Electronic Supplementary Material (ESI) for Soft Matter.

Supporting Information

Efficient and Economical Approach for Flexible Photothermal Icephobic Copper Mesh with Robust Superhydrophobicity and Active Deicing Property

Heng Xie[1], Wen-hua Xu[2], Cong Fang[2], Ting Wu[2*]

[1]School of Chemistry and Chemical Engineering, Huazhong University of Science &Technology, Wuhan, Hubei, 430074, China.

[2]Key Laboratory of Polymer Processing Engineering, Ministry of Education, South China University of Technology, Guangzhou, Guangdong, 510640, China.

*Corresponding author: wuting@scut.edu.cn

S1. The effect of TEOS on adhesion of the coatings

To characterize the effect of TEOS on the adhesion of the coatings, we prepared three coatings with the same SiC/SiO_2 ratio (2:1). One coating was unaltered (SiC/SiO_2), FAS-17 alone was mixed into one coating (SiC/SiO_2/FAS-17), and both FAS-17 and TEOS were mixed into the third coating (SiC/SiO_2/FAS-17/TEOS). Water flow impact and tape peeling tests were used to study the difference in adhesion amongst the particles or between the copper mesh and the particles. Water flow impact was tested and results are shown in Fig. S1. Fig. S1 shows that the SiC/SiO_2 coating is not superhydrophobic, allowing complete wetting of the surface under water flow, and much damage to the coating. The SiC/SiO_2/FAS-17 coating is superhydrophobic due to the addition of FAS-17. However, the water flow causes some wetting of the coating surface and began to destroy the hydrophobicity of the surface. The SiC/SiO_2/FAS-17/TEOS coating retains its superhydrophobicity under the water flow. The water flow could not wet the surface or damage the surface structure.

