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Supporting Information

Multiple Functional Materials from Crushing Waste Thermosetting Resins

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Experimental Section

Materials

E-51 epoxy resin and curing agent, 4, 4-diaminodiphenyl methane (DDM) were provided by Bluestar Chemistry Company and Aladdin Chemistry Company, respectively. Phosphoric acid (H_3PO_4, ≥85 wt%), hydrochloric acid (HCl, 36 wt%), sulfuric acid (H_2SO_4, 98 wt%), nitric acid (HNO_3, 65 wt%), acetic acid (CH_3COOH, ≥99.5 wt%), ammonia ($NH_3•H_2O$, 25 wt%), Ferric chloride, sodium hydroxide, acetone, n-hexane, chloroform, toluene, and ethanol were purchased from Chengdu Kelong Chemical Reagent Company (China). Polydimethylsiloxane (PDMS, Sylgrad-184) was obtained from Dow Corning. Gasoline and diesel were purchased from local stores. All chemicals were directly used as received without further purification.

Simple oil-water mixture separation

The crushed epoxy resin particles (CEPs) with different sizes were fabricated using a pulverizer. 0.25 g CEPs were first packed in a cylindrical polytetrafluoroethylene (PFTE) mold (hollow diameter =1 cm, height =0.5 cm), and 800 mesh stainless steel welded mesh (SSWM) was used as a gasket above and below the CEP column. Next, the as-prepared CEPs filter column was inserted in the separation apparatus and 20 mL mixture of chloroform and water (1/1, v/v) was poured into the upper tube. Then, chloroform quickly passed through the CEPs filter column while leaving the water on the top. The separation process is gravity-driven. The separation efficiency is determined by measuring the water quality before and after separation. The flux with respect to filtration time during every separation cycle was recorded.

Water-in-oil emulsions separation

Five kinds of water-in-oil emulsions were prepared in this study. First, 0.1 g Span-80 was added in 99 mL organic solvents (n-hexane, chloroform, toluene, gasoline or

diesel, respectively), followed by 1 mL water. Then, the surfactant-stabilized water-in-oil emulsions were obtained by using an emulsifier with a stirring rate of 8000 rpm for 15 min.

The phosphoric acid-modified particles (HEPs) were prepared as following: 1 g CEPs were immersed in 10 mL phosphoric acid at 80°C. After stirring for 30 min, the mixture was filtered to obtain solid particles. The residual acid on the particles surface was subsequently washed with deionized water. The obtained particles were dried in an 80°C oven before use.

To evaluate separation property of HEPs for water-in-oil emulsions, 1 g HEPs were first equipped in the above home-made separation device. Then the newly prepared water-in-n-hexane emulsion was poured into HEPs filtration column and spontaneously penetrated quickly under the driving of gravity. During the separation process, the emulsion was kept at a relatively stable liquid level of $\approx$3.5 cm. The permeation flux was determined by calculating the filtrate volume of at a fixed time of 1 min. The separation efficiency was calculated by measuring the water content of the feed emulsions and the corresponding filtrates using Karl Fischer titrator.

Preparation of superhydrophobic surfaces

For strong adhesive hydrophobic surfaces, first, 4 g E-51 epoxy resin was dissolved in 40 mL acetone, and 1 g DDM was added under stirring. Then, the resulting solution was uniformly dripped onto a glass plate. When the most of solvent was evaporated, the CEPs with a particle size of 0.075 mm or less were spread on the adhesive layer. After 3 min, the excess CEPs were blown away with an ear wash ball. Finally, the CEPs deposition was pre-cured at 80°C for 2h and followed by a post-cure at 120°C for 3 h in an oven. While for weak adhesive superhydrophobic surfaces, the process is almost the same except a different adhesive was used. Instead, 1 g PDMS and 0.1 g

curing agent were dissolved in 10 mL n-hexane for use. After cured at 80°C for 4h, weak adhesive CEPs coating was obtained. The water contact angle of hydrophobic surfaces was measured by JC2000D2H Powereach using a 5 mL droplet as the indicator. Adhesive force was tested on a high-sensitivity microelectromechanical balance (DCAT 25 from Data Physics Instruments) with a constant moving speed of 0.02 mm s^{-1} at room temperature, and the volume of water droplet was 4 μL.

