Electronic Supplementary Material (ESI) for Chemical Communications.

Supplementary Information
An integrated mesh with anisotropic surface for unidirectional liquid manipulation

Cong Liu,[ab] Jinxia Huang,[*b] Zhiguang Guo [*ab] and Weimin Liu [b]

[a] Ministry of Education Key Laboratory for the Green Preparation and Application of Functional Materials, Hubei University, Wuhan 430062, People's Republic of China

[b] State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000, People's Republic of China

Corresponding author:

*E-mail: zguo@licp.cas.cn (Guo) and huangjx@licp.cas.cn (Huang); Fax: +86-931-8277088; Tel.: +86-931-4968105

Experimental Section

Materials

Copper wires (diameter: 0.4 mm and purity ~ 99.9%) were bought from taobao.com. Ethanol, acetone, n-octane, sodium hydroxide (96%, NaOH), and ammonium persulfate (98%, $(NH_4)_2S_2O_8$) were obtained from Tianjin Rionlon Pharmaceutical Science & Technology Development Co., Ltd. n-Octadecanethiol (96%, $C_{18}H_{38}S$) was obtained from Sinopharm Chemical Reagent Co. Ltd. PDMS prepolymer (silicone oil) was purchased from the Dow Chemical co., Ltd. Polystyrene box (length × width × height: 4 cm× 4 cm× 1 cm) was purchased from Fujian taizhi Co., Ltd. Adjustable angle tilt platform was purchased from Hubei ganwei Co., Ltd. Double-sided tape was bought from Deli Group Co., Ltd.

Fabrication of copper wires with (super)hydrophobic

First, the copper wires (5 cm in length) were ultrasonically washed in acetone and deionized water for 20 min, immersed in 0.1M HCl solution for 1min to remove the oxide layer and impurities on the surface and then dried in nitrogen. Next, copper wires were immersed in an aqueous solution prepared by mixing 2.4 g of NaOH, 0.92 g of $(NH_4)_2S_2O_8$ and 40 g of H_2O for 4 min.

After the ammonia corrosion, copper wires were immersed in 2 mM n-octadecanethiol (96 %)/ethanol for 15min, and then repeatedly cleaned with deionized water, so that the wettability of the copper wires changed from hydrophilic to superhydrophobic.

After modified with n-octadecanethiol, superhydrophobic copper wires were dipped into silicone diluted with n-octane for 24h, and the excess lubricant was removed by placing the copper wires.

Fabrication of IMAS

Through the ammonia corrosion, copper wires covered with dense Cu $(OH)_2$ nanowires have been fabricated successfully, and the surface roughness were further improved. Then, modified with n-octadecanethiol (ODT), the copper wires showed great superhydrophobicity. The surface superhydrophobicity of the copper wires guarantees the efficient lubrication with silicone oil. After silicone oil impregnation, the surface wettability changed from superhydrophobicity to hydrophobicity, and the wettability decreased.

Superhydrophobic copper wires and hydrophobic copper wires were used to prepare the integrated mesh, respectively. Glue the copper wires to one side of the polystyrene box at a certain distance. In the same way, copper wires are glued to adjacent side in an orthogonal manner. The manipulating modes of the droplet can be efficiently switched via the 90° rotation of the IMAS. In order to find the best results during the experiment, double-sided adhesive was used to adhere the copper wire to the box which should be replaced with a more stable other adhesive or other strong bonding methods in practice application. In order to accurately control the mesh aperture should be replaced by other accurate methods.

Characterization

The surface morphologies and microstructure of as-prepared samples were observed by a field emission scanning electron microscope (FESEM, JSM-6701F). To analyse the content of chemical elements of the sample, energy dispersive spectroscopy (EDS, JSM-5600LV) with an EDAX system attached to the FESEM, and X-ray photoelectron spectroscopy (XPS, Thermo Scientific ESCALAB 250Xi, Physical Electronics, USA) using Cu Kα X-ray source. The water contact angle of 5 μL were obtained by a JC2000D goniometer (Zhongchen Digital Equipment Co. Ltd., Shanghai, China). The adhesion forces of the sample were tested by a highly sensitive microelectromechanical balance system (DCAT25, Data-physics, Germany). Firstly, hang water droplets (5 μL) with a metal ring hanging from a metal balance. The sample placed on the balance is moved upward at a constant speed of 0.05 mm/s, until it comes into contact with water droplets. We set the measuring parameters of microelectromechanical balance system to 0.3 mm of sample compression distance and 5 μL of testing fluids. The lubricant oil content in water was tested by chemical oxygen demand (OCD) meter (Hach DRB 200). Then move the sample down. All optical photos and movies were taken by a mobile phone (Huawei Honor 30).

