

Supporting Information:

Integrative Bioinspired Surface with Wettable Patterns and Gradient for Enhancement of Fog Collection

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Supplementary Analysis I

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Figure S1:

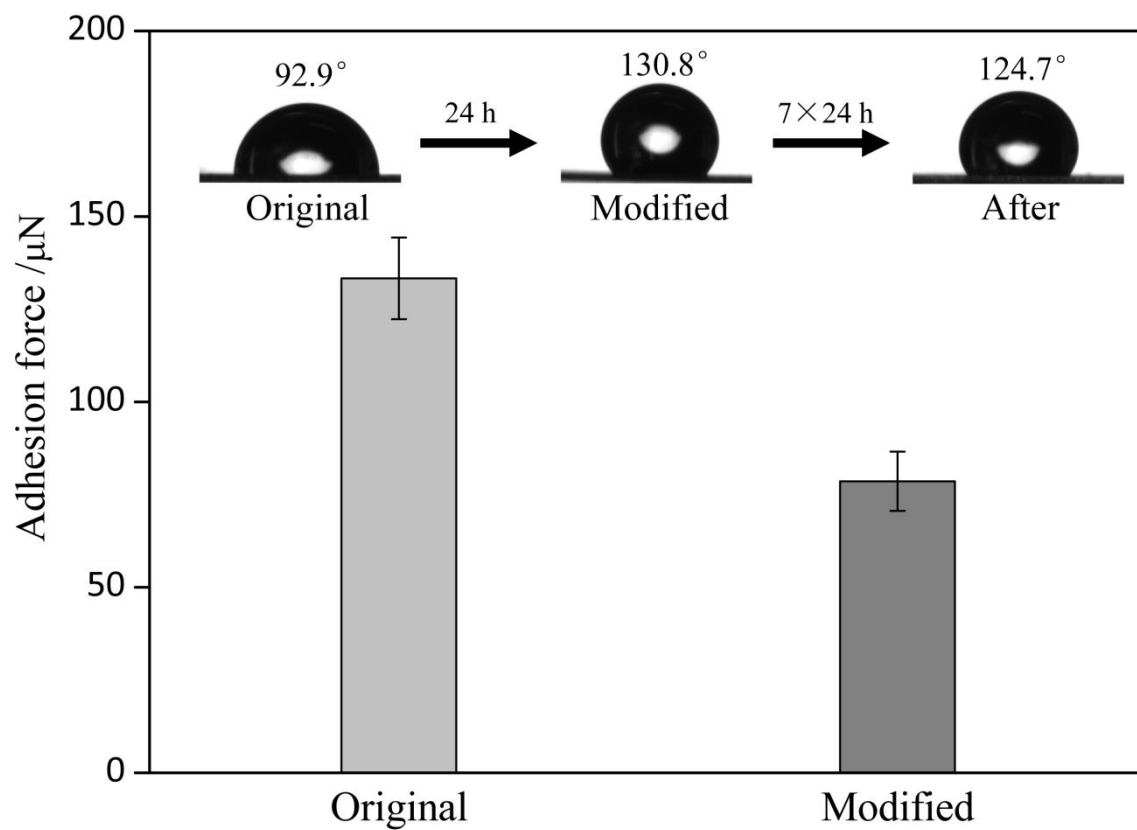


Figure S1 CA and adhesion force on original and dodecanethiol solution modified copper substrate. CA of the substrate increases from 92.9° to 130.8° after treatment by dodecanethiol solution. In addition, the CA changes little in the air under room temperature in a week. At the same time, the adhesion force decreases significantly from 133.3 μN to 78.6 μN after modification.

Figure S2:

