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Mechanism study of condensed drops jumping on super-hydrophobic surfaces

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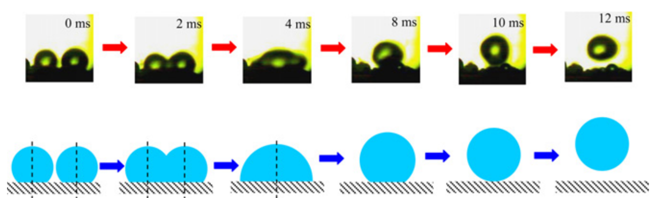
HIGHLIGHTS

- ▶ Initial shape of a coalesced droplet is determined based on energy conservation.
- ▶ The driving force and resistance during drop transformation are analyzed.
- ▶ A dynamic equation describing shape conversion of a droplet is proposed and solved.
- ▶ Merged droplets jump because they are in unstable state on nanostructure surfaces.

GRAPHICAL ABSTRACT

The process of coalescence, transformation and jumping of two condensed micro-drops on super-hydrophobic surfaces was recorded and modeled.



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ABSTRACT

The out-of-plane jumping motion of coalesced condensed drops on super-hydrophobic surfaces can potentially enhance dropwise condensation greatly. But the jumping mechanism is not clear. In this paper, the initial shape of a coalesced droplet is determined based on the conservation of drop interface free energy (IFE) and viscous dissipation energy before and after two or more condensed droplets merge. The coalesced drop is in unstable state with a driving force to reduce its base radius toward equilibrium state. Then, the driving force and resistance on three-phase contact line (TPCL) are analyzed during the drop transformation. And the dynamic equation describing the shape conversion of the droplet is proposed and solved. The jumping height of a merged drop is determined according to the up moving speed of drop gravity center when the base radius of the droplet reduces to 0. The calculation results show that a coalesced droplet on flat surface can transform its shape limitedly. It cannot jump since its transformation stops before it comes to its equilibrium state. A wetted drop on rough surfaces is even more difficult to transform and jump because of the greater TPCL resistance. However, on a two-tier surface, a partially wetted drop impaling only the micro-scale roughness exhibits a shape transition to Cassie state and possible jumping upon coalescence if the micro and nanostructure parameters are suitable. Furthermore, after the coalescence of two or more Cassie state drops with their scale range from tens micrometer to millimeter on a textured surface, the merged composite drop can easily transform until its base radius becomes 0 and then jumps. A too small or too large merged drop will not jump because the obvious viscous dissipation energy or drop gravity respectively dominates the behavior of the drop. Meanwhile the coalescence-induced jumping of two drops will also not take place if their scales are significantly different. It can be concluded that the key factors resulting in condensed drops jumping are the merged drop in unstable state with enough surplus IFE and small TPCL resistance on nano or micro–nano two-tier surfaces.

1. Introduction

Condensation is an important and widely accepted heat transfer type in lots of industries and engineering processes, such as petrochemical industry, power industry, air conditioning and

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