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Droplets on substrates with moving and oscillating wettability patterns

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Droplets are set in motion on substrates with a spatio-temporal wettability pattern as generated, for example, on light-switchable surfaces. To study such cases, we implement the boundary-element method to solve the governing Stokes equations for the fluid flow field inside and on the surface of a droplet and supplement it by the Cox–Voinov law for the dynamics of the contact line. Our approach reproduces the relaxation of an axisymmetric droplet in experiments, which we initiate by instantaneously switching the uniform wettability of a substrate quantified by the equilibrium contact angle.

First, we investigate a droplet on substrates with oscillating uniform wettability by varying minimum and maximum contact angles and frequency. After a transient regime the droplet performs steady oscillations, the amplitude of which decreases with increasing frequency. For slow oscillations our numerical results agree well with the linearized spherical-cap model. They collapse on a master curve when we rescale frequency by a characteristic relaxation time extracted from the spherical cap model. In contrast, for fast oscillations we observe significant deviations from the master curve. Since the droplet's shape changes induce fluid circulation, which is controllable from the outside, our findings envisage the design of targeted microfluidic transport of solutes inside the droplet.

Second, we investigate a droplet on substrates with a moving step profile of wettability, which pushes the droplet towards locations with higher wettability. Using a feedback loop to keep the distance or offset between step and droplet center constant, induces a constant velocity with which the droplet surfs on the wettability step. We analyze the velocity in terms of droplet offset and step width for typical wetting parameters. Moving instead the wettability step with constant speed, we determine the maximally possible droplet velocities under various conditions. The observed droplet speeds agree with the values from the feedback study for the same positive droplet offset. Thus, moving droplets with a wettability step can add to the toolbox of microfluidics.

In the future, we are interested to extend our method to include the effects of substrate adaptivity and to integrate novel findings from experiments in the first phase of the priority program.

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Sitzung Einordnung: Short talks