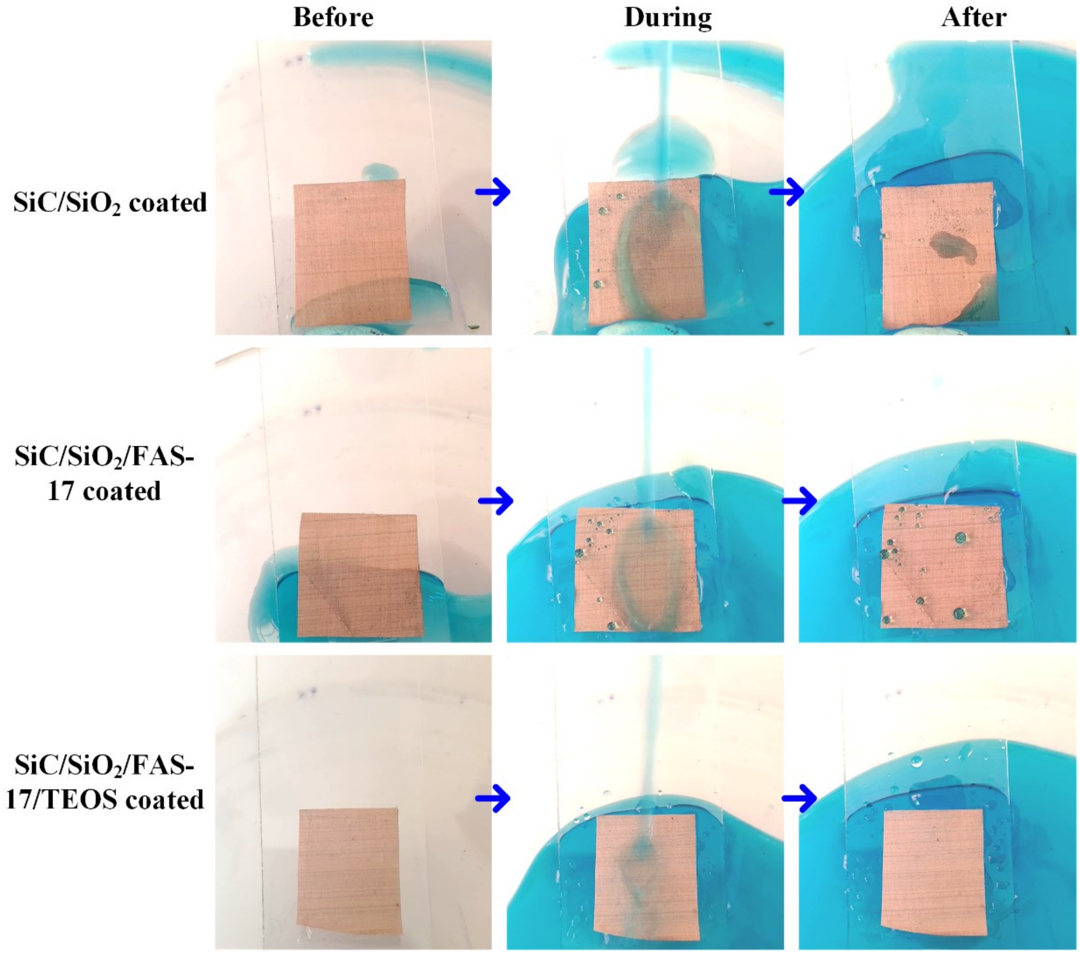

Fig. S1 Water flow impacting tests of SiC/SiO_2, SiC/SiO_2/FAS-17 and SiC/SiO_2/FAS-17/TEOS coatings.

Furthermore, tape peeling tests were applied to the SiC/SiO_2/FAS-17 coated copper mesh and the results are shown in Fig. S2 and Video S4. Compared with the SiC/SiO_2/FAS-17/TEOS coated copper mesh, the SiC/SiO_2/FAS-17 coated copper mesh loses its hydrophobicity only after 10 times of tape peeling and the impacting dyed water droplets wet the surface, which means the bonding amongst the particles or between the copper mesh and the particles is not strong enough.

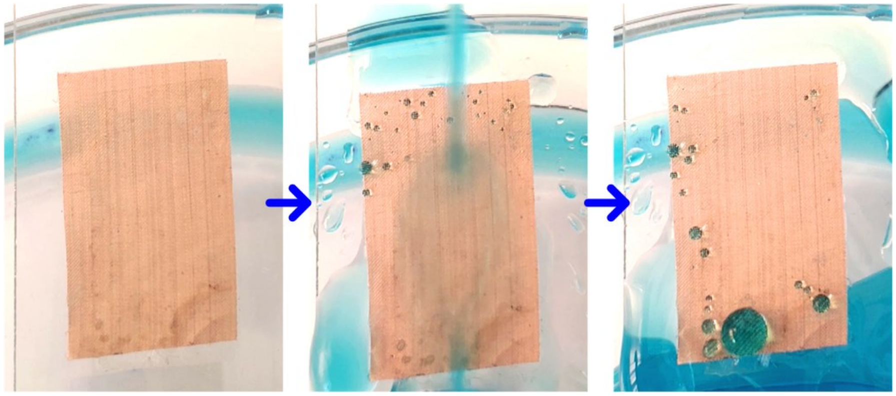

Fig. S2 Wettability of the SiC/SiO_2/FAS-17 coated copper mesh after 10 times of tape peeling.

S2. The ice adhesion strength on the pristine and coated copper mesh

As shown in Fig. S3, once a water droplet is placed on the substrate, it is subject to deformation. For a small water drop, it is rational to assume that the water bead holds its round shape. Hence, r can be defined as the radius of 10 μL (V) water droplet, l is the radius of the contacting area of the water droplet and substrate, and δ is the sagging distance. θ^* is the contact angle (CA) on the coated copper mesh (162 ± 2°) Then, the following relationship applies when $\theta^* \geqq 90°$.

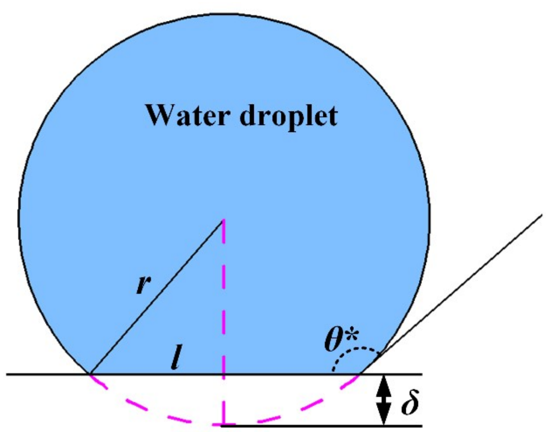

Fig. S3 Wetting model of a small water droplet maintaining non-wetting state on a surface.

