

Electronic Supporting Information

Design and **construction** the Laplace and wettability gradient field for efficient water collection

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Affiliations

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Experimental Section

Materials.

Concentrated hydrochloric acid was purchased from Sichuan Xilong Chemical Co., Ltd. Before use, it was diluted to 0.1 mol/L with deionized water. Anhydrous ethanol is purchased from Sinopharm Chemical Reagent Co., Ltd. NaOH and $(\text{NH}_4)_2\text{S}_2\text{O}_8$ were purchased from Shanghai Macklin Biochemical Co., Ltd. N-octadecaptan was purchased from Shanghai Aladdin Biochemical Technology Co., Ltd. The 0.2 mm thick piece of copper was purchased from Zhenyue Materials Co., Ltd. through Taobao.com. Deionized water (resistivity $>18.2 \text{ M}\Omega\cdot\text{cm}^{-1}$) was produced by ultra-pure water machine purchased by Sichuan Youpu Ultra-pure Technology Co., Ltd.

Preparation of patterned surface.

First, the copper sheet was cut into a size of $4\times 4 \text{ cm}^2$, and then ultrasonic cleaned with anhydrous ethanol and deionized water successively for 5 min. The cleaned copper sheet was soaked in 0.1 mol/L HCl solution for 5 s to remove the oxidation layer, and then was put into the mixed solution of 2.5 mol/L NaOH and 0.1 mol/L $(\text{NH}_4)_2\text{S}_2\text{O}_8$ for 20 minutes. After the reaction is complete, the surface is rinsed with deionized water and dried to obtain a super-hydrophilic surface. Then the super-hydrophobic surface was obtained by soaking in 0.01 mol/L ethanol solution of n-octadecaptan for 5 min and drying. Set the printing speed of the 3D printer (DC-2030) to 100 mm/s, the temperature of the sprinkler head to 200 °C, and the temperature of the hot bed to 50 °C. The Poly Lactic Acid (PLA) was used as raw material to print a mold with a size of $4\times 4 \text{ cm}^2$. The mold was placed over the SHB copper sheet so that the two were placed perfectly coincident, and the surface scan was performed with a laser marking machine (JN-20). The scanning speed is set at 30 mm/s, the frequency at 20 KHz, and the power at 100%. After the scanning was completed, the dust was cleaned with deionized water to obtain the patterned hydrophilic and hydrophobic hybrid surface.

Water collection experiment

As shown in Fig. 3b, the sample is fixed to a stand and placed vertically, and a container is placed below to store the collected water. The humidifier (ZG-KC05) is used to produce a steady

fog flow (flow rate of 1.5 m/s). The distance between the fog outlet and the sample was 10 cm. During the test, the ambient temperature was about 15 ± 2 °C and the humidity was above 90%. Weigh the water every fifteen minutes.

Characterization.

The emission scanning electron microscope (FESEM, Sigma 500) was equipped with energy dispersive spectrometer (EDS) to characterize the micromorphology and element distribution of the samples. SEM images were obtained using InLens secondary electron detector with an acceleration voltage of 15 KV, and an aperture size of 60 μm . The crystal structure of the sample was detected by X-ray diffractometer (XRD, D8 Advance), where the XRD target was copper and the wavelength of the X-ray was 0.154056 nm, the Angle range was 5° – 80° , and the step size was 0.02° . In attenuated total reflection (ATR) mode, Fourier Transform infrared Spectrometer (FTIR Spectrometer, Nicolet iS50) was used to analyze the group type and molecular structure of the material. The elemental and chemical valence states of the samples were characterized by X-ray photoelectron spectroscopy (XPS, Escalab 250XI). XPS has an energy resolution of 0.45 eV, a step size of 1 eV, a CAE pass energy of 100 eV, a working voltage of 14.6 KV, and a working current of 10 mA. The electron binding energy of the spectrum was calibrated, and the peak of C1s was 284.8 eV. The contact Angle and slip Angle of the sample (droplet volume of 4 μL) were measured with a contact Angle measuring instrument (JC 2000D1) at room temperature. The adhesive force measuring instrument was evaluated by DataPhysics Company (Germany), and the version is DCAT 25.

