Droplets perform daredevil feats on gel surfaces

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Martin Coux, Piaget Scientific Award 2018. Credit: DR

Welcome to the amazing world of soft substrates. These materials are made of silicon gels and have the same texture as panna cotta—but without the delicious flavor. They are used in a range of applications,

especially in the pharmaceutical industry, because their biocompatible and antiadhesive properties make them resistant to corrosion and bacterial contamination. These substrates are so soft that they can be deformed (reversibly) by the capillary forces that occur at the edges of droplets when placed on their surfaces. However, droplets move very slowly on these surfaces; in order to flow, the droplets have to dynamically deform the substrates and overcome the resistance created by the substrate's viscoelastic proprieties. A millimeter-sized droplet placed on a substrate positioned vertically will flow at a speed of only between a few hundred nanometers per second and a few dozen micrometers per second. In other words, it would take the droplet three hours to move just one meter! This slowing effect is known as viscoelastic braking and is a big obstacle to the more widespread use of soft substrates, especially in manufacturing.

A team of scientists at EPFL's Engineering Mechanics of Soft Interfaces (EMSI) laboratory, within the School of Engineering, has shown that viscoelastic braking can be overcome by placing tiny pillars on the substrate's surface. More fundamentally, the scientists were able to observe, for the first time, the contact between a fluid and a soft substrate in a complex geometry. Their findings have just been published in *PNAS*.

A new geometry

The EPFL scientists employed a method that's already widely used in wetting processes: altering a substrate's surface texture so that it becomes superhydrophobic. More specifically, they covered a gel surface with tiny pillars 100 µm high and 100 µm wide, so that droplets placed on the gel lie only on the pillar tops—much like a daredevil walking on a bed of nails. Viewing the droplets through a confocal microscope, the scientists saw that the pillars deform as the droplets move along them. What's more, the size of the solid deformation was almost the same as that

obtained on a flat gel surface, meaning the droplets are in fact being held up by the hundreds of tiny pillars. And even though the deformation sizes were so close, the droplets moved at the same speed as they would on a hard surface.

"These altered textures 'kill' the viscoelastic braking effect, even though there is a fairly large contact area between the fluid and the solid," says Martin Coux, one of the authors of the study, along with Prof. John Kolinski. "Due to the unique geometry of the contact points between the fluid and the solid, raised slightly above the substrate surface, the droplets adopt configurations that they usually wouldn't be able to on a soft surface. That lets them flow along the substrate just as fast as they would on a hard surface." Using the EMSI's high-speed microscope, the scientists were able to observe and understand this previously unknown phenomenon of fundamental physics.

It's worth pointing out that all this occurs on a micrometric scale (the solid deformations are on the order of 1–100 μm). "Thanks to the advancements made in viewing technology over the past ten years, scientists can now see the deformations that occur when fluids come into contact with soft substrates—and not just statically (like when the droplets are stationary), but also dynamically, such as when the droplets flow on the surface," says Coux. This new capability has given a boost to physicists who specialize in fluid mechanics, accelerated their understanding of elastocapillary interactions between soft substrates and fluids, and put the EPFL scientists on the path to their breakthrough discovery.

More information: Martin Coux et al. Surface textures suppress viscoelastic braking on soft substrates, *Proceedings of the National Academy of Sciences* (2020). DOI: 10.1073/pnas.2008683117

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