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Micro/Nanostructures for Enhanced Phase-Change Heat Transfer

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Abstract

Condensation plays an essential role in many thermal systems. Condensation, which involves heterogeneous nucleation, growth, and departure of liquid droplets, is intrinsically a random process. We report the ability to spatially control heterogeneous nucleation on a superhydrophobic (SHB) silicon nanowire array-coated surface. The control of nucleation can potentially enhance condensation heat and mass transfer. Meanwhile, SHB surfaces are being applied to enhance condensation heat transfer. Nevertheless, the condensation heat transfer on SHB surfaces is greatly deteriorated by the flooding phenomenon at high subcooling. Thus, a novel three-dimensional (3D) hybrid surface was proposed to enhance the condensation at high subcooling temperatures. The 3D hybrid surface consists of SHB SiNW arrays and hydrophilic microchannels. The heat transfer coefficient on the 3D hybrid surface can be enhanced over a large subcooling range. More remarkably, a high heat flux of 655 ± 10 kW·m-2 is obtained on the 3D hybrid surface. Ice formation may cause many adverse effects in a number of ways on many natural and industrial systems. SHB surfaces lose their ice-phobic property once a frosting layer coves their surface. We demonstrated the abilities of spatial control of ice formation and confinement of ice-stacking direction by manipulating the free energy barrier to nucleation. The controlled ice formation enhances anti-icing and deicing performances. The concept demonstrated could lead to the development of new engineered ice-phobic surfaces. In addition, nylon nanofibers are applied to enhance anti-icing and deicing. The surfaces coated with nylon nanofiber membranes could delay the ice formation and extend the ice-covering time. These results suggest the potential anti-icing applications of the nylon nanofiber membranes.

Droplets impacting a superheated surface are seen in numerous thermal systems. When the surface temperature is higher than the Leidenfrost point (LFP), a stable vapor cushion forms on the solid surface; this results in a drastic reduction in heat and mass transfer due to the thermally insulating vapor layer. The contact time of an impacting droplet is the amount of time during which the droplet comes in contact with the solid surface. A short contact time enhances heat transfer. Thus, a high LFP and a short droplet contact time are of interest to researchers. A superhydrophilic (SHP) SiNW array is applied to increase LFP and reduce contact time. A large LFP of 655 °C and a small contact time of 1.3 ms are obtained on the SiNW array. However, the contact time reduction on the SiNW array is restricted to below 400 °C because of the strong solid-liquid interaction at high temperatures on the SHP surface. For that reason, a hydrophobic (HB) double-reentrant groove (DRG) array surface is proposed to suppress the Leidenfrost effect and reduce contact times at high temperatures. The DRG surface's LFP is observed at approximately 530 °C, which is higher than the LFP on other HB surfaces. Moreover, a contact time smaller than the inertia-capillary limit on the DRG surface is observed at between 400 and 500 °C. The DRG surface avoids the limitation of low LFPs observed on HB surfaces and is currently the only HB surface for contact time reduction at high temperatures. Due to its HB properties, the DRG surface is determined to exhibit self-cleaning characteristics and can be used in various applications at high temperatures.

References

1. Ming-Chang Lu, Chien-Chang Lin, Ching-Wen Lo, Cheng-Wei Huang, and Chi-Chuan Wang, Superhydrophobic Si Nanowires for Enhanced Condensation Heat Transfer, *International Journal of Heat and Mass Transfer*, **2017,** 111, 614-623.
2. Ching-Wen Lo, Chi-Chuan Wang, and Ming-Chang Lu, Spatial Control of Heterogeneous Nucleation on the Superhydrophobic Nanowire Array, *Advanced Functional Materials*, **2014**, 24, 1211-1217.
3. Ching-Wen Lo, Yu-Cheng Chu, Ming-Han Yen, and Ming-Chang Lu, Enhancing Condensation Heat Transfer on Three-Dimensional Hybrid Surfaces, *Joule*, **2019**, 3, 2806- 2823.
4. Ching-Wen Lo, Venkataraman Sahoo, and Ming-Chang Lu, Control of Ice Formation, *ACS Nano*, **2017**, 11, 2665-2674.
5. Venkataraman Sahoo, Ching-Wen Lo, and Ming-Chang Lu, Leidenfrost suppression and contact time reduction of a drop impacting on silicon nanowire array-coated surfaces, *International Journal of Heat and Mass Transfer*, **2020**, 148, 118980.
6. Chung-Te Huang, Ching-Wen Lo, and Ming-Chang Lu, Reducing Contact Time of Droplets Impacting Superheated Hydrophobic Surfaces, *Small*, **2022**, 18, 2106704.

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