Supplementary Figures

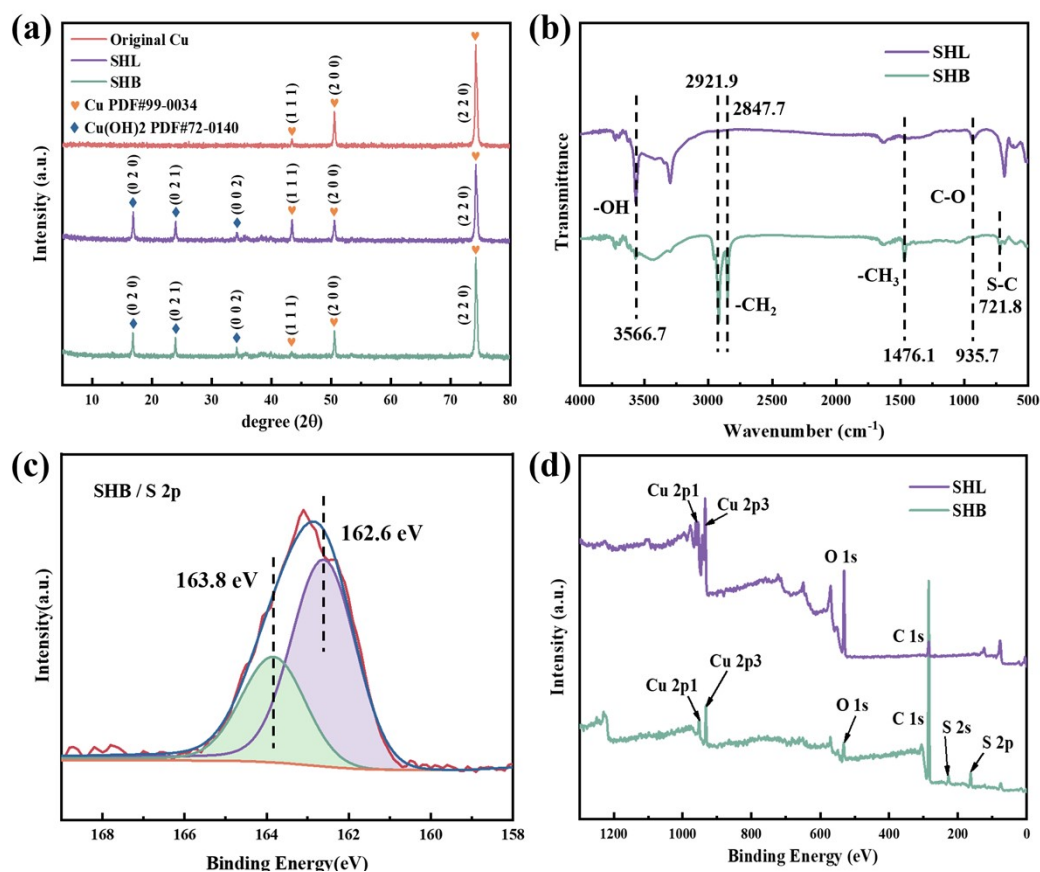


Fig. S1 (a) XRD spectrum of original copper, SHL copper and SHB copper. (b) Infrared absorption spectra of SHL and SHB copper sheets. (c) S 2p spectrum of the modified surface. (d) XPS analysis of copper sheet before and after modification.

The crystal structure was further characterized by XRD analysis. As shown in Fig. S1a, clearly visible Cu(OH)₂ diffraction peaks of (020,021,002) were observed in the etched SHL and the modified SHB copper sheet, which is well consistent with PDF#72-0140, indicating that the Cu(OH)₂ grown on the copper surface is of high purity.^{1, 2} In order to further verify the modification results, XPS and FT-IR analysis were performed on the samples. As shown in Fig. S1b, it can be seen from the infrared absorption spectrum that the antisymmetric stretching vibration peaks and symmetric stretching vibration peaks of C-H bond in the -CH₂ group appear at 2921.9 cm⁻¹ and 2847.7 cm⁻¹ of the modified copper sheet.³ The stretching vibration peak of -CH₃

appeared at 1476.1 cm^{-1} , and the stretching vibration peak of S-C bond appeared at 721.8 cm^{-1} .⁴ Two peaks of S 2p were observed in the high resolution after modification (Fig. S1c). The peak centred at 162.6 eV is associated with $\text{Cu}(\text{SC}_{18}\text{H}_{37})_2$, while the peak of 163.8 eV is due to the free n-octadecaptan.² As can be seen from the full spectrum of XPS (Fig. S1d), after modification, the peak of O1s was significantly weakened, and the strong C1s peak of alkyl group appeared at 284.6 eV. This provides evidence for the existence of $\text{Cu}(\text{SC}_{18}\text{H}_{37})_2$ compound.⁵

