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# Fabrication of anisotropic PTFE superhydrophobic surfaces using laser microprocessing and their self-cleaning and anti-icing behavior

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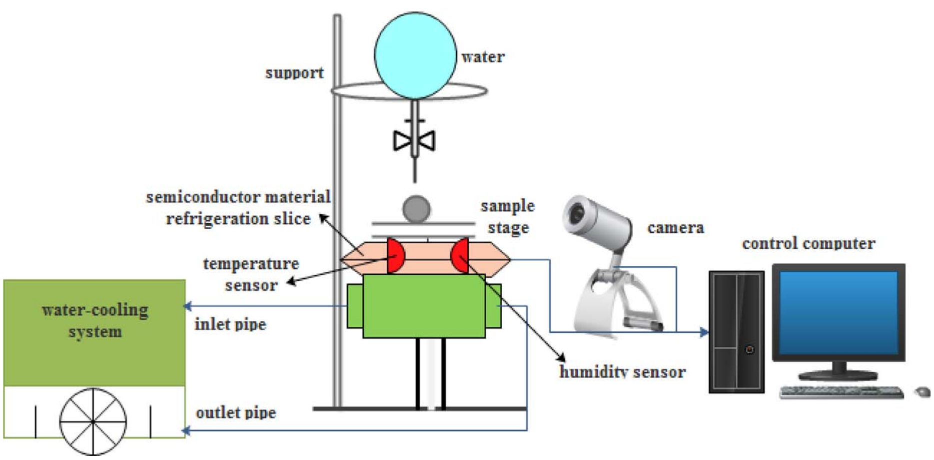
## GRAPHICAL ABSTRACT

Scheme diagram of the self-made icing monitoring system.

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## ABSTRACT

Due to excellent stability and intrinsic low surface energy, polytetrafluoroethylene(PTFE) is widely utilized to fabricate biomimetic superhydrophobic surfaces. We proposed a facile and rapid method to obtain outstanding superhydrophobic surfaces by $CO_2$ laser microprocessing PTFE plate. Scanning electron microscope(SEM) and contact angle measuring instrument were employed to characterize the structure and wettability. The effects of different micro channels spacing, different processing times and different processing power on wettability and morphology were studied. The self-cleaning and anti-icing properties of the prepared PTFE superhydrophobic surface were investigated. It was demonstrated that the maximum static contact angle was up to 168.36°. The degree of anisotropy could be controlled by adjusting the micro channels spacing. The as-prepared PTFE superhydrophobic surfaces exhibited self-cleaning properties, and water droplets were easy to take away dusts attached to the surfaces. Especially, it was found using the self-made icing monitoring system that as-prepared PTFE superhydrophobic surface showed an outstanding dynamic anti-icing performance even if the surface temperature was as low as −25 °C and surrounded by ice and frost. The present study therefore suggests that $CO_2$ laser microprocessing could be applied to large-scale preparation of superhydrophobic surface for practical

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applications in different fields of self-cleaning, anti-icing, microfluidic devices, lab-on-chips system, directional water harvesting, drag reduction and other fields.

## 1. Introduction

As a typical polymer composed of all carbon and fluorine, PTFE is a kind of synthetic polymer material, which all the hydrogen atoms in polyethylene are replaced by fluorine atoms, known as the king of plastics. This material has a series of excellent physical and chemical properties, such as acid and alkali resistance, anti-organic solvent, almost insoluble in all solvents, high temperature resistance, low friction coefficient, low dielectric constant, and excellent charge storage stability. By virtue of its numerous characteristics, it is widely used in many fields such as aerospace, electronics and electrical, chemical, mechanical, instrument, construction, textile, metal surface treatment, pharmaceutical and medical, food and other fields.

