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Preparation and anti-frosting performance of super-hydrophobic surface based on copper foil

Lingyan Huang [a], Zhongliang Liu [a,*], Yaomin Liu [a], Yujun Gou [a,b]

[a] Key Laboratory of Enhanced Heat Transfer and Energy Conservation, Ministry of Education and Key Laboratory of Heat Transfer and Energy Conversion, Beijing Education Commission, College of Environmental and Energy Engineering, Beijing University of Technology, Beijing 100124, PR China

[b] Tangshan University, Tangshan 063000, PR China

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ABSTRACT

A flower-like super-hydrophobic surface on the copper foil was fabricated by means of a facile method using solution immersing. The water contact angle of this surface was measured to be as high as 156.2° after modified with fluoroalkylsilane (FAS) coating. To study its effect on frost deposition, a series of micro-observations of the water droplets formation, initial frost crystals growth and frost layer melting process were carried out on both the super-hydrophobic surface and the plain copper foil surface. The experimental results show that the water droplets condensed on the super-hydrophobic were smaller and present a more spherical shape when compared with that on the plain copper foil surface. The freezing time of the droplets on the super-hydrophobic surface was later than that on the plain copper foil surface. Moreover, the super-hydrophobic surface can restrain initial frost crystals formation for 20 min after exposed to the air for one month. The mechanism of surface hydrophobicity influence on droplets frozen and frost formation was analyzed theoretically based on the surface wettability and the phase transition theory.

1. Introduction

Frost formation is a well-known and undesirable phenomenon in cryogenics, refrigeration, air conditioning, and aerospace industries. The continuous and uncontrolled frost layer formed on the heat transfer surfaces will adversely affect the performance of the refrigeration system due to the additional pressure drop and thermal resistance. Thus, defrosting is required to remove frost layer periodically in most applications. This of course will increase both operation cost and energy consumption. As the development of refrigeration, cryogenics and aerospace industries, investigation concerning the frost formation has received great attention in recent years [1–3]. Numerous researchers have focused themselves on the investigation of frost formation mechanism and try to find an effective defrosting method. They discussed the factors that influence the frost formation such as the ambient conditions, cold surface temperature and surface characteristics [4–6]. Lee et al. [7] and Liu et al. [8] have investigated the effect of surface energy on frost formation under free convection. They found that surface hydrophilicity is one of the more advanced and attractive methods to reduce frost formation on cold surfaces. Furthermore, some researchers tried to retard frost formation by means of additional force such as electric field [9], magnetic field [10], ultrasonic [11] and mechanical oscillation [12]. However, their experimental results demonstrate that these methods have no remarkable influence on the frost layer full growth period as the increasing of frost layer thickness and density.

Recently, super-hydrophobic surfaces with water contact angle higher than 150° have attracted special attention due to their unique properties and many potential applications [13]. A perfect example of super-hydrophobic surface from nature is the lotus leaf. When water falls on the lotus leaves, it formed nearly perfect spheres that readily roll off the surface, collecting particulates along the way. This phenomenon was firstly put forward by Barthlott and Neinhuis [14] as the Lotus Effect. Such surface shows a double roughness along with a waxy coating, resulting in high contact angle of water on it [15]. Presently, there is an intense interest in mimicking the lotus leaf to produce artificial super-hydrophobic surface for a wide range of potential applications [16–20]. Although great successes have been made in the fabrication of such surfaces, most of these methods were subject to certain limitations, such as severe conditions, multistep processes, expensive materials, poor durability, etc. Therefore, simple and cost effective approaches are highly desirable for the fabrication of biomimetic super-hydrophobic surfaces. On another hand, inspired by this kind of binary micro/nano structures and low

* Corresponding author. Tel.: +86 10 67391917/67392566; fax: +86 10 67391983.
E-mail address: liuzl@bjut.edu.cn (Z. Liu).

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