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2. Q. Pan, M. Wang and H. Wang, *Appl. Surf. Sci.*, 2008, **254**, 6002-6006.
3. T. P. Ang, T. S. A. Wee and W. S. Chin, *J. Phys. Chem. B*, 2004, **108**, 11001-11010.
4. H. Zhu, F. Yang, J. Li and Z. Guo, *Chem. Commun.*, 2016, **52**, 12415-12417.
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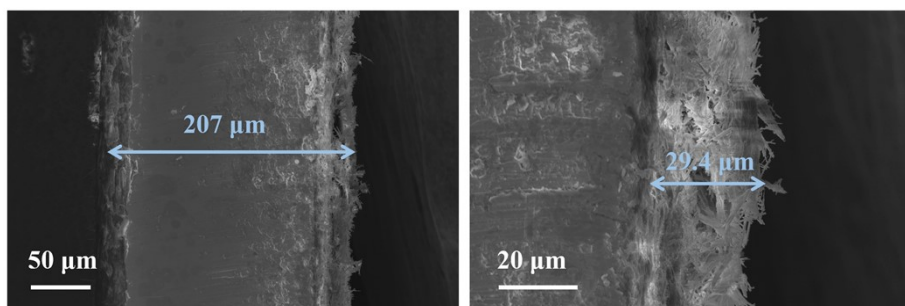


Fig. S2 Scanning electron microscopy (SEM) images of the cross-section of the copper sheet reflects the thickness of the substrate and nanoneedle layer.

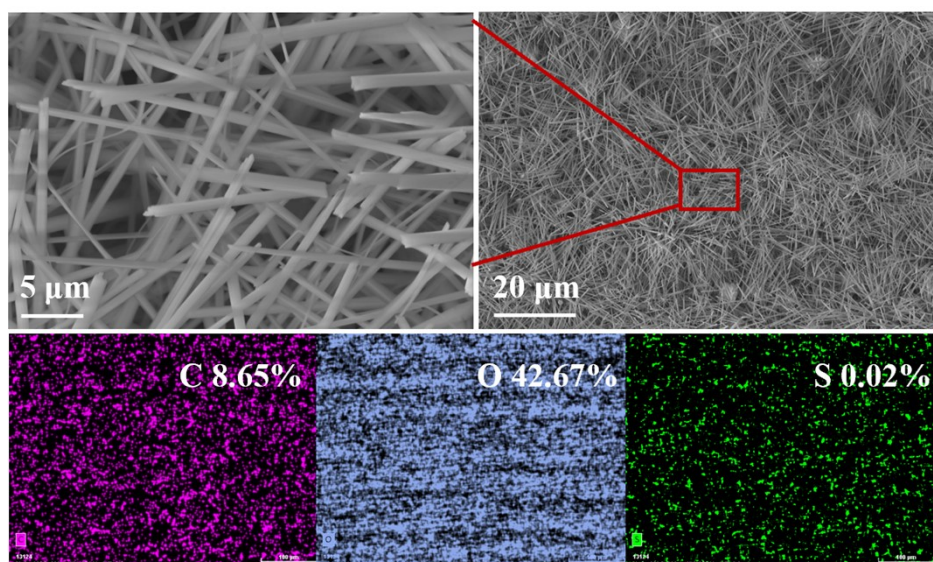


Fig. S3 SEM image and element analysis of SHL copper sheet.

