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Biphilic Functional Surfaces for Icing and Anti-icing Applications

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Extended Abstract

Ice formation and accumulation have been problematic in critical applications [1]. Superhydrophobic surfaces have been extensively used as a passive anti-icing technique to delay condensation and frosting in energy systems [2]. However, given enough time, ice formation will be observed on engineering surfaces and active methods such as heating or mechanical removal are required to clean the surfaces [3]. Water retention is one of the common issues caused by active de-icing techniques leads to decrease in heat transfer coefficient, material degradation and acts as a stimulating layer for the next icing cycles [4]. As active techniques have been an intrinsic component of anti-icing/de-icing processes in industry, it is important to develop surfaces which not only contribute passively to delay icing but also can be effective when it comes to active de-icing. More specifically, our work provides a thorough study on condensation-frosting and defrosting behaviour of biphilic surfaces comprised by superhydrophobic circular islands surrounded by hydrophilic regions.

In this study, the biphilic samples with different superhydrophobicity ratios A* (defined as the area corresponding to superhydrophobic regions to the total area) were accurately designed and fabricated. We observed a significant delay in frosting on samples with higher A*. As the superhydrophobic island diameter increased from D = 500 μm to D = 700 μm (A* from 19.62% to 38.46%), a 50% improvement was observed in terms of preventing icing. Besides delaying icing, the presence of superhydrophobic areas empowered the formation of porous and nonuniform ice structure, which facilitate ice removal during passive de-icing process. Furthermore, de-icing behaviour of the biphilic designs was observed at 0 °C. During defrosting, the biphilic design having superhydrophobic islands with the diameter of D = 500 μm, A* of 19.62% showed a complete passive cleaning performance within only 23 s without any need for additional heating. After defrosting was done completely, only 7.28% of the surface was covered by the retained water. The Laplace pressure gradient generated due to the presence of the domains with different wettability results in a dynamic slush/water flow. Additionally, the circular shape of the superhydrophobic islands generates a capillary force on the slush/water flow moving on the hydrophilic network and consecutively creates a pumping force through the network. Due to these effects, travel of slush/water on surface with D=500 μm resulted into a slush/water free surface after defrosting. Although the samples with a higher superhydrophobicity ratio exhibited slush/water mobility, complete cleaning was not achieved. However, the retained water had different behaviour on each surface as a result of the interfacial phenomena occurring on the biphilic designs.

In this study, we conclude on the optimum biphilic ratio, which is not only effective as a passive method by hindering icing but also leads to a slush/water free surface after defrosting. Findings presented here are of importance for the efficient design of anti-icing, self-cleaning and/or thermal management applications.

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