INDUCING WATER DROP REBOUND ON WETTABLE SURFACES WITH ALCOHOL VAPOR

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ABSTRACT

In general, a water droplet impacting a superhydrophobic surface typically rebounds due to air trapped within the micro- or nanostructures on the surface. In our tests, we found that a droplet with a low Weber number could bounce off a hydrophilic surface when exposed to alcohol vapor. Since alcohol molecules contain both a hydrophilic head and a hydrophobic tail, providing alcohol vapor allows the hydrophilic head to adhere to the surface. This adherence effectively traps a layer of alcohol vapor close to the surface, which is key to causing the bouncing effect. Notably, a certain concentration of alcohol vapor is required to produce droplet bouncing, and this threshold changes depending on the Weber number of the impacting droplets.

KEY WORDS

Hydrophilic, droplet, rebound, bouncing, Leidenfrost.

1. INTRODUCTION

Generally, droplets colliding with hydrophilic surfaces are known to stick, whereas they bounce off superhydrophobic surfaces. Utilizing droplet rebound presents various benefits, such as anti-fouling (1), anti-frost (2), and anti-condensation (3). However, applying the rebound effect described above has its limitations, as most solid surfaces found in nature are hydrophilic, leading collision droplets to adhere to those surfaces. To induce the rebound effect on hydrophilic surfaces, methods like applying a thin hydrophobic coating (4) or using the Leidenfrost effect (5) by heating the surface have been proposed. In this study, we discovered that droplets could rebound on a hydrophilic solid surface in ambient air simply by providing alcohol vapor nearby, without the need for a physical coating or applying heat. This effect occurs because the alcohol vapor adsorbs onto the hydrophilic surface, creating a vapor layer above it. As a result, the droplets do not directly contact the solid surface but instead bounce over the alcohol vapor layer. This occurs when the Weber number of the droplet is below the critical Weber number. However, for droplets with a high Weber number, they displace the alcohol vapor layer, coming into contact with and adhering to the hydrophilic surface. In this research, the newly observed rebound phenomenon of droplets was captured with high-speed cameras, and its characteristics were examined using both experimental and theoretical analyses.

2. EXPERIMENTAL SETUP

In this experiment, a silicon wafer was used as the solid surface, made hydrophilic through Piranha and air plasma treatments. Isopropyl alcohol (IPA) served as the alcohol, while distilled water was used for the droplets. IPA was evaporated and supplied near the hydrophilic surface. To regulate droplet size, a syringe pump (NE-300) along with needles of different gauges (18~30G) was used. High-speed cameras (Chronos 2.1HD) captured the droplet behavior upon impact with the surface. Additionally, a vertical stage allowed variation of the collision height, adjusting the droplet impact height from 3 to 15 mm.

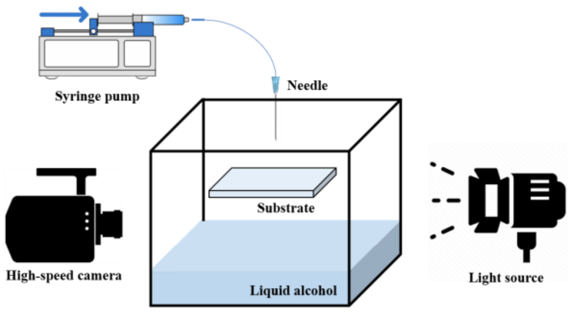

Fig.1: A diagram illustrating the experimental setup to observe water droplet rebound on a hydrophilic surface. An alcohol liquid layer is placed at a distance *s* beneath the surface. The height from which the droplet is released is adjustable, providing control over its impact velocity.

RESULT

In the experimental setup shown in Figure 1, experiments were performed by varying droplet diameters (D), release heights (h), and distances between the surface and the IPA interface (s) during droplet collisions with the hydrophilic surface. Figure 2(a) depicts the collision on a hydrophilic surface, where the droplet adheres to the surface as expected. Figure 2(b) shows the collision on a superhydrophobic surface, resulting in the droplet rebounding off the surface. Figure 2(c) demonstrates the collision process on the same hydrophilic surface as (a), but with IPA vapor supplied. Despite the surface being hydrophilic as in (a), the introduction of alcohol vapor causes the droplet to rebound, as shown in the image. Figure 3 displays experimental results with varying Weber numbers for droplets colliding on the hydrophilic surface, under conditions similar to those in Figure 2(c). As the Weber number increases, representing a greater inertial force, the droplet adheres to the surface.

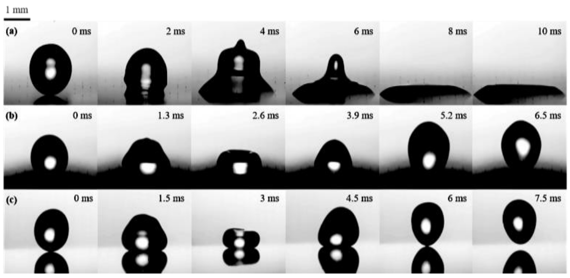

Fig.2: Sequential images showing the collision of a water droplet on different surfaces, with *D* = 1.6 mm and *V* = 0.313 m/s. (a) Droplet impacting a hydrophilic surface, (b) droplet impacting a superhydrophobic surface, and (c) droplet impacting a hydrophilic surface in an alcohol vapor-saturated environment.

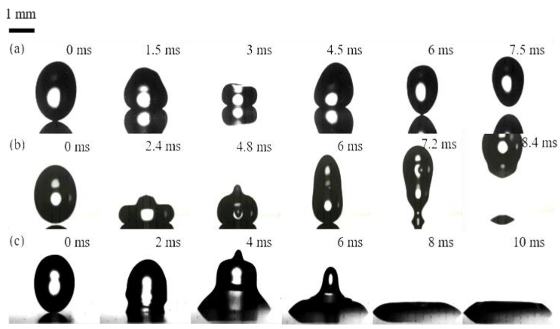

Fig.3: Sequential images illustrating the impact of a water droplet on a hydrophilic surface in alcohol vapor-saturated environments, at different Weber numbers: (a) We = 0.9, (b) We = 2.2, (c) We = 3.5.

CONCLUSION

In this research, we examined the Leidenfrost effect occurring on hydrophilic surfaces in the presence of alcohol vapor. Introducing alcohol vapor to the hydrophilic surface leads to the formation of a vapor layer above the solid at room temperature. This effect prevents the droplets from adhering upon collision, enabling them to rebound instead. Additionally, we observed that this behavior is highly sensitive to changes in the Weber number.

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