Density and porosity of filter column

For filter column consisted of particles, packing density and porosity are important parameters. The stack density, that is, the apparent density, is defined as the weight per unit volume of powdery or granular materials. The calculation formula is as follows:

$$\rho_a = m/V$$

Where, m and V are the weight and volume of the filter column, respectively.

Porosity (ε) is the volume ratio (volume fraction) of the void in particles, and calculated by the following equation:

$$\varepsilon = (1-\rho_a/\rho_P) \times 100\%$$

Here, ρ_P is the true density of particles.

The ρ_P of CEPs is 1.19 g/ cm^3, so the ε of CEPs filter column was approximately 46.22%. For HEPs filter column, the ρ_P is 1.24 g/ cm^3. Thus, the ε was around 43.55%.

Water collection measurements

A superhydrophilic surface with two superhydrophobic circle-shaped patterns was fabricated as follows: first, the glass substrate was cut into plates with the dimensions of 25 × 50 mm^2, and then two circles with a diameter of 20 mm are coated with CEPs according to the preparation process of superhydrophobic surface. In the water collection experiment, the as-prepared samples were fixed on a holder with a 90°

angle from the horizontal plane. The horizontal distance between the test sample and the humidifier was 10 cm. Micro water droplets generated by humidifier were used to simulate a fog flow and then collected on the sample surface. During the measurements, the relative humidity is maintained at 80% and the temperature is 25°C. The quality of the collected water was tested every half hour in a cycle of 4 h.

Acidic liquid and gas detection

The color of the CEPs coating was observed when added in different concentrations of HCl solution for 2 min. The acidic gas detection was conducted in a 500 mL closed container and concentrated HCl was used as the source of acidic vapors. Responsive sensitivity of the CEPs coating was measured by increasing the exposure time to acidic gas and the amount of acidic gas, respectively. The cycle stability of the CEPs coating was also tested.

Information storage

Amine-cured and anhydride-cured CEPs were placed into the different areas of PDMS adhesive layer to form concealed patterns, and then the coating was cured at 80°C oven. After that, the resulting samples were sequentially placed in an acid and alkali solution for color observation.

Table S1. Various wastes with different particle sizes for simple oil-water mixture separation.

Name	The thickness filter column (cm)	Flux (L m^{-2} h^{-1})	Separation efficiency (%)
Unsaturated polyester resin	3	30573	91
Ramie fiber reinforced epoxy resin (Pentaerythritol glycidyl ether)	2	22930	92
Carbon fiber reinforced epoxy resin (Not clear)	2	28662	91
Polyethylene (PE)	2	57325	99
Polypropylene (PP)	2	57325	99
Polyamide-6 (PA6)	2	50955	99
Amorphous poly alpha olefin (APAO)	2	57325	97
Rubber powders	0.5	3057	98
Melamine formaldehyde resin	0.5	35277	94

Table S2. Glass fiber reinforced epoxy resin with various acid treatments for the water-in-oil emulsions separation.

Acid	The thickness of HEPs filter column (cm)	Flux (L m^{-2} h^{-1})	Separation efficiency (%)
HNO_3	2	1529	99
H_2SO_4	2	1223	99

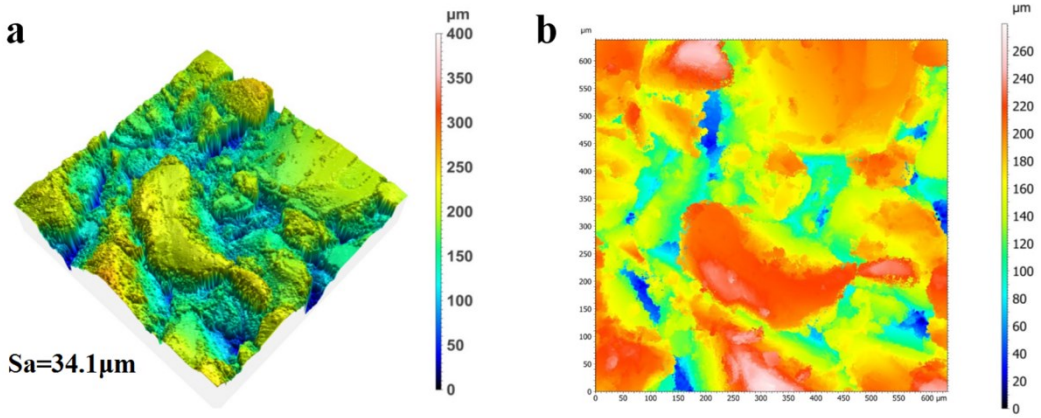


Figure S1. (a-b) LSCM images of CEPs filter column.