$$r = \sqrt[3]{\frac{3V}{4\pi}} \quad (1)$$

$$l = r\cos(180° - \theta^*) \quad (2)$$

Then, the contacting area (S) of the water droplet and the coated copper mesh can be calculated as follows.

$$S = \pi l^2 \quad (3)$$

The ice adhesion strength (P) on the icephobic copper mesh can be calculated by equation (4).

$$P = \frac{F}{S} \quad (4)$$

Where F is the adhesion force between the frozen droplet and the copper mesh. The ice adhesion force for the coated copper mesh in the parallel and vertical directions is 1.7 N and 2.3 N, respectively. Substituting the volume (V=10 μL) of the water droplet to equation (1) and combine equations (2)~(4), the P for the coated copper mesh in the parallel and vertical directions is calculated to be about 1.66 kPa and 2.25 kPa, respectively. Similarly, the P for the copper mesh in the parallel and vertical directions is 5.87 kPa and 8.12 kPa, respectively.

S3. UV-vis-NIR reflection and absorption spectra of the pristine and coated copper mesh

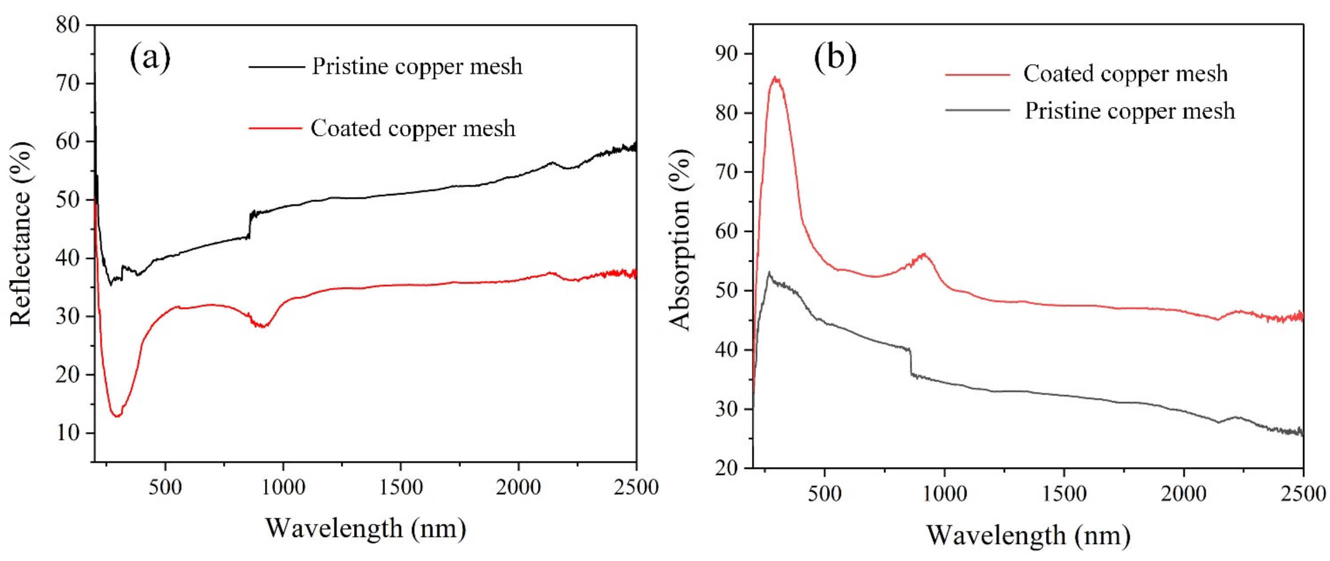

Fig. S4 (a) Reflection and (b) absorption spectra of the pristine and SiC/SiO_2 coated copper mesh.

S4. The light-to-heat conversion efficiency of the coated copper mesh

Due to the good photothermal conversion and thermal conductivity properties of the coated copper mesh, heat efficiently transfers from the photothermal coating zone towards the surrounding coating, which will melt ice at the ice-solid interface first and then melt adjacent ice. A photothermal deicing test is conducted on the coated copper mesh in order to identify the light-to-heat conversion efficiency η. The spherical ice droplet (60 μL) originally frozen on the coated copper mesh surface is melted into a spherical droplet under NIR irradiation, and the entire deicing process can also be clearly observed from Fig. S5 and Video S9. After ~36 s, the average temperature of the coating surface increases from -30 to ~0 °C under NIR irradiation (0.2 W). The light-to-heat conversion efficiency η is calculated as follows:

$$\eta = \frac{C \cdot \rho \cdot V \cdot \Delta T}{P \cdot t}$$

Herein, V is the volume of ice (60 μL) ρ is the density of ice (920 kg/m^3) and C is the specific heat capacity of ice (2100 J kg^{-1} °C^{-1}). Thus, η is about 49.3%, which is similar to the reports in ref [25] of the manuscript.