Mechanical test of IMAS

10 g sand granules (diameter: 200-300 μm) in a funnel were fell down to impinge on the IMAS, and 10 times was defined as one cycle. The height was 20 cm. The angle of the IMAS and the horizontal line is 45°. After 5 cycles, the water contact angles of the sample were measured. (Fig. S1a). Then the surface wear experiment was tested by sandpaper (grit no. 1000). Drag the sandpaper on the sample for 4cm at a weight of 50g. Ten times was defined as one cycle, and the surface contact angles of five cycles were measured. (Fig. S1b)

Droplet directional transport properties measurements

The sample was fixed on the platform in an open environment. The aperture of the integrated mesh was fixed, and the unidirectional droplet manipulation requirements of IMAS were studied by changing the inclination angle and droplet volume. The video recording was performed with mobile phone.

Water collecting measurements

A homemade fog collector system was prepared to explore the water harvesting performance of IMAS. Fixing the as-prepared samples on the holder and keeping the sample parallel to the fog outlet in an open environment (Fig. S2). Here, the distance between the fog outlet and sample was 5 cm. The distance between the container and sample was 20 cm. The fog flow rate was 0.0556 g/s, and the fog velocity was approximately 25 cm/s. The temperature and relative humidity were controlled at 15 ℃ and 70 %, respectively. The collected water droplets from the IMAS can fall into the container by gravity. This unique droplet manipulation capability is demonstrated by observing droplet control during fog collection.