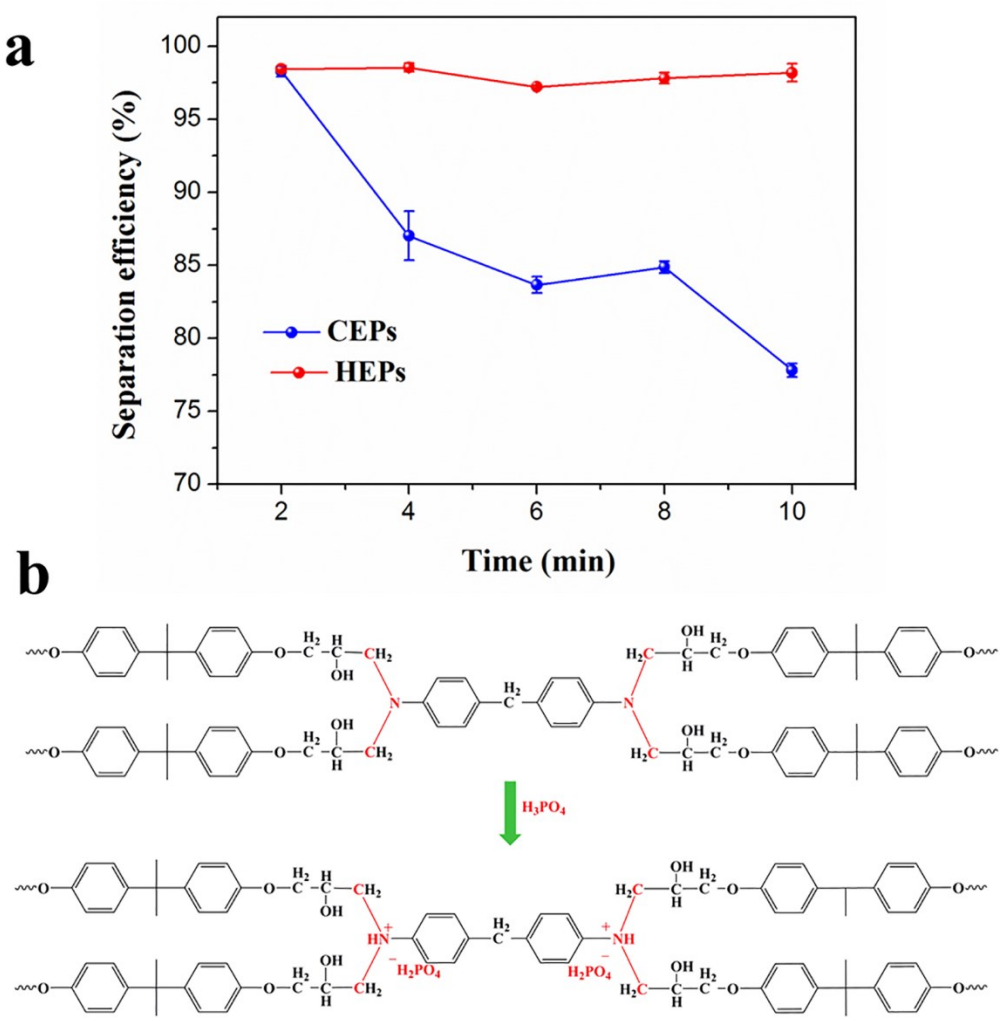


Figure S2. (a) Separation efficiency of surfactant-stabilized emulsions through CEPs and HEPs filter column with different time. (b) EP was protonized by phosphoric acid.