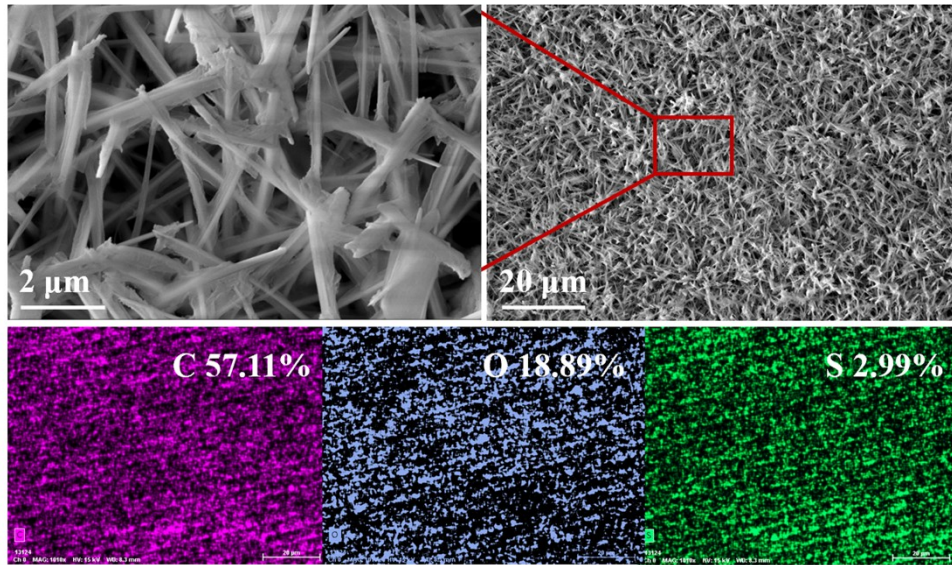


Fig. S4 SEM image and element analysis of SHB copper sheet.

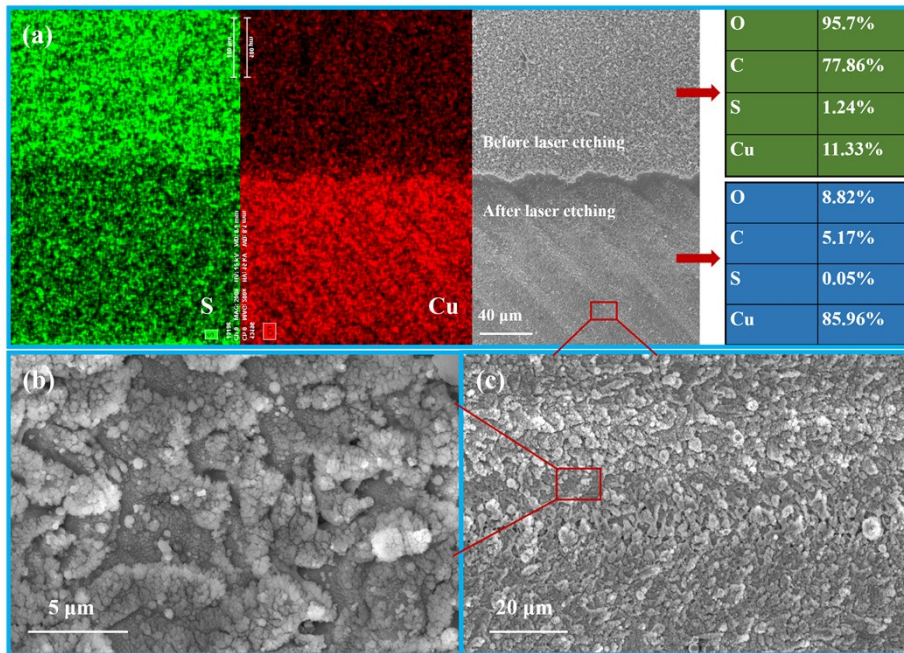


Fig. S5 (a) Element content and surface topography changes before and after laser irradiation. (b, c) Local zoom for laser irradiation creates microscopic granular structures.

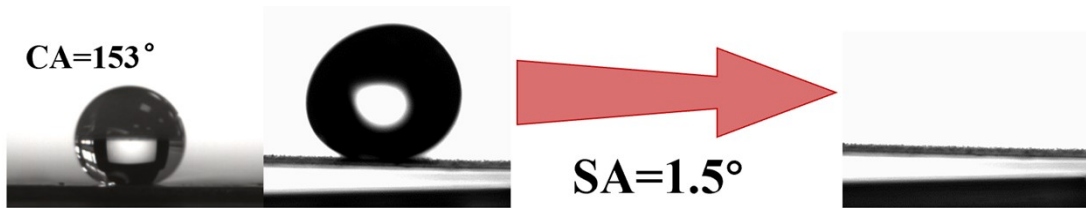


Fig. S6 Contact angle and sliding angle of the SHB surface.

