Exploring dynamics and dissipation on superhydrophobic surfaces with magnetic water drops

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Aqueous droplets show a number of fascinating dynamical effects on superhydrophobic surfaces, including giant hydrodynamic slip and nearly frictionless motion and small roll-off angles.[1] Quantification of the small but non-zero "friction" experienced by individual moving drops has proven to be challenging under well-controlled tangential and normal forces.

Here we present two different applications for ferrofluids on superhydrophobic surfaces: the droplet oscillator[2] and self-assembly of droplets[3].

At first, we describe a new way for investigating dynamics and energy dissipation on superhydrophobic surfaces by using magnetic drops as probes.[2] These drops consist of ca. 0.2% of 4.6±1.4 nm superparamagnetic iron oxide nanoparticles well-dispersed by surface-bound citrate anions in water. Density, surface tension and viscosity are within a couple of percent from those of pure water. The magnetic nanoparticles allow any vectorial force to be induced on the drop by applying an appropriate external magnetic field. We focus on trapping the magnetic probe drop in a harmonic potential well (resulting in a Hookean restoring force) and demonstrate both freely decaying and externally driven horizontal oscillations of the drop on the test surface. We calculate two dissipative forces (due to contact angle hysteresis and viscosity) by analyzing the damping rate and/or frequency-dependent oscillation amplitude, and quantify these two as a function of normal force.

Secondly, strongly magnetic droplets with nanoparticle loading up to 25% can be split on a superhydrophobic surface into multiple droplets by applying a perpendicular magnetic field.[3] The resulting daughter droplets self-assemble into various static arrangements in a similar harmonic potential well as in the dissipation measurements. These static arrangements can be switched reversibly into dynamic dissipative ones by applying a time-varying oscillating magnetic field.

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[2] *J. V. I. Timonen, M. Latikka, O. Ikkala, and R. H. A. Ras. Free-decay and resonant methods for investigating the fundamental limit of superhydrophobicity, Nature Communications 4, 2398 (2013)*

[3] J. V. I. Timonen, M. Latikka, L. Leibler, R. H. A. Ras, and O. Ikkala, Switchable Static and Dynamic Self-Assembly of Magnetic Droplets on Superhydrophobic Surfaces, *Science* 341, 253-257 (2013)