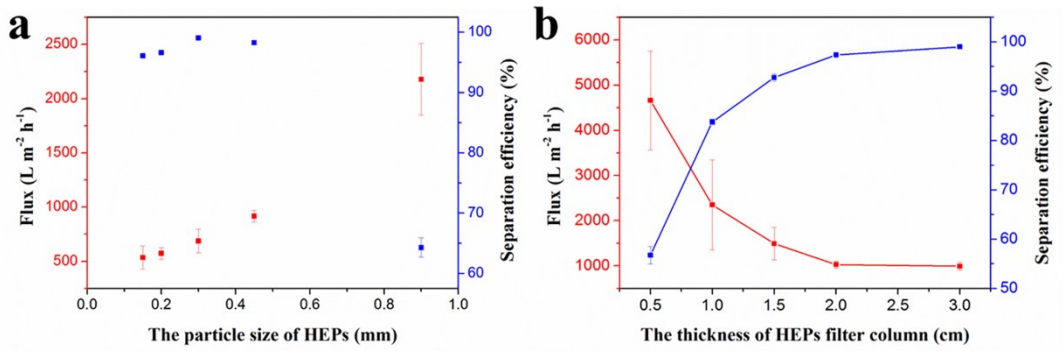


Figure S3. The influence of (a) the particle size of HEPs and (b) the thickness of HEPs filter column on flux and separation efficiency for oil-water emulsion separation.

Figure S3a showed the influence of the particle size of HEPs filter column on flux and separation efficiency. When the particle size of HEPs increased from 0.1 to 0.9 mm, the flux displayed a clear increase, while the separation efficiency was decreased to 64%. In order to balance the flux and separation efficiency, we chose the HEPs with the particle size below 0.45 mm for the subsequent experiments. As shown in **Figure 3b**, the increase in thickness of HEPs filter column resulted in the longer separation channel, corresponding to better separation efficiency. Nevertheless, the change of flux was exactly the opposite. The excellent separation performanc was achieved at the thickness of 2 cm of HEPs filter column.

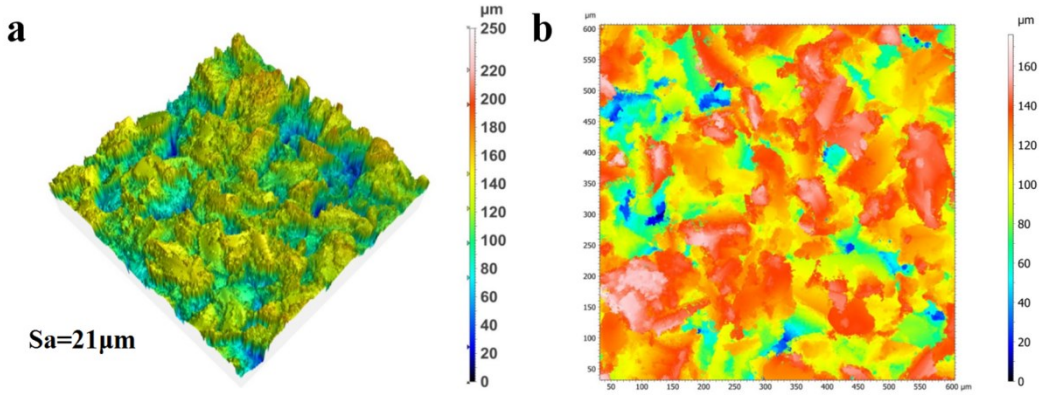


Figure S4. (a-b) LSCM images of HEPs filter column.