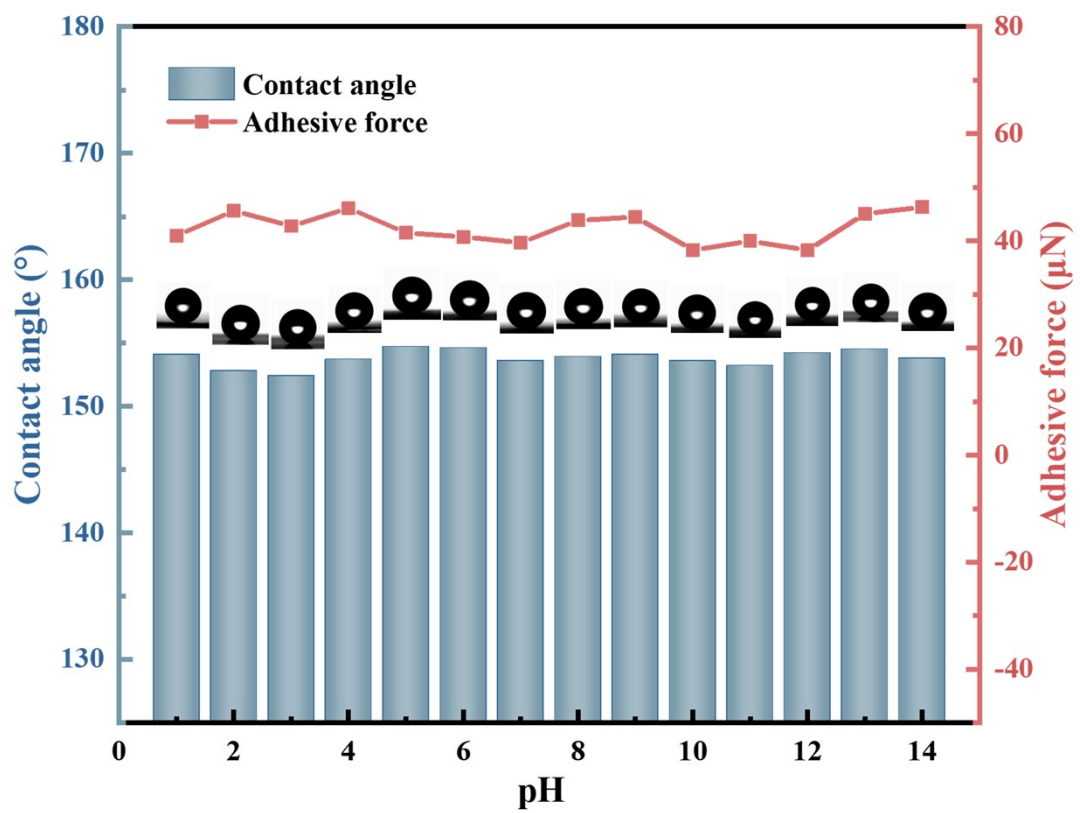


Fig. S7 Contact angle testing of SHB surfaces for solutions at different pH values.

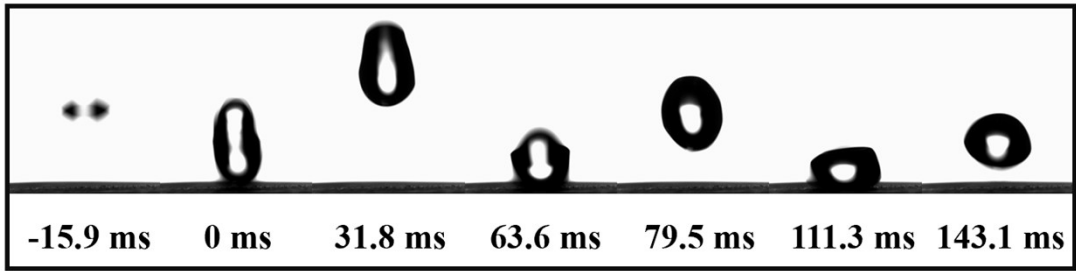


Fig. S8 Optical image of water droplets bouncing on the SHB surface.