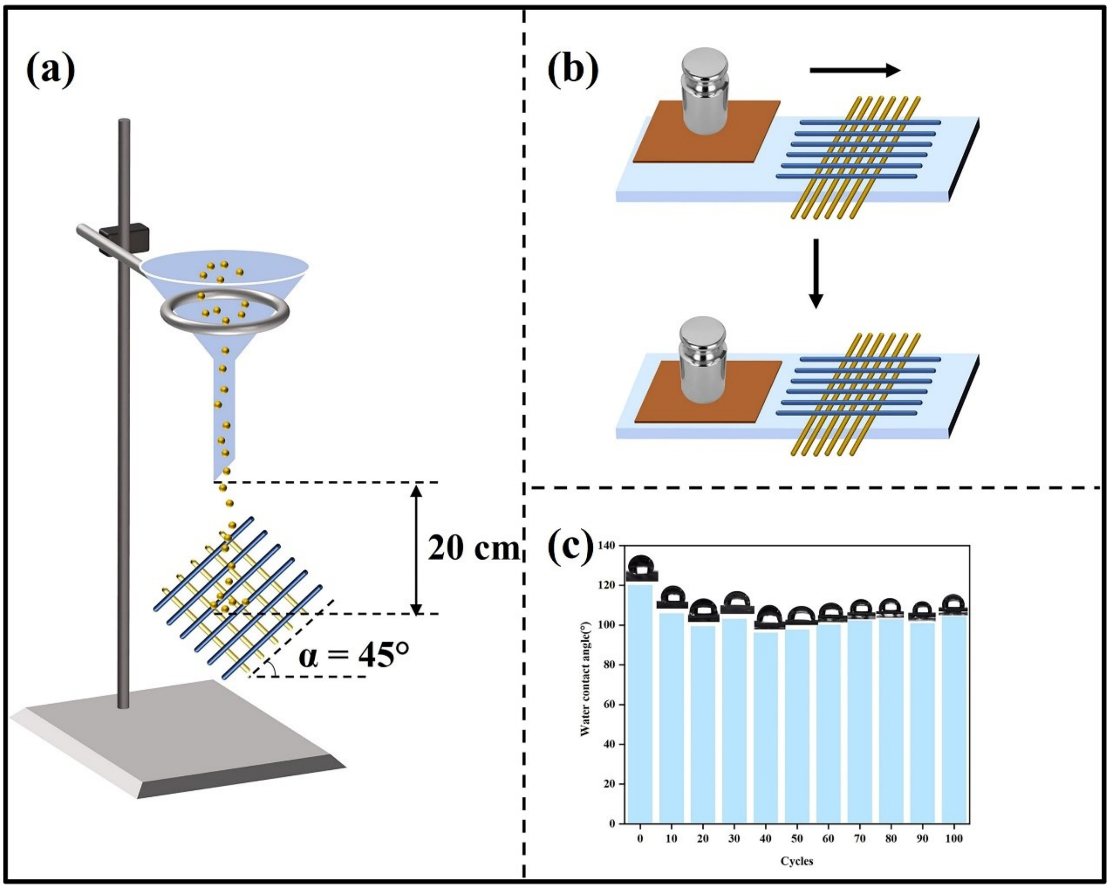

Fig. S1. Mechanical test of IMAS (a) Schematic diagram of sand impact test device and method. (b) Schematic diagram of the sandpaper abrasion device and method. (c) Contact angle after sand impact and abrasion test. 0-50 times are sand impact test, 50-100 times are abrasion test.

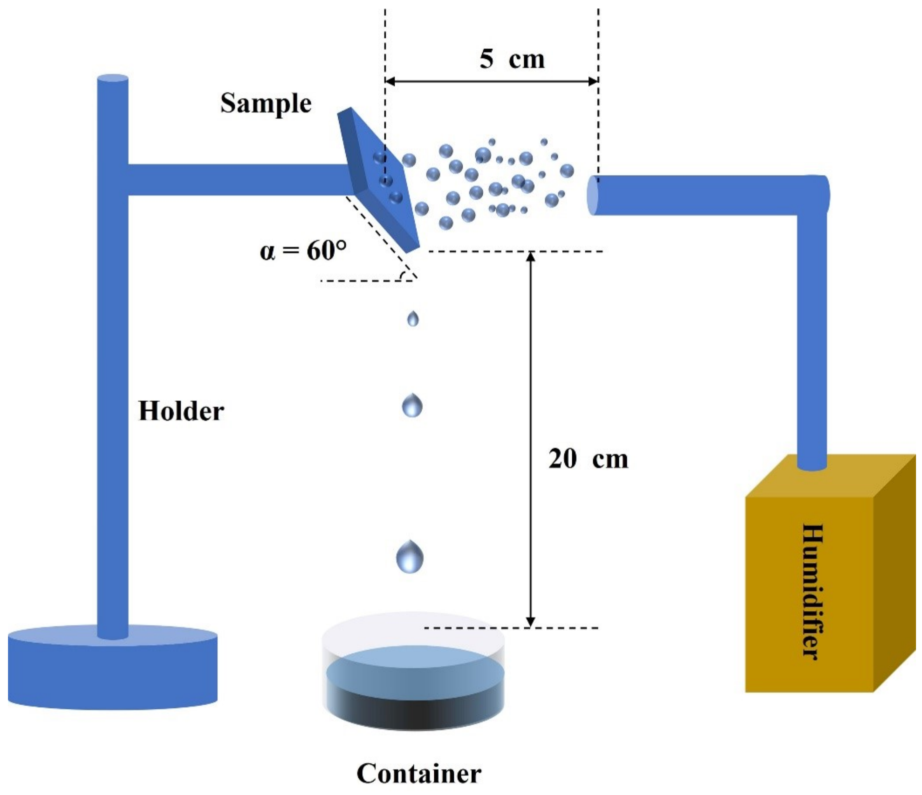

Fig. S2. Schematic diagram of the water collection device.