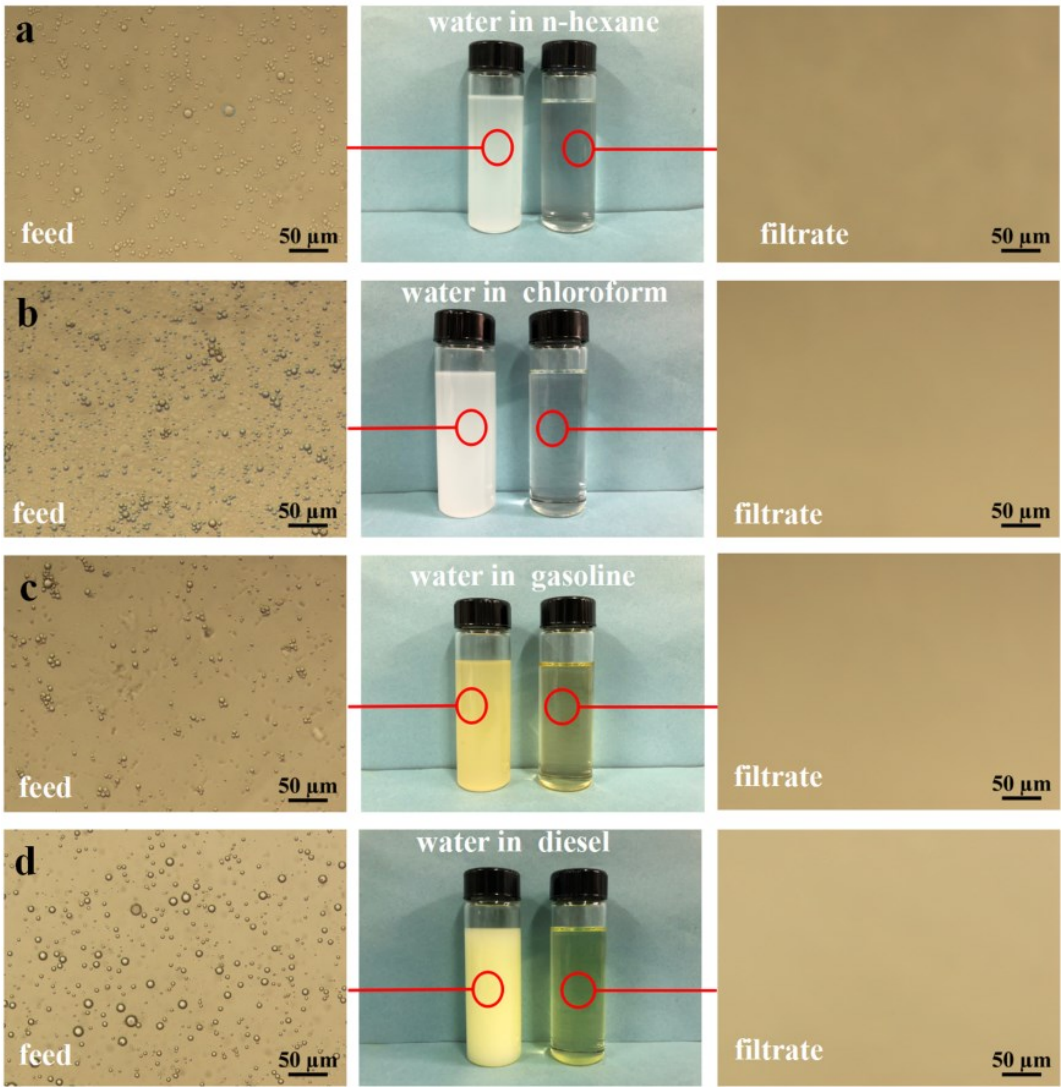


Figure S5. Optical images and photographs of various water-in-oil emulsions before and after filtration: (a) water-in-n-hexane, (b) water-in chloroform, (c) water-in-gasline and (d) water-in-diesel emulsion, respectively.

