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Driving Liquid Barrels with Electrowetting

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Liquid barrels—droplets trapped in a wedge geometry—appear in biological physics, granular media and microfluidics. Recent electrowetting experiments show that the equilibrium configuration of a liquid barrel is a truncated sphere that intersects the wedge walls with an equilibrium contact angle adjusted by the applied voltage [1] (see Fig. 1). The ability to control the motion of liquid barrels promises applications of droplet manipulation in microfluidic channels; however, the dynamics to new equilibria induced by sudden changes in voltage has not been studied in detail. In this talk, we present experiments and simulations of the dynamics of liquid barrels driven by electric fields.

The experimental setup (see Fig. 1) consists of two glass plates coated with indium tin oxide and fixed to form a wedge. The plates are treated with a layer of parylene-C using a chemical vapor polymerization process, and a thin layer of Teflon AF to form a dielectric hydrophobic coating [1]. Water droplets (KCl electrolitic solution; conductivity 5 mS cm^{-1}) were immersed in non-conducting bromohexadecane (of density 0.998 g cm^{-3} to avoid buoyancy effects), and driven by applying an alternating voltage.

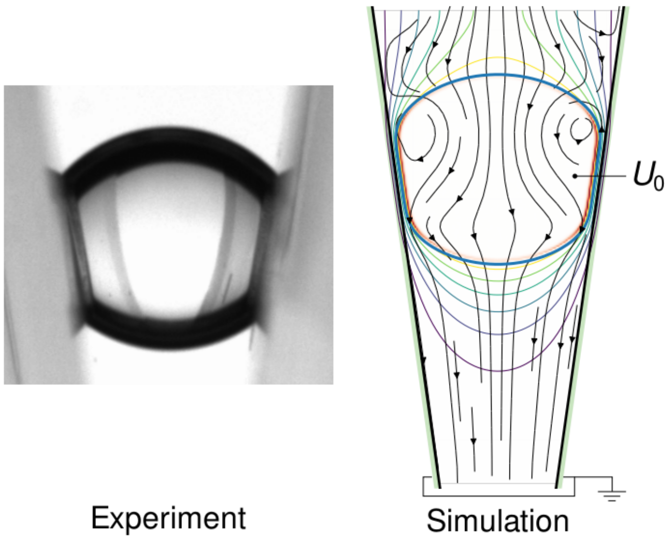

Figure 1. Experiments and simulations of a droplet moved by electrowetting.

To model the liquid-barrel dynamics, we carried out lattice-Boltzmann simulations of the coupled Navier-Stokes and Cahn-Hilliard equations [4] (see Figure 1). To account for electrowetting, we equipped our lattice-Boltzmann algorithm with a solver of the electric potential field; this allows us to analyse in detail the competition of viscous, capillary and electrostatic forces that act on the shape of the liquid-barrel.

From recent theoretical results [2], one might expect that the liquid barrel follows an exponential relaxation to equilibrium with a single characteristic time determined by the ratio of dissipative to restitutive forces. Surprisingly, we found that the dynamics occurs in two steps: a fast initial motion followed by a slow final relaxation. The dynamics of the first step is consistent with a relatively small dissipation [3], suggesting that a lubricating film allows the liquid barrel to slide without touching the wedge walls. This is different to the second step, in which the relaxation is paced by the motion of a contact line.

References

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