《光学学报》“英文长摘要”格式要求

1、篇幅：英文长摘要篇幅要求在800~1200字（单词数）。

2、结构：

（1）题目、作者和单位（与中文信息对应的英文信息）

（2）英文长摘要正文：

1）研究目的**(Objective)**（突出所做工作的重要性和必要性）；

2）研究方法**(Methods)**；

3）创新性结果**(Results and Discussions)**：请标示出所对应的正文中的图表，以括号标注，如 (Fig.5) 等；

4）结论**(Conclusions);**

（3）关键词**(Key words)**。

3、不要加参考文献。如果有引用其他文章，建议作者转述。

4、请删除原英文摘要。

5、“英文长摘要”题目中的单词首字母请大写（除介词外）。

6、“英文长摘要”请放在文末，另起一页。

附研究论文参考示例：

Ultrafast Laser Hybrid Fabrication and Ice-resistance Performance of a Triple-scale Micro/nano Superhydrophobic Surface

Pan Rui[1,2], Zhang Hongjun[1,2], Zhong Minlin[1,2,*]

[1]*Laser Materials Processing Research Center, School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China*

[2]*Key Laboratory for Advanced Materials Processing Technology, Ministry of Education, Tsinghua University, Beijing 100084, China*

Abstract

Objective Ice accretion and its subsequent removal can be great threats to aircrafts, power lines, wind turbines, marine structures and even pipes of air conditioners or refrigerators, which may lead to serious life safety problems and enormous economic loss. The traditional deicing methods, such as mechanical vibration deicing, electro-thermally deicing or chemical fluid deicing, usually energy-intensive and/or environmentally unfavorable. Alternatively, emerging passive anti-icing (for prevention or delay of ice accumulation) and icephobic (for easy removal of ice) surfaces have been widely studied. Among them, superhydrophobic surfaces are promising candidates due to their extremely high-water repellency. However, superhydrophobic-based ice-resistant surfaces are facing three possible problems, including the low humidity tolerance, a relatively high ice adhesion strength which needs to be further reduced and the poor deicing mechanical durability. In present study, we report a novel kind of triple-scale micro/nano structured superhydrophobic surfaces with comprehensive anti-icing and icephobic properties via ultrafast laser hybrid fabrication. Such a superhydrophobic surface exhibits excellent Cassie state stability, high humidity resistance and good deicing durability. We hope that our basic strategy and findings can be helpful on the design of new robust ice-resistant superhydrophobic surfaces and on the understanding of the relationship between superhydrophobicity and ice resistance.

Methods Copper and Al alloy are employed in present study. First, the triple-scale micro/nano structures, composed of microcone arrays covered with densely grown nanograsses and dispersedly distributed micro and/or submicron flowers, are fabricated on the surfaces via a hybrid method combining ultrafast laser ablation and chemical oxidation. Then, the resultant surfaces are chemically modified by fluoride to become superhydrophobic. After that, contact angle and sliding angle of the surfaces are tested on a video-based optical contact angle measuring device. Then, the morphology and the chemical composition of the textured surfaces are analyzed by scanning electron microscope and X-ray diffraction. The effect of chemical oxidation time on the morphology and the superhydrophobicity of the prepared surfaces are studied. In the next step, condensation observation and icing delay experiments are performed on the optimized superhydrophobic surfaces

to assess their anti-icing performance. In addition, ice adhesion strength and icing-deicing cycles are also measured and performed for the prepared superhydrophobic surfaces to characterize their icephobic properties.

Results and Discussions The prepared triple-scale micro/nao-structured surface possesses excellent superhydrophbicity with a contact angle higher than 160 °and a sliding angle lower than 1 °. With the increase of the oxidation time, the nanostructures formed on the microcone arrays on the surfaces evolves from nanorods to nanograsses via hydrolysis (Fig.5). Overall, the resultant contact angle increases and the sliding angle decreases with the increase of oxidation time (Table 3). The anti-icing function study shows that the optimized superhydrophobic surface is featured with hierarchical condensation and coalescence-induced jumping of the condensed droplets under condensation and freezing conditions due to its low surface adhesion. Since the air pockets trapped in the surface structures perform as a thermal barrier layer, the prepared superhydrophobic surface exhibit good icing delaying performance with an icing delaying time of 52'39" (Fig.8). The icephobicity study of the prepared superhydrophobic surfaces shows that the ice adhesion strength of the superhydrophobic surface can be as low as 6 kPa, which is 40 times lower than that of the original Al alloy surface (Fig.10). In addition, after 10 repeated times of icing-deicing cycles, the ice adhesion strength of the superhydrophobic surfaces are still no more than 20 kPa, demonstrating a decent deicing robustness.

Conclusions In present study, a novel kind of triple-scale micro/nano structured superhydrophobic surfaces, composed of periodical microcone arrays covered with densely grown nanograsses and dispersedly distributed micro/submicro-flowers, are successfully fabricated via ultrafast laser hybrid method. After chemical modification, such a surface possesses excellent superhydrophbicity with a contact angle higher than 160 °and a sliding angle lower than 1 °. The evolution of the surface morphology shows that the superhydrophobicity of the prepared surfaces is determined by the surface roughness and the hierarchical level. The observed hierarchical condensation phenomenon on the prepared superhydrophobic surface ensures the Cassie state stability of the primary condensed droplets even under a high humidity environment and the condensed droplets could slide off the surface before freezing due to the low surface adhesion, thus making the prepared superhydrophobic surface with a great anti-icing performance. The ice adhesion strength of the superhydrophobic surface can be as low as 6 kPa, which is very competitive even compared with the interfacial slippage surfaces and the low interfacial toughness surfaces (the reported ice adhesion strength of which could be as low as less than 5 kPa), indicating that superhydrophobic-based icephobic surface can also exhibit ultralow ice adhesion. Our study shows that such kinds of triple-scale micro/nano structured superhydrophobic surfaces with comprehensive anti-icing and icephobic properties can be obtained through the rational surface design, which couples multi-scale micro/nano roughnesses and hierarchical level.

Key words ultrafast laser; superhydrophobic surface; multi-scale micro-nano structures; anti-icing performance; icephobic property