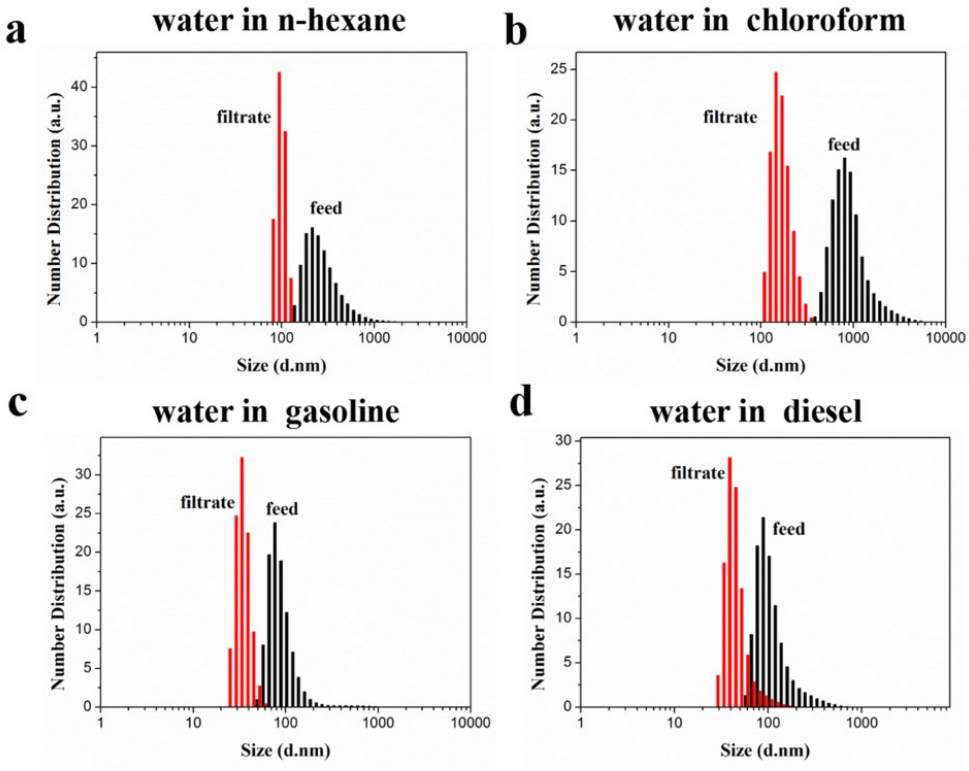


Figure S6. Particle size analysis of various feed emulsions and filtrates: (a) water-in-n-hexane, (b) water-in-chloroform, (c) water-in-gasline and (d) water-in-diesel emulsion.

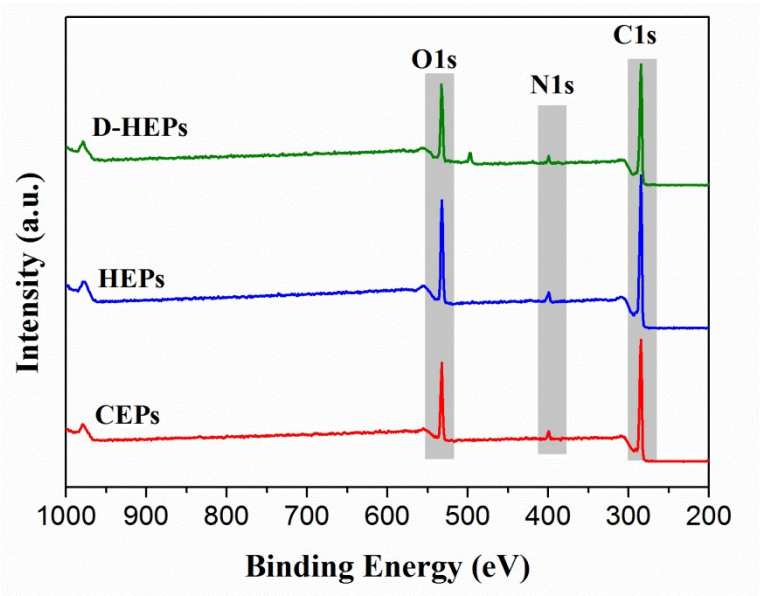
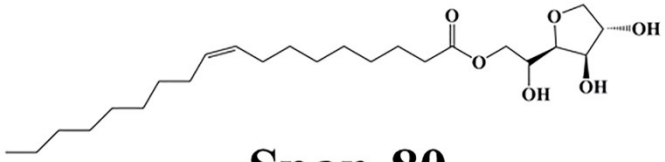


Figure S7. XPS survey scan spectra of CEPs, HEPs and D-HEPs.



Span-80

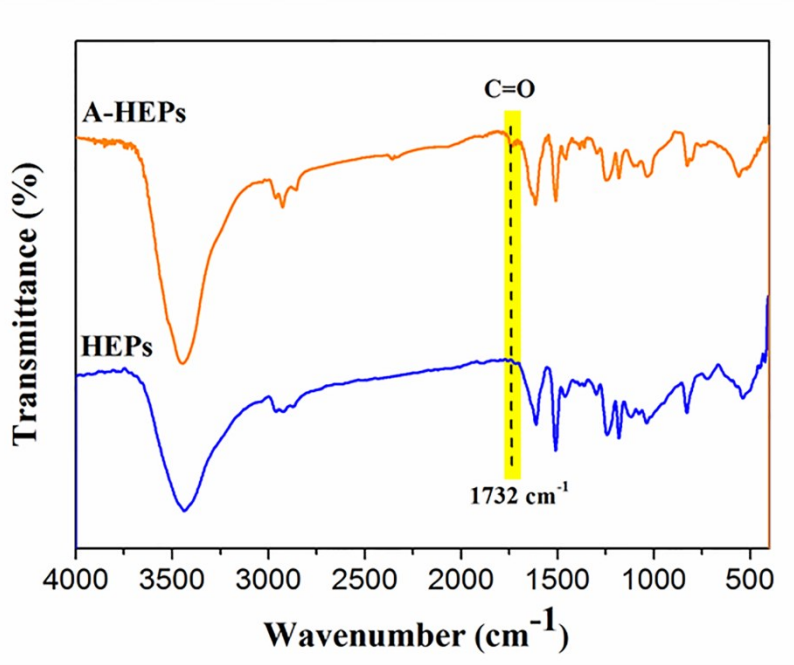


Figure S8. FTIR spectra of the HEPs and A-HEPs.