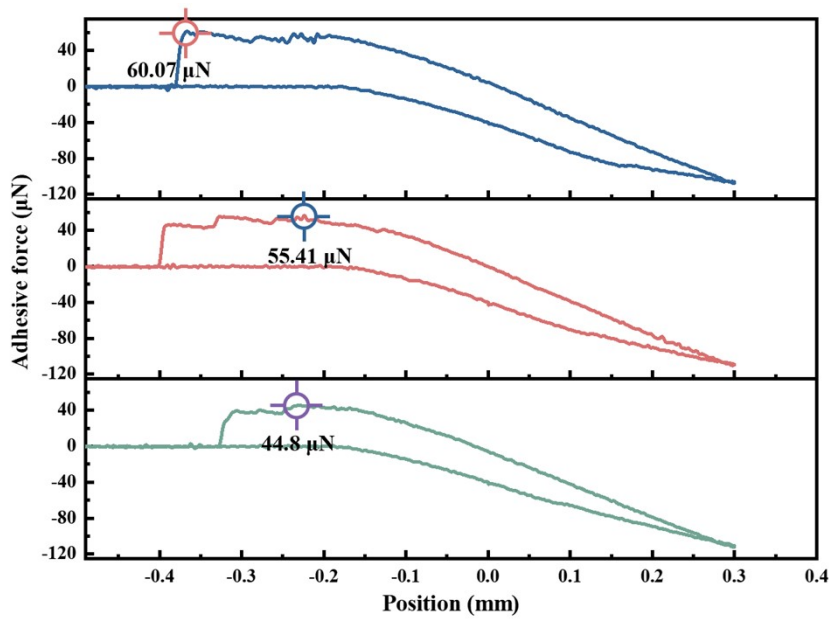


Fig. S9 Adhesion force test of SHB surface

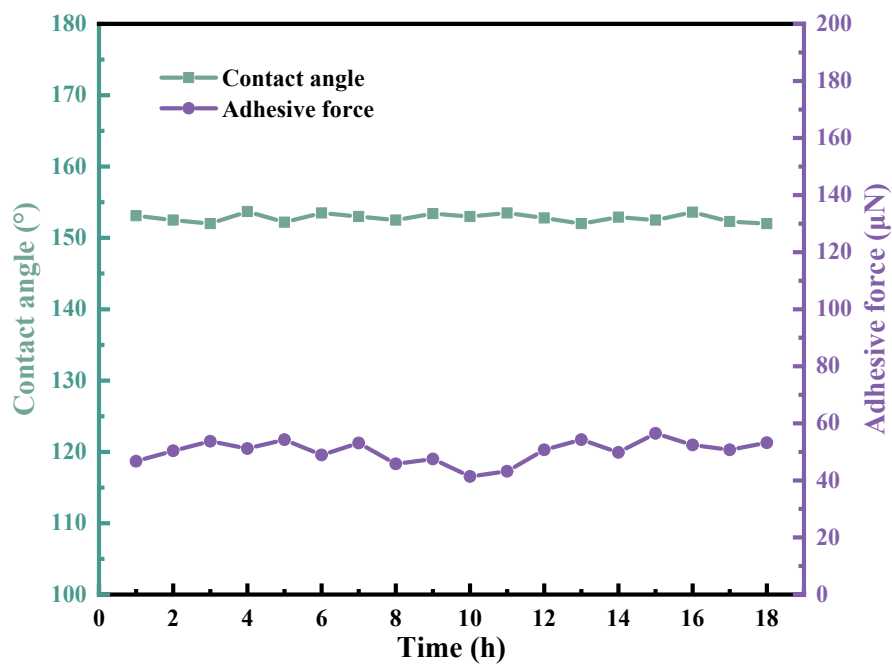


Fig. S10 Influence of long-term exposure to high humidity on contact angle and adhesion force of SHB surfaces.