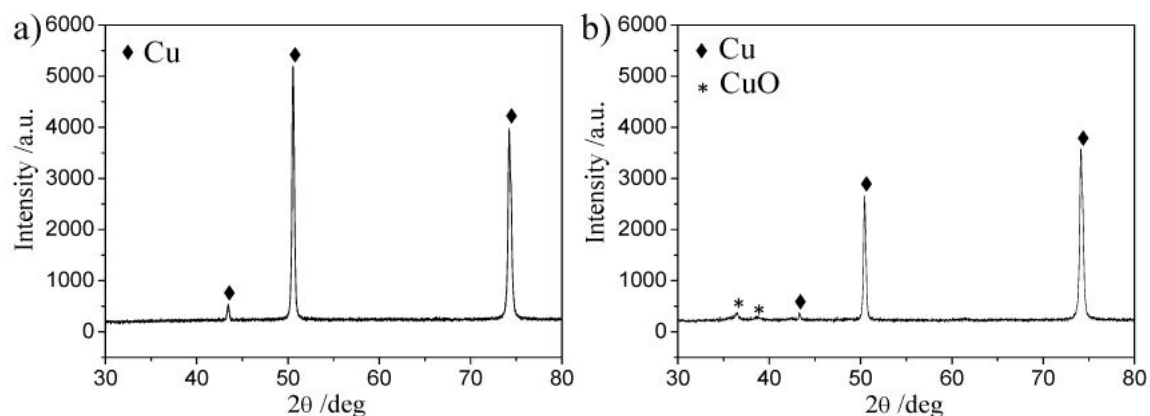


Figure S2 X-ray diffraction (XRD) patterns of the copper plates (a) before mask-based gradient anodic oxidation (MGAO) and (b) after MGAO treatment under current 0.12 A for 3 min. For the original copper plate surface, the peaks marked with diamond can be indexed to Cu substrate (JCPDS card No.85-1326). For the MGAO treated copper plate, except the peaks of Cu substrate, two other diffraction peaks marked with asterisk can be indexed to CuO tenorite phase (JCPDS card No. 80-1916), which indicates the generation of synthesized CuO on the copper substrate after MGAO.

Figure S3:

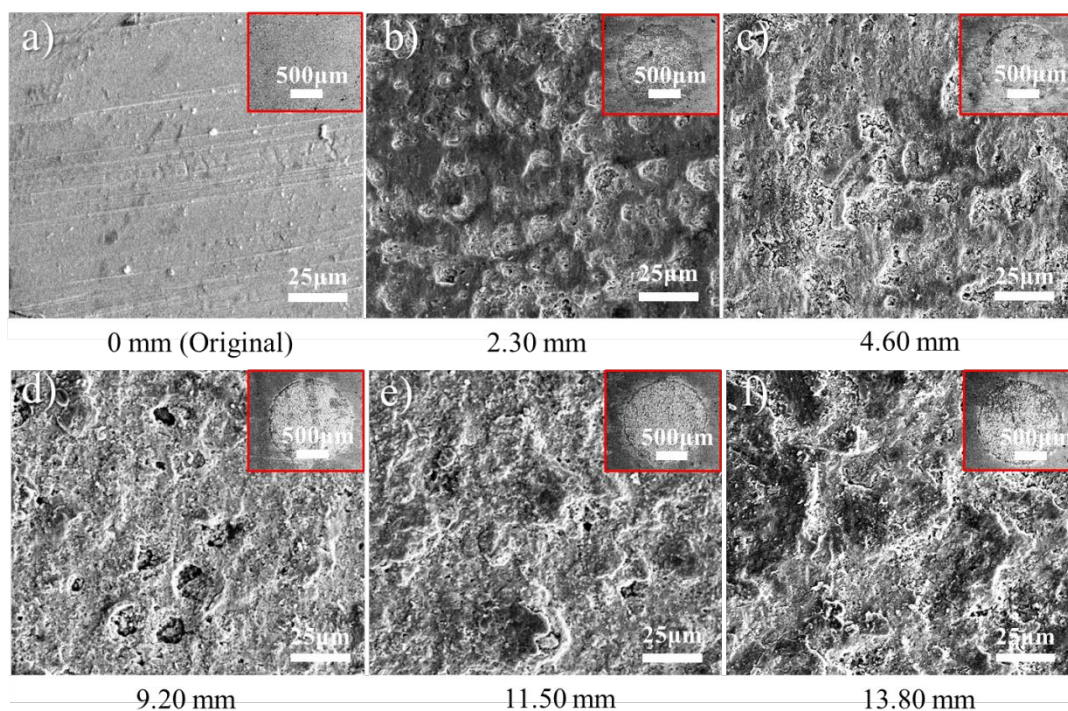
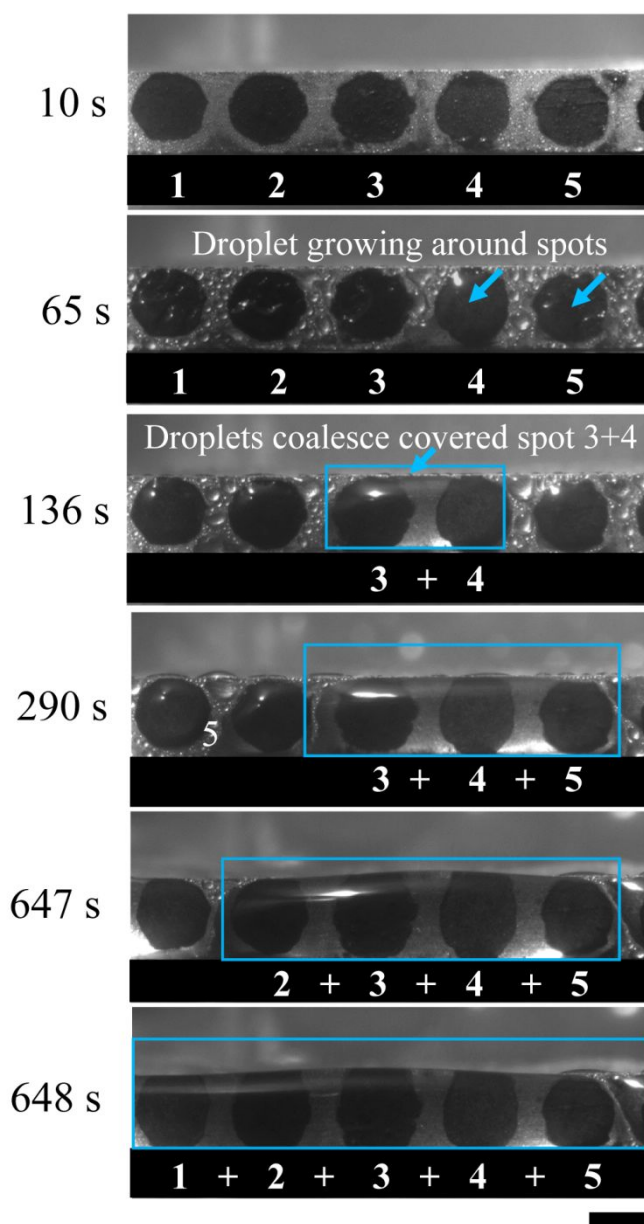