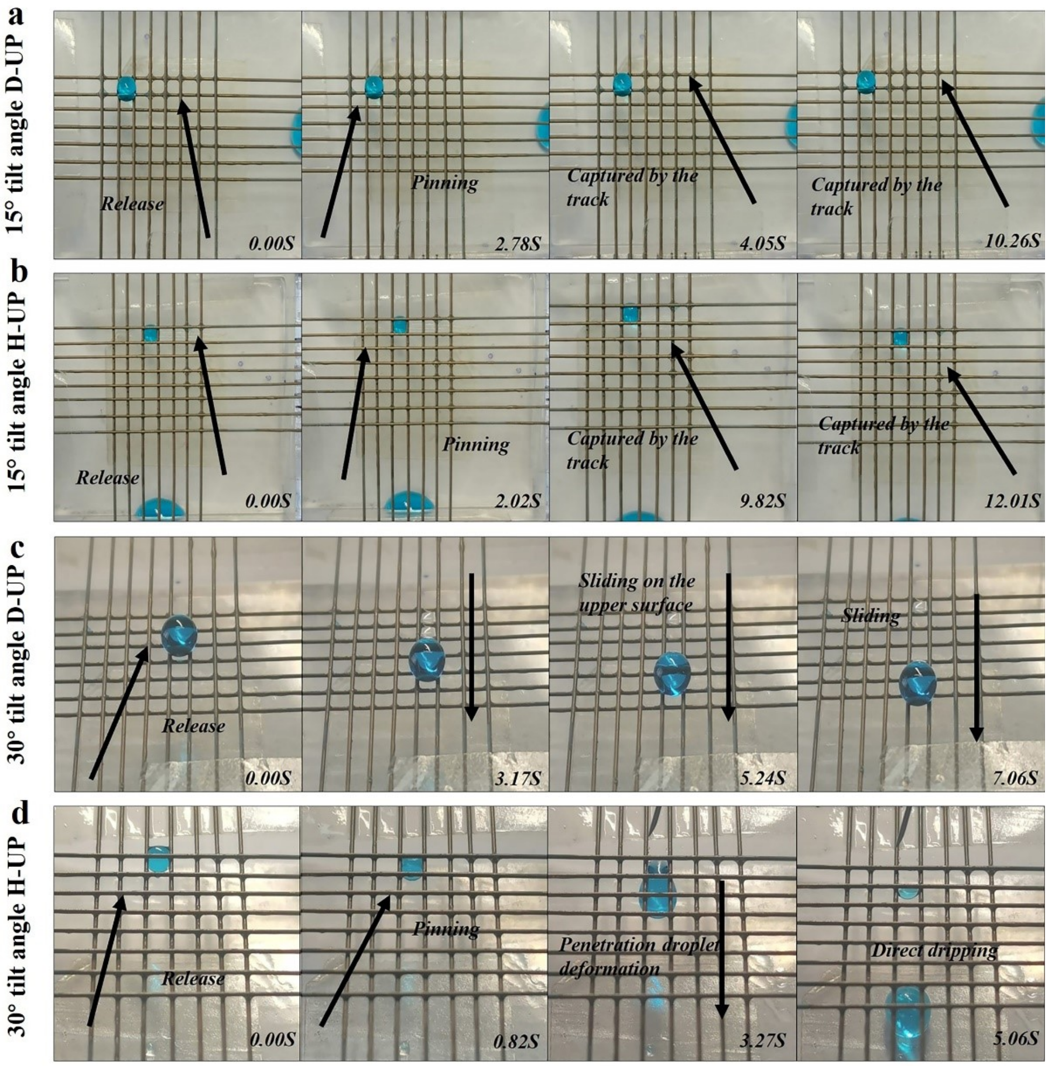

Fig. S3. The droplet manipulation on the IMAS with a small tilt angle. (a) 15° tilt angle with D-track up mode. (b) 15° tilt angle with H-track up mode. (c) 30° tilt angle with D-track up mode. (d) 30° tilt angle with H-track up mode.

