MATERIAL WITNESS

A QUICK FIX

Delicately patterned micro- and nanostructures can be produced without the need for laborious fabrication, by relying on physical forces to organize materials spontaneously into intricate forms. The capacity of soft materials such as surfactants and block copolymers to self-organize into regular patterns has been long recognized[1–3], and superlattices and other ordered arrays in two and three dimensions can be produced from the microphase separation of block copolymers[4–6]. Many of these approaches recognize the precedence of nature, which uses the same parsimonious principles to make elaborate micropatterns such as exoskeletons[7] and photonic crystals[8,9].

Not all of the rich patterns generated spontaneously by physical forces are long-lived, however, which may limit opportunities for exploiting them in technologies. Fluids are particularly apt to display transient patterned instabilities that are gone in an instant. Yet an instant is more or less all it takes to 'freeze' such structures in a method described by Grilli *et al.*, who have used rapid heat curing of a liquid polymer to create a range of transparent microstructures that might find uses in optics[10].

The researchers have focused primarily on the 'beading' of a liquid filament — a variant of the Rayleigh instability studied since the late nineteenth century. This describes the way a column of liquid will become spontaneously unstable to undulatory perturbations that break it up into a string of roughly spherical droplets, often of alternating size. The instability can be seen in a narrow liquid jet, and it is responsible for the way the glue coating the threads of a spider's web forms a string of beads. Dew does likewise, decorating the web with a beautiful array of droplets.

Grilli *et al.* induce the patterning artificially by using an electrohydrodynamic method[11] in which a strong electric-field gradient produces instabilities in a dielectric fluid, here the molten polymer polydimethylsiloxane. In a typical example, a thin liquid bridge is formed by using the field between two plates to draw up a droplet of polymer sitting on the lower plate. The bridge drains to a very narrow column that then bunches into 'beads on a string'. A hot-air jet cures the structure within seconds, before it can fragment. The result is a string of linked, transparent, spherical or lenticular beads just a few or a few tens of micrometres across. These can be used as, for example, one-dimensional arrays of optical resonators, with optical properties tunable by mixing fluorescent particles into the liquid polymer.

Other 'frozen' instabilities that may be created this way include 'axicons': conical structures with a needle tip at their apex, which might be used as elements for optical tweezers with a

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large depth of focus, or as the tips of near-field optical microscopes.

The idea of using the self-organizing forces in liquids to create devices too small to be easily fabricated by hand is actually a very old one. It is how Anton van Leeuwenhoek made the tiny lenses for the microscopes that enabled him to launch the field of microbiology, by rapidly cooling molten glass into tiny spherical beads. ❐

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