CAPILLARY-INDUCED DROPLET MOBILITY DURING CONDENSATION ON THIN LUBRICANT FILMS

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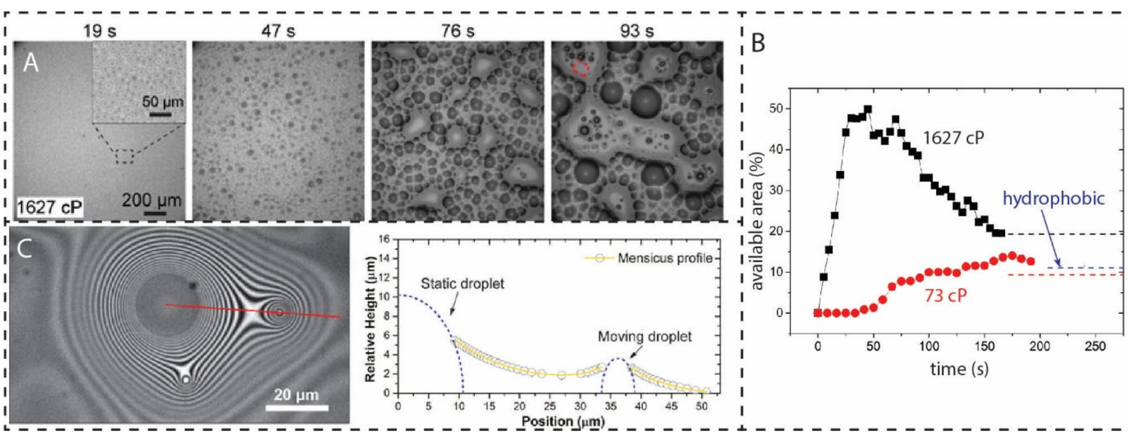
Condensation is ubiquitous in nature any many industrial applications, including water harvesting, power generation, and thermal management of power electronics and medical equipment. As compared to traditional filmwise condensation, dropwise condensation on lubricant-infused surfaces (LIS) can lead to an order-of-magnitude increase in heat transfer rates.[1] Small droplets ($D \leq 100$ µm) account for nearly 85 % of the total heat transfer and droplet sweeping plays a crucial role in clearing nucleation sites, allowing for frequent re-nucleation. We showed previously that the droplet size distribution during condensation on LIS follows that of droplets condensing on solid hydrophobic surfaces for $D \geq 10$ µm, but is higher for smaller droplets.[2,3] Here we show using high-speed microscopy and interferometry that the nucleation rate density is more than an order of magnitude higher on LIS than on solid hydrophobic surfaces. Furthermore, we show that the initially uniform lubricant film re-distributes during condensation, resulting in lubricant-rich and lubricant-poor regions (fig. A). While droplet nucleation is limited to lubricant-poor regions (Fig. B), their high mobility compensates for the reduced area-availability. Governed by lubricant height gradients (Fig. C), microdroplets as small as 2 µm in diameter undergo rigorous and gravity-independent self-propulsion, travelling distances multiples of their diameters at velocities up to 1100 µm/s. Although macroscopically the movement appears to be random, we show that on a microscopic level capillary attraction due to asymmetrical lubricant menisci causes this gravity-independent droplet motion. Combining experiments and modeling, we show that the maximum sliding velocity is inversely proportional to the lubricant viscosity and is strongly dependent of the droplet sizes. This novel and non-traditional droplet movement is expected to significantly enhance the sweeping efficiency during dropwise condensation, leading to higher nucleation and heat transfer rates.



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