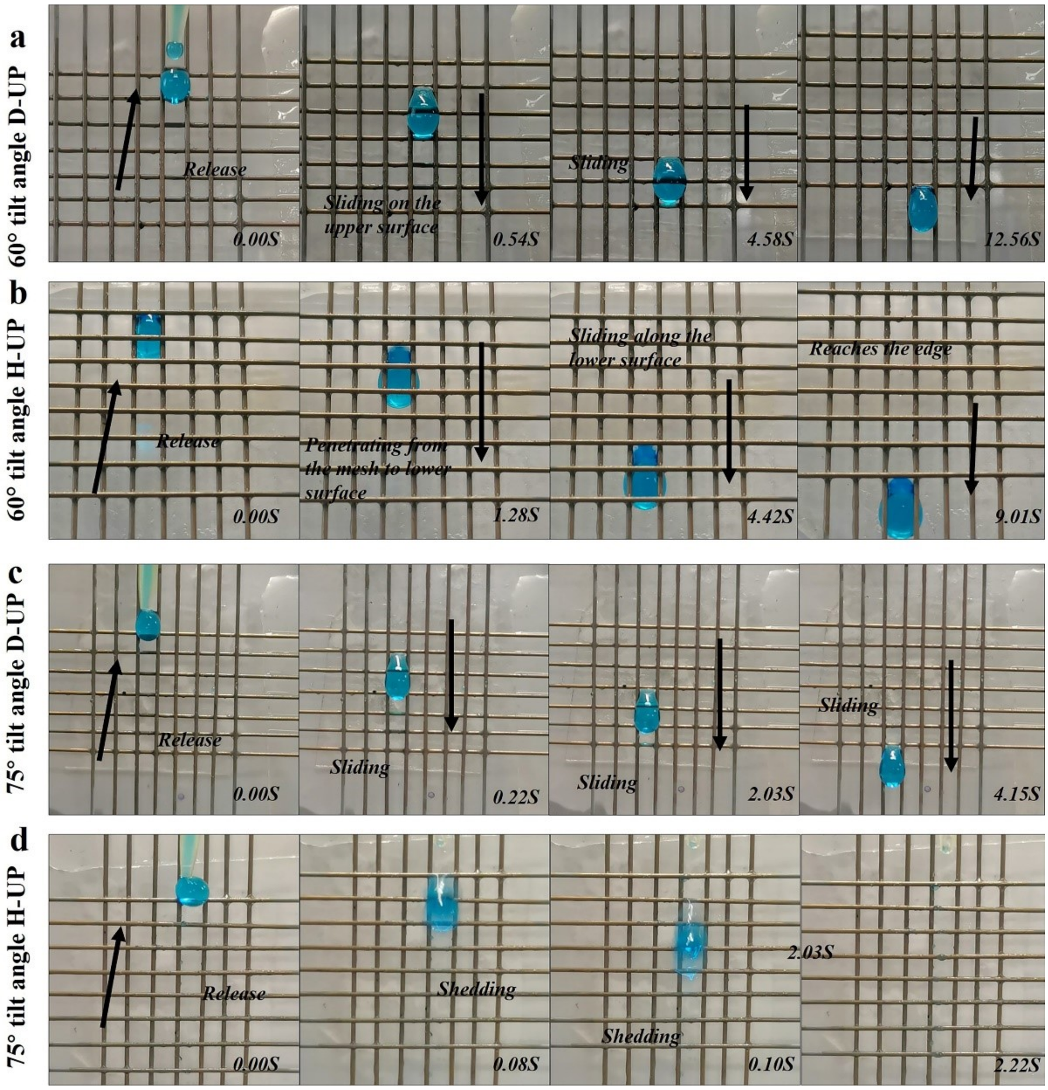

Fig. S4. The droplet manipulation on the IMAS with a large tilt angle. (a) 60° tilt angle with D-track up mode. (b) 60° tilt angle with H-track up mode. (c) 75° tilt angle with D-track up mode. (d) 75° tilt angle with H-track up mode.