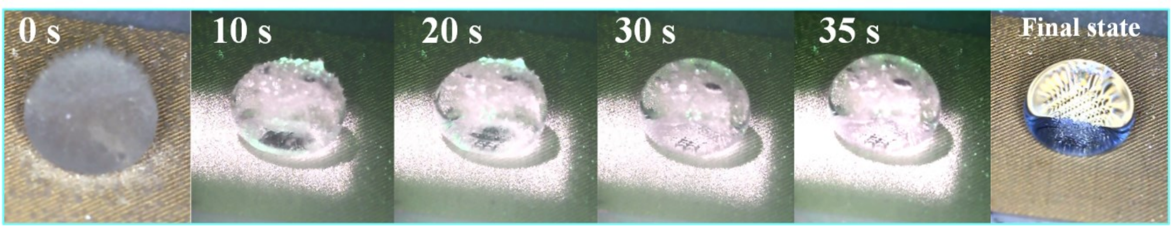

Fig. S5 Photothermal deicing process of the SiC/SiO_2 coated copper mesh.

S5. The photothermal efficiency of the coated copper mesh after bending-twisting and tape peeling test

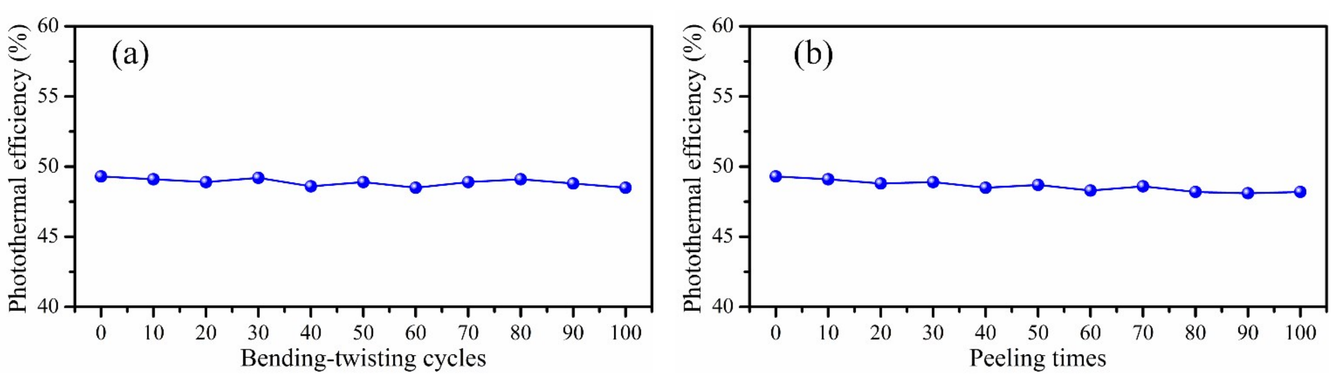

Fig. S6 Photothermal efficiency as a function of (a) bending-twisting cycles and (b) peeling times.

Video S1. The water flow impacting test on the SiC/SiO_2 coated copper mesh surface at a dynamic pressure of ~25 kPa.

Video S2. The processes of bending-twisting test for the SiC/SiO_2 coated copper mesh.

Video S3. The processes of tape-peeling test for the SiC/SiO_2 coated copper mesh.

Video S4. The processes for water flow impacting on the coated copper mesh without TEOS in the coating.

Video S5. The processes for a droplet impacting on the SiC/SiO_2 coated copper mesh at *We* of 40.8.

Video S6. The processes for a droplet impacting on the SiC/SiO_2 coated copper mesh at *We* of 81.7.

Video S7. The processes for a droplet impacting on the SiC/SiO_2 coated copper mesh at *We* of 121.8.

Video S8. The processes for a droplet impacting on the SiC/SiO_2 coated copper mesh at *We* of 163.4.

Video S9. Photothermal deicing process of the SiC/SiO_2 coated copper mesh.