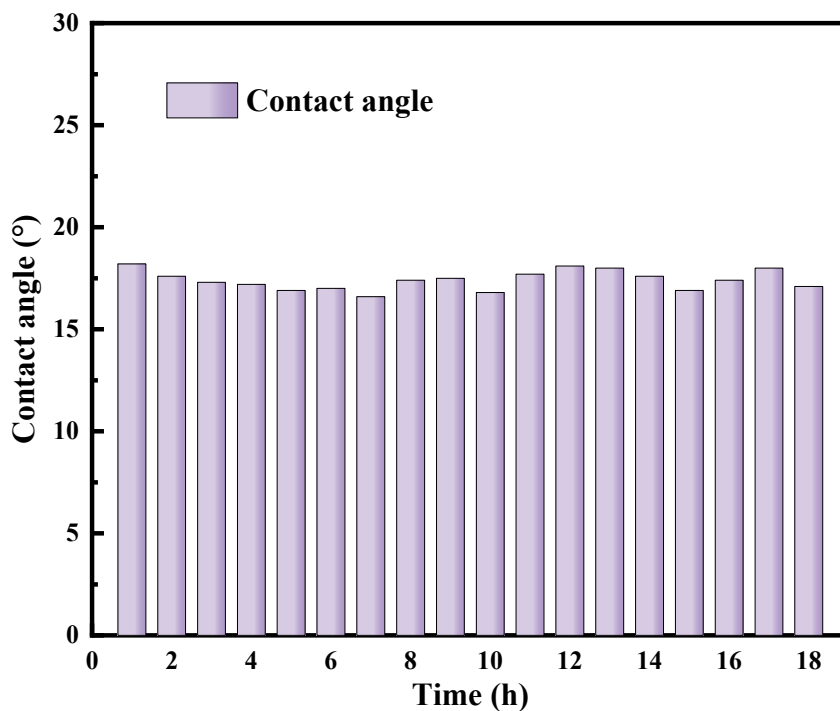


Fig. S11 Influence of long-term exposure to high humidity on contact angle of SHL surfaces.

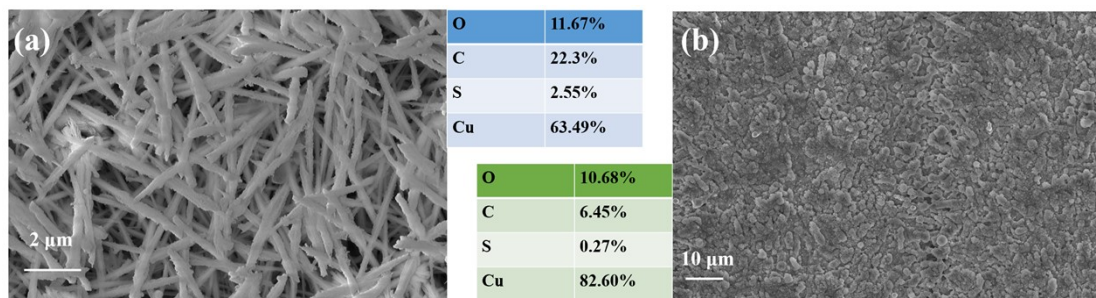
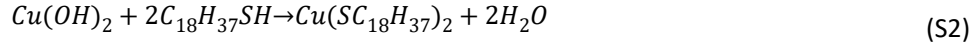
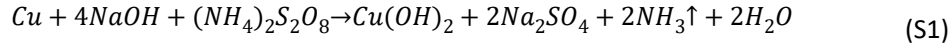


Fig. S12 (a, b) The surface morphology and element content of SHB and SHL surfaces impacted by fog flow.

Supplementary Chemical Reactions/Formulas and Table



$$\eta = \frac{(G_2 + g_2) - (G_1 + g_1)}{x \times y \times t} \quad (S3)$$

Where, G_1 and G_2 are the mass of the container before and after water collection, g_1 and g_2 are the mass of the sample before and after water collection, x and y are the length and width of the tested specimen, and t is the duration of water collection.

Table S1 Comparison with similar state-of-the-art water collection materials in the literature

T(°C)	RH	Fog flow rate	Distance (cm)	Efficiency (mg cm ⁻² h ⁻¹)	Ref.
—	—	—	10	5300	8
20	58%	—	10	580	9
20	—	300 mL h ⁻¹	20	1432.7	10
30±1	70±1%	—	—	160.38	16
20	90%	50 cm s ⁻¹	—	5424	17
22.2	92-94%	—	—	7195	18
—	—	—	12	1568	19
25	80%	12 cm s ⁻¹	7	894	21
24±2	85%	50 cm s ⁻¹	12	430	25
25	90%	75 cm s ⁻¹	5	5300	26
—	—	20 cm s ⁻¹	—	7421	27
—	—	75 cm s ⁻¹	—	2780	30
22	90-95%	10 cm s ⁻¹	—	61.8	34
20	80%	10 cm s ⁻¹	10	1309.9	35
15±2	90%	150 cm s ⁻¹	10	4258.59	This work