Jumping Droplet Electrostatic Charging and Effect on Vapor Drag

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Jumping droplet condensation occurs due to the conversion of surface energy to kinetic energy when condensed water droplets coalesce on a superhydrophobic surface, for example the copper oxide nanoblades functionalized with a hydrophobic coating (a) on the tube condensers shown here. When imaged with long-exposure photography (b), the trajectories of the jumping droplets reveal that the vapor flow towards the condensing surface necessitated by conservation of mass imparts a drag force on the droplets which, in some cases, causes the droplets to reverse direction (c). Meanwhile, electrostatic charging of jumping droplets offers a method to manipulate droplet motion. To study the effect of droplet charging, a 350 μm diameter copper wire electrode was placed beneath the superhydrophobic surface (d). With an applied constant voltage bias (ΔV), an electric field between the electrode and grounded tube was established. Long exposure time images (50 ms) of droplet motion (e) show that negative and positive applied biases result in droplet-electrode attraction and repulsion, respectively. Interestingly, the vapor drag which causes droplet reversal is overcome by Coulombic force as voltage is increased. A force balance governing this phenomenon is shown schematically in (f), where the vapor velocity v_{vapor} towards to the condensing surface results in an upwards component of the drag force, F_D, that causes small droplets to reverse direction; the Coulombic force, $F_{\bar{E}}$, may be tailored to pull the droplets downwards and overcome the vapor drag. F_b and F_g are buoyant and gravitational forces, respectively. These visualizations provide insights into vapor drag that degrades condensation heat transfer performance and application of the complex droplet-surface charging phenomena to overcome this vapor drag, which is relevant for the development of enhanced phase change surfaces.