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Frosts on cooling glass surfaces with micro-scale lattice-patterned grooves

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The growth of frost crystals and frost layers on solid surfaces causes serious troubles, such as poor visibility through automobile windshields and a deterioration of the performance of heat exchanger in the air. Thus, the growth controls of frost crystals and frost layers are very important for reducing these troubles. Many experiments for these controls have been conducted using grooved metals. However, frosts on micro-scale, grooved surfaces or non-metal surfaces have not yet been fully investigated. Thus, we have conducted experiments for glass plates with micro-scale lattice-patterned grooves. The width of grooves was half the pitch of pattern. Thus, 25% of the original surfaces remained regardless of the pitches (60μm, 80μm or 100μm). A hydrophobic surface was obtained by coating a silane coupling agent on the glass surface. Each glass plate was set on a cooling stage. The stage was closed and the nitrogen gas was filled before the experiments started. After the temperature reached -20℃, the stage was opened. The surfaces were observed with a digital video microscope, and the surface temperature was measured with a thermocouple.
We found that the scenario of growth of frost crystals and frost layers depended on the dimension of grooves and surface hydrophobicity: (1) In the case of the shortest pitch, condensation droplets appeared only on the protrusions of the surface first. Secondly, almost all the droplets grew. Thirdly, many droplets froze, and some droplets coalesced during the freezing. Also, small frost crystals grew from the edge of the protrusions. Next, a wide, thin, frost-layer grew. (2) In the case of the hydrophobic surface 60μm in pitch, small droplets appeared on the protrusions first. Next, many droplets coalesced and small frost crystals grew from the edge of the protrusions. These changes occurred quicker than those occurred in the case without the coating. Thirdly, a narrow, thick frost-layer appeared in a region, while small frost crystals with hexagonal-prism shapes were observed to stand on the protrusions in another region. After that, the frost layer grew rapidly, while the frost crystals grew slowly. (3) In the case of 80μm in pitch, many droplets on the protrusions started to freeze first. Also, small frost crystals grew from the peripheral of the protrusions. Secondly, the frost crystals grew rapidly, while some other crystals grew from the tops of the droplets. Thirdly, narrow, thin, frost-layers appeared in some small regions, while small frost crystals with hexagonal-prism shapes were observed to lay horizontally on the protrusions in another region. After that, both the frost layer and frost crystals grew gradually. Next, the frost layer covering the laid crystals grew. All the scenarios are different from those in the case of metal surfaces with large grooves. It is expected that the frost crystals and the frost layers seems to remove easily in our cases. Thus, the glass surfaces with micro-scale grooves are effective for attenuating the growth of frost crystals and frost layers.

Significance statement

The glass surfaces with micro-scale lattice-patterned grooves are effective for attenuating the growth of frost crystals and frost layers. All the scenarios for the frost growth are different from those in the case of metal surfaces with large grooves.

Primary author: Mr YONEZAWA, Sho (Kyoto Institute of Technology)

Co-authors: Ms AGUI, Haruka (Tamagawa University); Prof. OHKUBO, Hidetoshi (Tamagawa University); Prof. HAGIWARA, Yoshimichi (Kyoto Institute of Technology)

Presenter: Prof. HAGIWARA, Yoshimichi (Kyoto Institute of Technology)

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