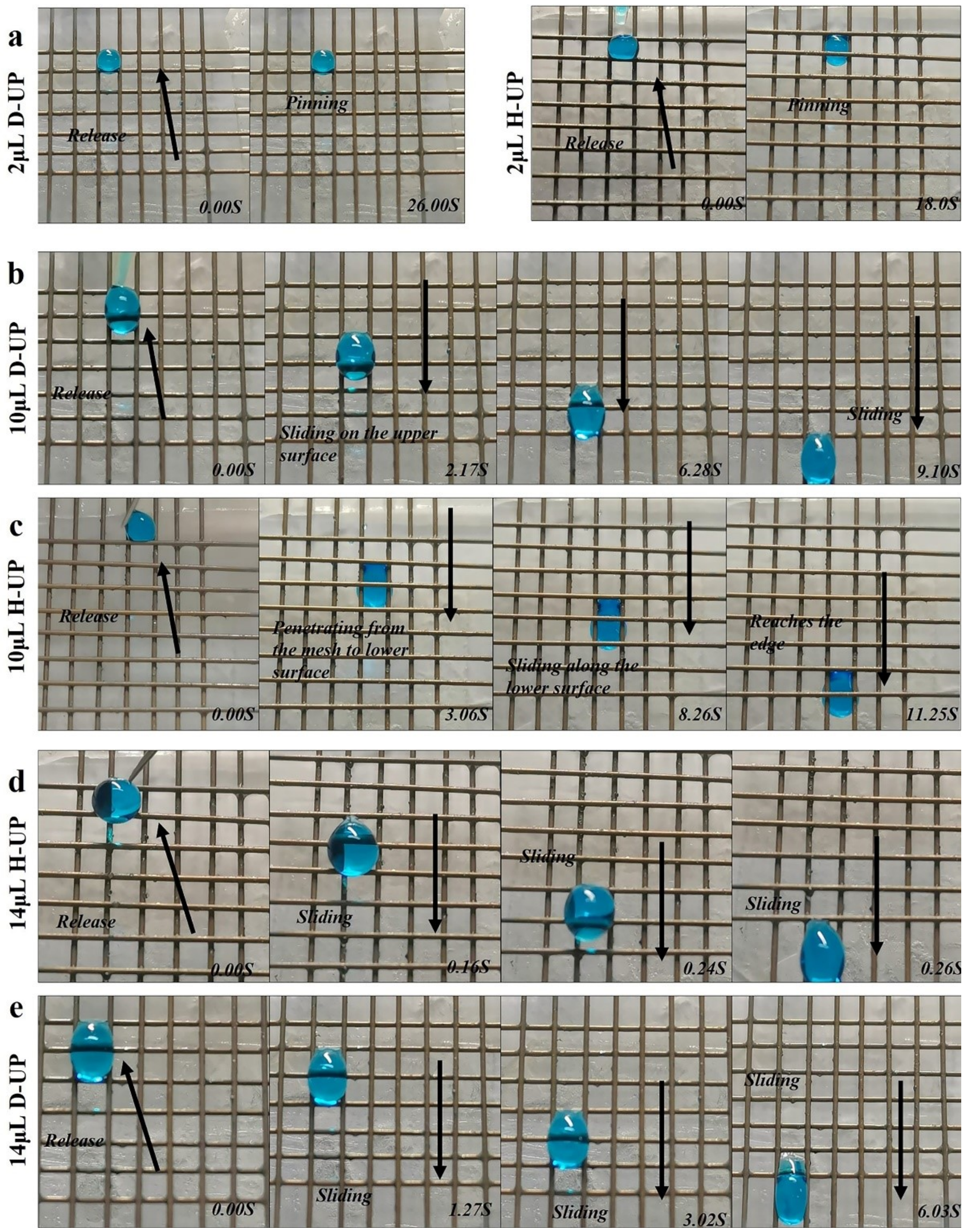

Fig. S5. The effect of droplet volumes on the slipping modes of IMOAS. The mode diagram of droplet behavior on the IMOAS with a pore-size of 2 mm under a tilt angle of 45°. A 2μL droplet with (a) D-UP mode and H-UP mode. A 10 μL droplet with (b) D- D-UP mode and (c) H- D-UP mode. A 14 μL droplet with (d) D- D-UP mode and (e) H- D-UP mode.

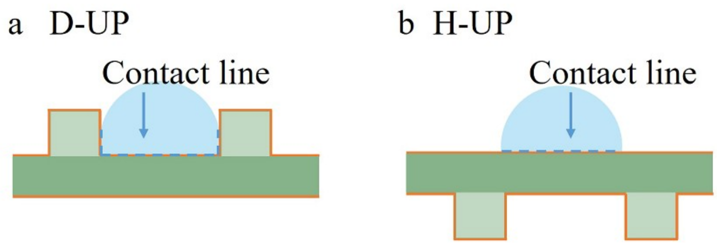

Fig.S6. Droplet contacts the specific surface of the IMAS, indicating the obvious difference in contacting area.

