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FLUID DYNAMICS

Shaping drops

A surface made from an array of widely spaced tapered posts enables water drops that hit it to bounce off with a pancake-like shape. This finding provides new strategies for reducing the contact time of drops impacting on surfaces.

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When a drop hits a surface, it may bounce back, it may stick, or it may splash into many small droplets. High-speed microscopy can reveal the dynamics of the impact in detail. The resulting images not only provide an intriguing, visually appealing sight for laymen; drop impact is also a fascinating field of scientific research. Early studies date back more than a century ago[1]. Harold Edgerton — a high-speed photography pioneer — already recorded drop impacts with millisecond resolution using a homebuilt stroboscope 75 years ago[2]. Today, there is still a need to understand and manipulate drop impact for applications like printing, spray coating, or heat transfer control (e.g. for preventing condensation and icing).

Whether the drop bounces, sticks or splashes first depends on the properties of the drop itself: its size and velocity, the liquid's density and surface tension[3]. Second, the air surrounding the drop influences the impact[4,5]: although the viscosity of air at normal pressure is much lower than that of a liquid, it still can stimulate bouncing and splashing. Third, the chemical composition of the surface and its structure on the micro- and nanolevel decides the fate of an impacting drop.

As they report in *Nature Physics*[5a], Yahua Liu and colleagues have now made a significant step towards understanding the influence of the details of the surface topography on drop impact. Using a cleverly designed superhydrophobic surface, they were able to make (originally spherically shaped) water drops bounce off with the distinct shape of a flat lammely. This surprising scenario, termed 'pancake bouncing' by the authors can be rationalized by a simple theoretical model based on inertia and capillarity.

The superhydrophobic surface Liu et al used consisted of an array of hydrophobic posts. A drop placed onto such a surface entraps air between the posts. Typically, the size and spacing of the posts is only in the micrometer range. Drops deposited on a surface with small inter-post spacing can stand a high pressure before the air cushion collapses; the opposing Laplace pressure increases with the inverse of the spacing. In addition to the spacing their height is important. High pillars enhance robust water repellency, whereas short and wide posts offer good mechanical stability[7].

Until now it was believed that on such surfaces impacting drops undergo two phases: a spreading and a retraction phase[6]. **[**In the spreading phase an impacting drop (Fig. 1, top) experiences an effective lateral acceleration that flattens the drop (Fig. 1, middle). The kinetic energy is converted to interfacial energy. In the retracting phase the drop balls up again, minimizing its interfacial energy. It recoils, unless the impact velocities is so high that the rim breaks up and the drop splashes.

Liu *et al.*[5a] fabricated posts with a height of almost 1 mm and a width and inter-post distances of more than 0.1 mm. All characteristic dimensions are one order of magnitude larger than those typically used for superhydrophobic pillar arrays. In addition, the authors coated the posts' surface with a nanoscopic superhydrophobic layer, resulting in a two-tier structure (Fig. 1). This design has several advantages. One is high mechanical stability due to the large width of the posts. A second aspect is more relevant for drop impact itself: usually, when a drop hits a surface, its momentum is transformed into horizontal flow, inducing lateral spreading over the surface. For the widely spaced, large posts used by Liu *et al.*[5a] the vertical component is also important in determining the rebound dynamics. Impact leads to significant penetration of the liquid into the post array (yet without touching the base) into a region approximately the size of the initial drop cross section. Penetration is followed by upward capillary emptying where the stored capillary energy is transformed back into kinetic energy, enabling lifting off celeration of the penetrating liquid increases with penetration depth. This permits modeling of the capillary force as a harmonic spring and, surprisingly, the timescale of lateral spreading and vertical penetration balance out — pancake bouncing becomes independent of impact velocity. A prerequisite is, however, that the posts are superhydrophobic. This greatly reduces viscous friction during capillary emptying, and ensures that enough capillary energy is stored required for lifting off. As the drop lifts off before recoiling sets in, pancake bouncing enables a reduction of the contact time by a factor of over four.

Pancake bouncing provides an intriguing example of how the shape of a rebounding drop can be engineered by means of well-designed surface texturing. The (at first sight) counterintuitive topography used by Liu *et al.* is especially intriguing and signifies a new direction in the field of drop impact. Their study also introduces a novel method for reducing the contact time of millimetre-sized drops to values that had been considered impossible so far. Hence, it complements and extends a recent approach by Bird *et al.*[8], who designed a surface in such a way that an impacting drop can split into two child drops, which bounce off about 40% faster than the parent drop. Both studies[5a,8] nicely show that clever surface structuring offers unexpected scenarios and challenges in the search for a lower limit for the contact time in drop bouncing.

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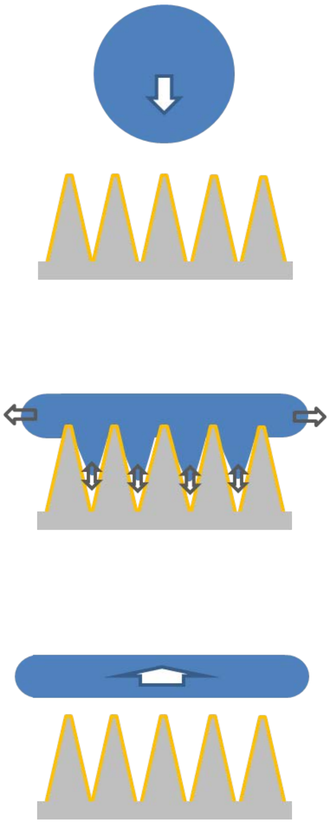

Fig. 1 | Drop impact dynamics usually displays two phases: a spreading and a retraction phase. Liu *et al.*[5a] now show that a drop can lift off of a surface before retraction sets in. This greatly reduces the contact time of the drop with the substrate. Top: A drop just before hitting the structured surface; Middle: Spreading and retraction dynamics resemble a Hooke spring in both the horizontal and vertical directions; Bottom: Lift off. To decreases friction with the walls, the post's surface is coated with a superhydrophobic layer (yellow).

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