Figure S3 SEM images of different oxidized areas of the patterned copper surface along the wettable gradient direction under low magnification (insets at the top-right corner) and high magnification. (a) 0 mm , (b) 2.30 mm, (c) 4.60 mm, (d) 9.20 mm, (e) 11.50 mm, (f) 13.80 mm (distance to the top end). It is clear that the substrate turns rough after treatment due to oxidation etching effect. While, after treatment, the images of different areas show little difference between each other.

Figure S4:



Coalesce in situ to formed a water film

Figure S4 The normal HHPS Sample-C with $D/S = 1.5 \text{ mm}/1.8 \text{ mm}$, the merged droplets coalesce on the surface in situ. Scale bars, 1 mm.

Figure S5:

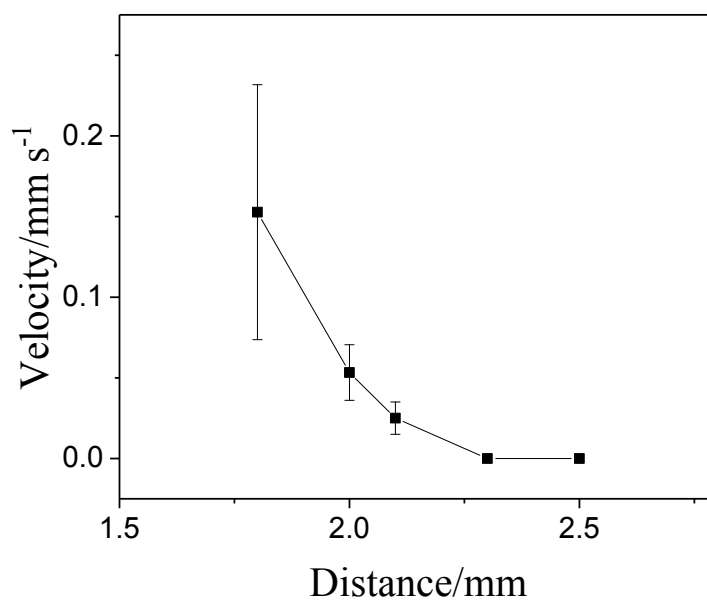


Figure S5 The relationship between velocity of droplet and separation distance between patterns (S).

Figure S6:

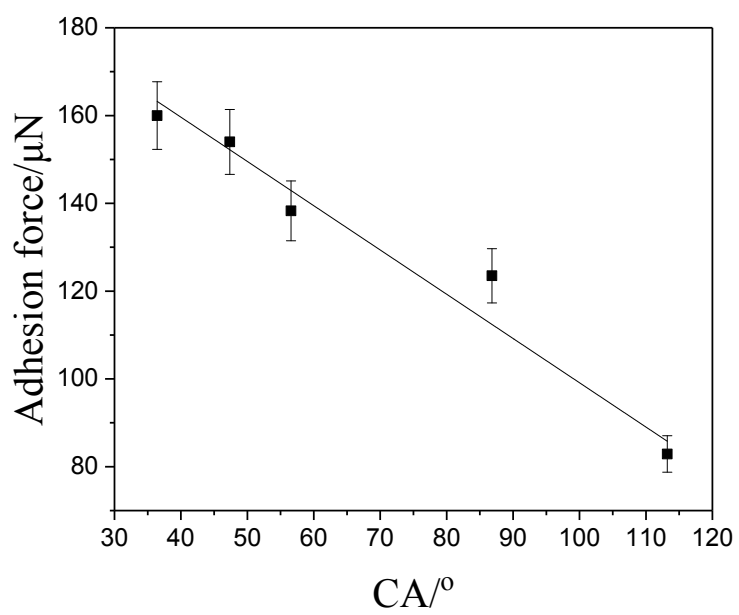


Figure S6 The relationship between adhesion force and contact angle.

Figure S7:

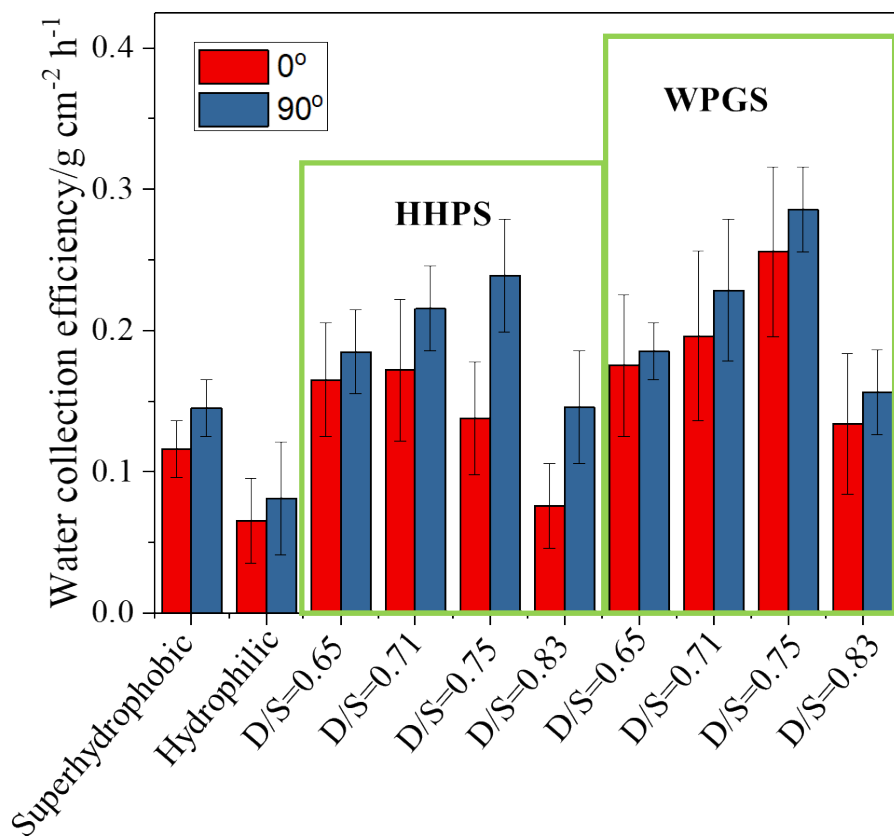
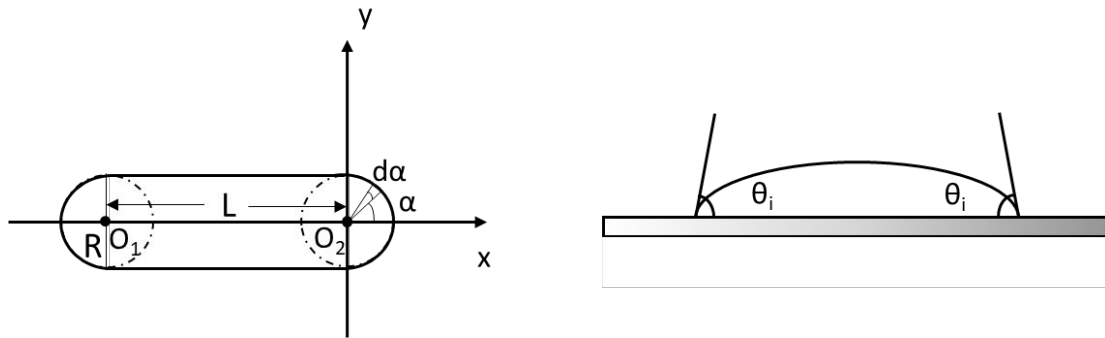


Figure S7 Water collection efficiency comparison of hydrophobic surface, hydrophilic surface, HHPS and WPGS with different tilt angles with the horizontal. The red bar is 0° and the blue bar is 90°.

