Gordon Research Conference: Micro & Nanoscale Phase Change Heat Transfer: The Role of Surface Structures

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Title: "When the Desert Beetle Met the Carnivorous Plant: A Perfect Match for Droplet Growth and Shedding"

Abstract: Phase change of vapor followed by coalescence and transport on ubiquitous bumped or curved surfaces is of fundamental importance for a wide range of phenomena and applications from water condensation on cold beverage bottles, to fogging on glasses and windshields, self-cleaning by jumping droplets, weathering, self-assembly, desalination, latent heat transfer, etc. Over the past decades, many attempts to understand and control the droplet growth dynamics and shedding of condensates on textured surfaces have focused on finding the role of micro/nanotexture combined with wettability.

In particular, inspired by the Namib desert beetle bump structure, studies tested the effect of topography on the preferential condensation. However, like the preferential condensation observed on flat surfaces, hybrid wettability rather than texture plays a major role;; the role of bump topography on local preferential condensation has been unexplored and still not clearly understood. In addition, given that not only facilitating the droplet growth but also transporting the condensed droplets toward the desired reservoir is essential to make fresh sites for renucleation and regrowth of the droplets for enhancing condensation efficiency, the current hybrid-wettability- based design is not efficient to transport the condensates due to the high contact angle hysteresis created by highly wettable pinning points.

Here we show that beetle-inspired bump topography leads faster localized condensation and transport of water. Employing simple analytic and more complicated numerical calculations, we reveal the detailed role of topography and predict the focused diffusion flux based on the distortion of concentration gradient around convex surface topography. We experimentally demonstrate the systematic understanding on the unseen effect of topographical parameters on faster droplet growth dynamics on various bump geometries. Further rational design of asymmetric topography and synergetic combination with slippery coating simultaneously enable both faster droplet growth and transport for applications including efficient water condensation.