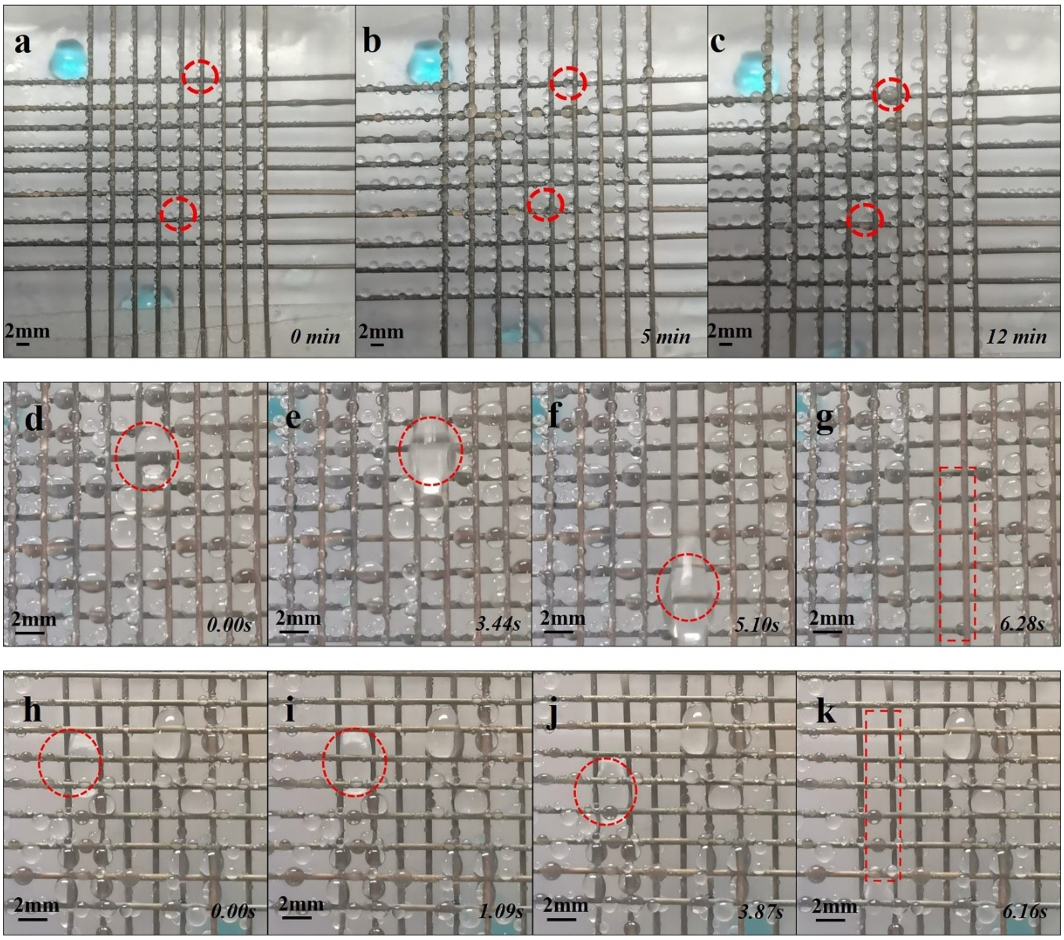

Fig.S7. (a-c) Process of merging and removing water droplets in the water collection. The unidirectional droplet manipulation during fog harvesting. Microdroplet in fog flow were captured by the tracks, and the collected droplet can be effectively controlled by complying with the mechanism described above. (d-g) When the D-UP, all the collected droplets are on the upper surface of the IMAS. After accumulating to a certain volume, it slides along the upper surface. (h-k) As the H orbit goes up, the collected droplets penetrate the lower surface and slide away with the smaller droplets.