Supplementary Analysis I:

We analyze the forces exerted on the coalesced droplet during the coalescence process.



During the coalescence process, due to the existence of excess interface free energy (IFE) which results in IFE greater than the corresponding equilibrium value, the coalesced droplet in initial state is usually in an unstable state. The coalescence driving force (F_D) is induced, which is attributed to the difference of surface tension component on surface between unstable and equilibrium states. The F_D is described as:

$$F_D = 2\pi R\gamma(\cos\theta_i - \cos\theta_E)$$

(1)

Where R is the radius of the circle pattern, γ is the surface tension of water, θ_i is the apparent contact angle of the initial state of coalesced droplet, θ_E is the equilibrium contact angle. The coalesced droplet has a tendency to convert

itself to equilibrium state through base radius reduction, which leads to the decrease of the IFE. Therefore, the direction of F_D on the both side of droplet is different (on the left side, the driving force (F_{LD}) points to right end; on the right side, the driving force (F_{RD}) points to left end). On a wettable surface, under effect of the Laplace pressure within the drop, coalesced droplet tends to create nearly equal contact angles both edges (θ_i), but the equilibrium contact angle (θ_{EL}) on the left side is greater than that (θ_{ER}) on the right side. Therefore, F_{LD} is larger than F_{RD} and the direction of F_D ($F_D = F_{LD} - F_{RD}$) points to the direction of wettable gradient.

$$\begin{aligned} F_D &= 2R\gamma(\cos\theta_i - \cos\theta_{EL}) - 2R\gamma(\cos\theta_i - \cos\theta_{ER}) \\ &= 2R\gamma \left[-2\sin\left(\frac{\theta_{EL} + \theta_{ER}}{2}\right) \sin\left(\frac{\theta_{ER} - \theta_{EL}}{2}\right) \right] \end{aligned} \quad (2)$$

where θ_{EL} , θ_{ER} are the left and right position sessile CA of the coalesced droplet in equilibrium state. Due to the little difference between θ_{EL} and θ_{ER} , $\sin[(\theta_{ER} - \theta_{EL})/2] \approx (\theta_{ER} - \theta_{EL})/2$, we can simplify the equation into form as following:

$$\begin{aligned} F_D &\approx 4R\gamma \sin\theta \frac{k(L + 2R)}{2} \\ &= 2R\gamma k(L + 2R) \sin\theta \end{aligned} \quad (3)$$

θ is the center position-responsive sessile CA of coalesced droplet, k is the average wettable gradient, L is the length of O_1O_2 (O_1O_2 is the line of the center of the two circles).

As is well known, the wettable gradient force (F_w) induced by surface energy gradient would drive droplet towards the more wettable region of surface, which can be described by the diverse CAs of the two side of the coalesced droplet:

$$\begin{aligned} F_w &= 2\gamma \int_0^{\frac{\pi}{2}} R \cos \alpha (\cos \theta_{ER} - \cos \theta_{EL}) d\alpha \\ &= 2\gamma R \int_0^{\frac{\pi}{2}} -2 \sin \theta \sin \frac{\theta_{ER} - \theta_{EL}}{2} \cos \alpha d\alpha \end{aligned} \quad (4)$$

Where α is the polar angle. Due to the little difference between θ_{EL} and θ_{ER} , $\sin[(\theta_{ER}-\theta_{EL})/2] \approx (\theta_{ER}-\theta_{EL})/2$, we can simplify the equation into form as following:

$$\begin{aligned} F_w &\approx 2\gamma R \int_0^{\frac{\pi}{2}} \sin \theta [k(L + 2R \cos \alpha)] \cos \alpha d\alpha \\ &= (2L + \pi R) R \gamma k \sin \theta \end{aligned} \quad (5)$$

The hysteresis force rises from the resistance on three-phase contact line. It is hard to measure the exact hysteresis force directly on WPGS so that we use adhesion force to take the place of hysteresis force. We tested the adhesion forces on different hydrophilic patterns, and found a linear relationship between adhesion forces and water contact angles, as shown in Figure S6, it can be described as:

$$F_H = 197 - 0.96\theta \quad (6)$$

To simplify the calculation, we shall assume that the adhesion force is proportional to the length change of three phase contact line. Finally, the adhesion force of coalesced droplet on WPGS can be described as:

$$F_H = \frac{R(197-0.96\theta)}{r_c} \quad (7)$$

Where r_c is the radius of the contact area of the droplet during the adhesion force test.