Bionic superhydrophobic surface has excellent hydrophobic properties, which endows it a serial of merits such like water-repellent [1,2], anti-icing [3,4], anti-pollution [5,6], anti-corrosion [7,8] and other characteristics. Superhydrophobic has potential applications in many fields [9–16], such as anti-icing in power grid, drag-reduction in pipeline transportation, directional water-collecting, increasing buoyancy for boats, anti-corrosion for all kinds of metal, waterproof and self-cleaning for building external wall, microfluidic chip in biological and medical sciences and so on. There are many methods for preparing superhydrophobic, such as template method [17], chemical etching method [18], sol-gel method [19], vapor deposition method [20] and so on. However, most of these methods are limited to experimental preparation and can not be prepared on a large scale, it is very difficult to promote the application in practice. With the development of laser devices, all kinds of gas lasers, solid lasers and liquid lasers are widely utilized in various fields. Along with the development of a variety of laser technology is also widely applied. Laser processing technology has the characteristics of rapid surface micromachining, contrivable patterns and controllable various parameters [21]. In recent years, some laser technologies have been used to prepare superhydrophobic biomimetic materials [22–28]. Such as interference lithography [29], UV lithography [30], picosecond laser technology [31], femtosecond laser technology [32], excimer laser [33]. Xia et al. [34] used an interference photolithography method to obtain a one-dimensional nanometer pattern with a strong anisotropy. Chen et al. [35] utilized femtosecond laser technology to prepare superhydrophobic surfaces with anisotropic structures on Si surfaces. Liang et al. [36] used femtosecond laser to ablate polytetrafluoroethylene to obtain a strong non-wetting surface. Falah et al. [37] detailedly studied how the different parameters of the femtosecond laser to effect surface morphology and wettability of polytetrafluoroethylene surface.

Based on the inherent stability, low surface energy and wide applications, this study used $CO_2$ gas laser to microprocessing the surface of polytetrafluoroethylene to fabricate superhydrophobic surface. The effects of different micro channels spacing, different processing times and different processing power on surface wettability and morphology were studied. The anisotropic and self-cleaning performance of the PTFE superhydrophobic surface were investigated, and anti-icing performance was also explored using a self-made icing monitoring system.

## 2. Experimental

### 2.1. Experimental materials and equipments

Polytetrafluoroethylene plate was purchased from Shenzhen Xinnuode Engineering Plastics Materials Co., Ltd. Anhydrous ethanol, AR, purchased in Tianjin North Union Fine Chemicals Development Co., Ltd. Deionized water was produced by laboratory. DHG-9123A electric constant temperature blast oven, KQ-400KDE high power CNC ultrasonic cleaner. The CT-LEG 10 $CO_2$ laser purchased from Wuhan Chutian Industrial Laser Equipment Co. Ltd has a total output power of 10 W, a scanning frequency of 20 KHz, a wavelength of 1064 nm, and a processing line width of 100 μm. The surface wettability was characterized by the America First Ten Angstroms FTA1000 contact angle measuring instrument. The surface morphology of the samples was observed by Hitachi S-3400N scanning electron microscope.

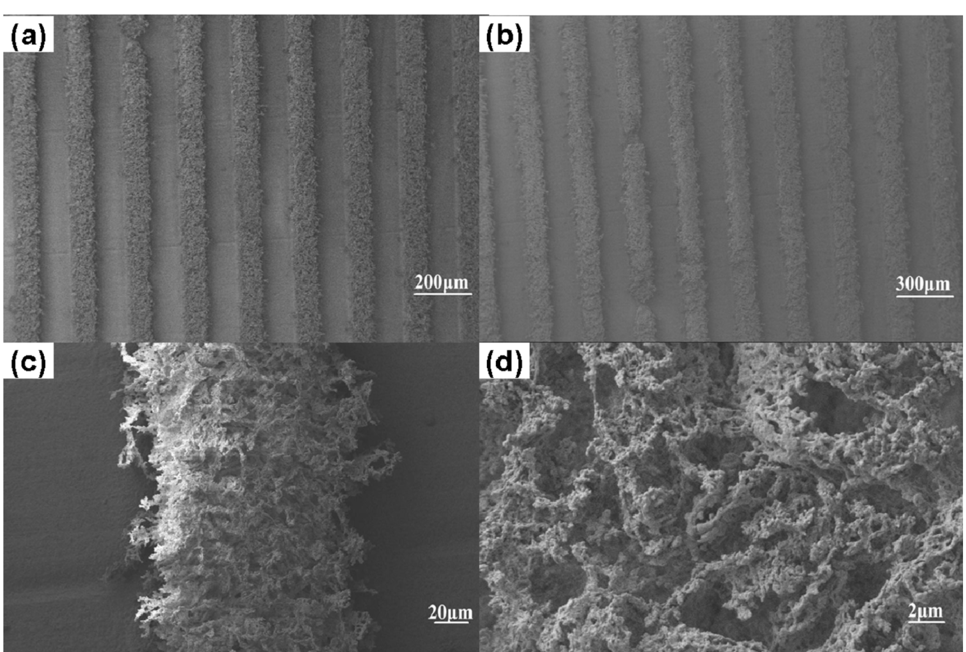


**Fig. 1.** SEM images of PTFE superhydrophobic surface with different micro channels spacing. (a) 200 μm; (b) 300 μm; (c) the morphology of the individual micro channel after laser ablation; (d) the magnified SEM image of the surface morphology of the laser processing area.