ($4g$, $50g$, $280g$ from left to right, where g is the acceleration of gravity).
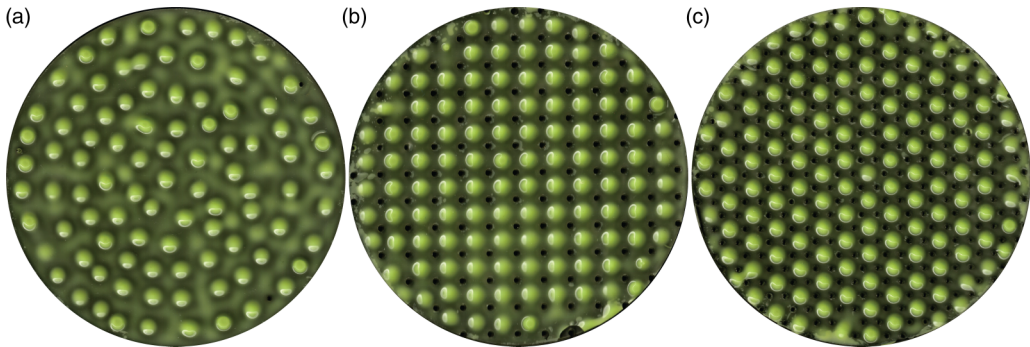
FIG. 2. Taming the instability. (a) Pattern naturally arising in our system. [(b), (c)] Results obtained with seeds arranged in square and hexagonal lattices, respectively. The seeds are drilled into the base plate as evidenced by the small black dots between adjacent drops. Their spacing is 12 mm so as to match the wavelength of the most unstable mode.

advantage of this fundamental feature and use the Rayleigh-Taylor instability [5] in thin polymeric liquid films to form regular elastic structures [6].

In Fig. 1(a), we show our experimental approach. A thin liquid film is initially deposited on the outside of a cylinder, which is then rotated. As a result, the coating destabilizes due to the Rayleigh-Taylor instability, forming drop lattices with a wavelength set by the balance between capillary forces and centrifugal forces. In particular, as the acceleration increases, the drops become smaller, as evident from Fig. 1(b). As the film cures [7], these drops formed by a fluidic instability eventually yield elastic structures.

In Fig. 2, we show that the instability can be tamed. We have designed defects on the solid substrate onto which the film is initially coated so as to control the organization of the drop arrangement. Square and hexagonal lattices are shown in Figs. 2(b) and 2(c), respectively. In such cases, the amplitude of the drops is almost monodisperse. With this methodology, we have shown that tangible structures can be formed in the laboratory when harnessing an interfacial fluidic instability. In addition to their aesthetically pleasing appearance, these organized drops could find use in practical settings [8–10].

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