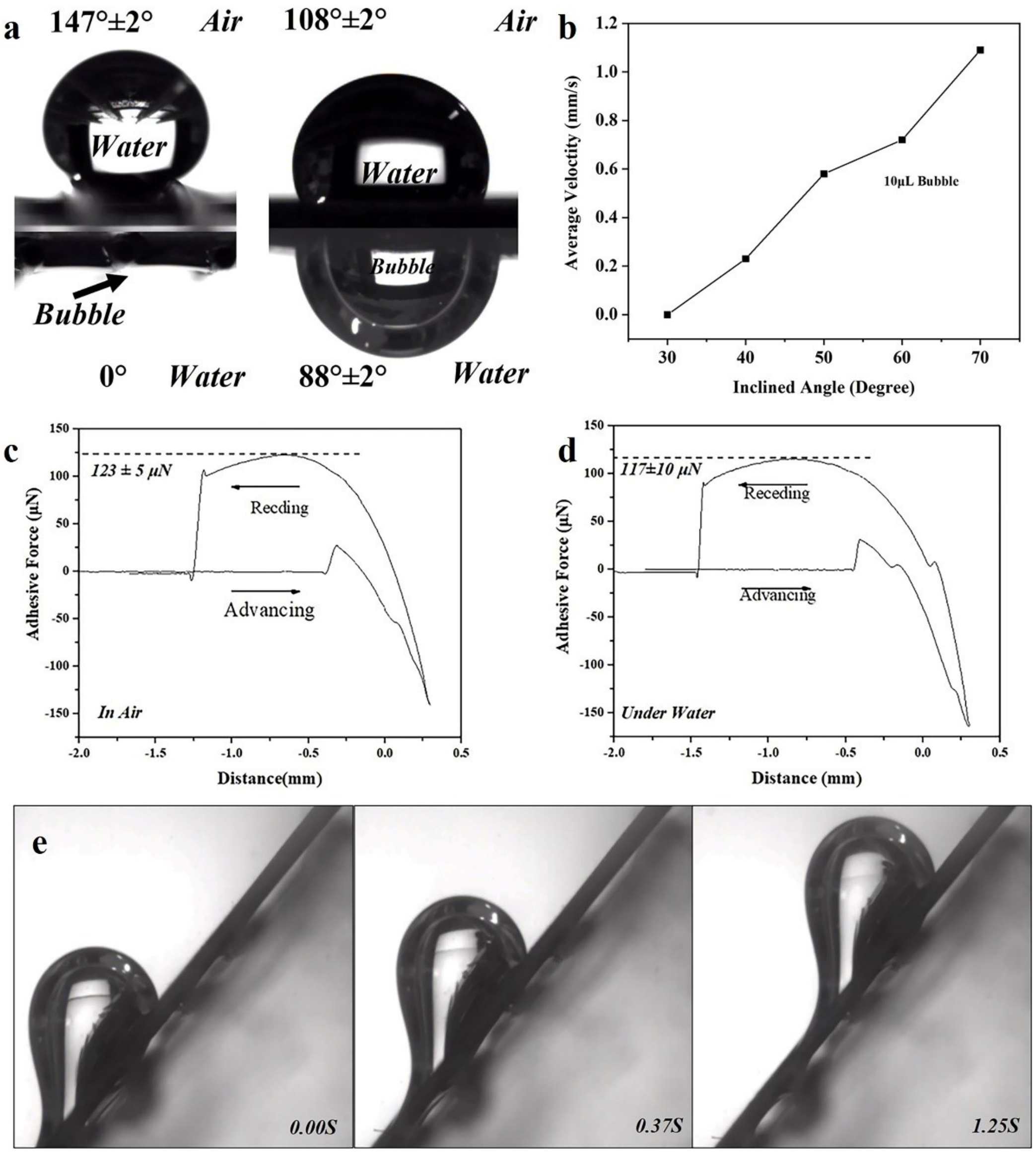

Fig.S8. (a) Images of in air WCA and underwater BCA of the SHB integrated mesh and the HB integrated mesh. (b) With the increase of substrate tilt, the bubble velocity enhanced obviously due to the enlarged driving force. The fluids interacting forces of the IMAS surface, including (c) the water adhesion in air and (d) the bubble adhesion under water, can be directly obtained using the microbalance system. (e) A 10 μL bubble was slid on the IMAS at a 50° tilt.

Movie S1

Droplet motion state of superhydrophobic integrated mesh.

Movie S2

Droplet movement of lubricant impregnated mesh at 45° inclination angle.