Reduction in Contact Time of Bouncing Droplets on Compact Nanostructured Superhydrophobic Surfaces

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Many natural surfaces are capable of shedding water droplets rapidly, which has been attributed to the presence of low solid fraction (Φ_S ~ 0.01) (*1*) according to the classical wetting theories (*2-4*). However, recent high-resolution microscopic observations revealed the presence of unusual high solid fraction nanoscale textures on water-repellent insect surfaces. For example, superhydrophobic mosquito eyes, springtails, and cicada wings possess solid fractions (Φ_S) as high as 0.25 – 0.64 (*5-7*). In addition, the texture size on these insect surfaces is typically on the order of 100 – 300 nm. To understand why both high solid fraction and nanoscale textures are important for these superhydrophobic insect surfaces, we systematically designed and fabricated a series of textured surfaces with texture size varying from 100 nm to 30 μm at solid fractions of 0.25 and 0.44, and investigated their static and dynamic wetting behaviors. Here we show that the contact time of bouncing droplets on high solid fraction surfaces can be reduced by reducing the texture size to nanometer scale. Specifically, we discovered that high solid fraction surfaces (Φ_S ~ 0.44) with texture size ~100 nm could reduce the contact time by ~2.6 ms compared to that with texture size >300 nm. This texture-size dependent contact time reduction on solid surfaces has not been observed previously, and cannot be explained by existing surface wetting theories. We showed theoretically that the reduction in droplet contact time can be attributed to the dominance of three-phase contact line tension (*8*) on compact nanoscale textures. Through pressure stability analysis and experiments, we have further shown that high solid fraction (Φ_S > 0.25) is an important requirement for insects to withstand high-speed impacting raindrops. Our results suggest that the compact and nanoscale textures on water repellent insect surfaces may work synergistically to repel and shed impacting raindrops rapidly, which could be an important survival strategy for flying insects. Technologically, the ability of compact nanoscale textured materials to repel high-speed impact of liquid droplets with reduced contact time may find use in a range of applications including fouling-resistant personal protective equipment (PPE) to insect-sized flying robots and miniaturized drones.

Keywords: contact time | drop impact | insects | nanoscale textures | pressure stability | superhydrophobic surfaces

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