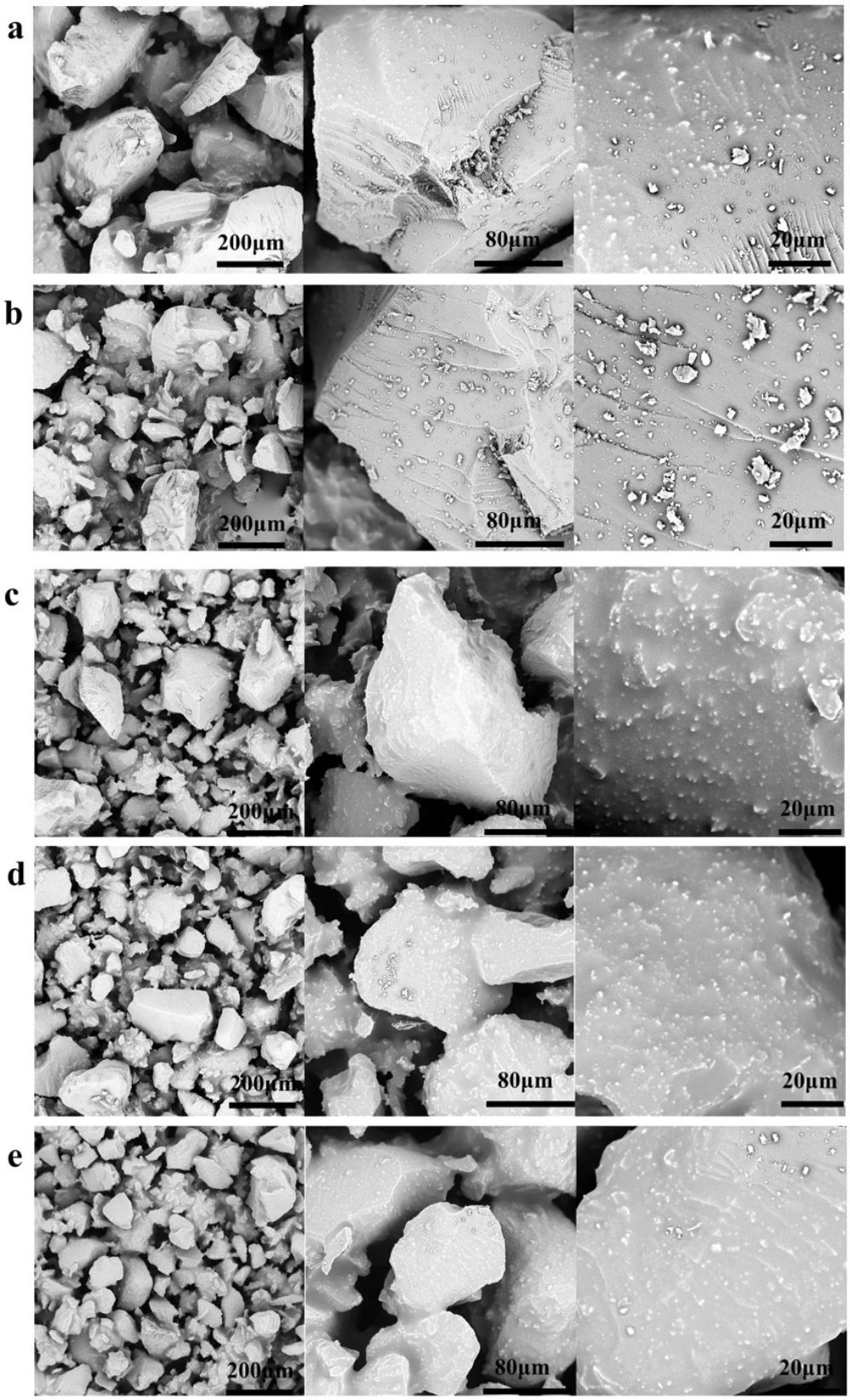


Figure S9. SEM images of HA-CEPs with different sizes, ranging from (a) 0.038-0.9 mm, (b) 0.038-0.45 mm, (c) 0.038-0.3 mm, (d) 0.038-0.2 mm, (e) 0.038-0.15 mm.

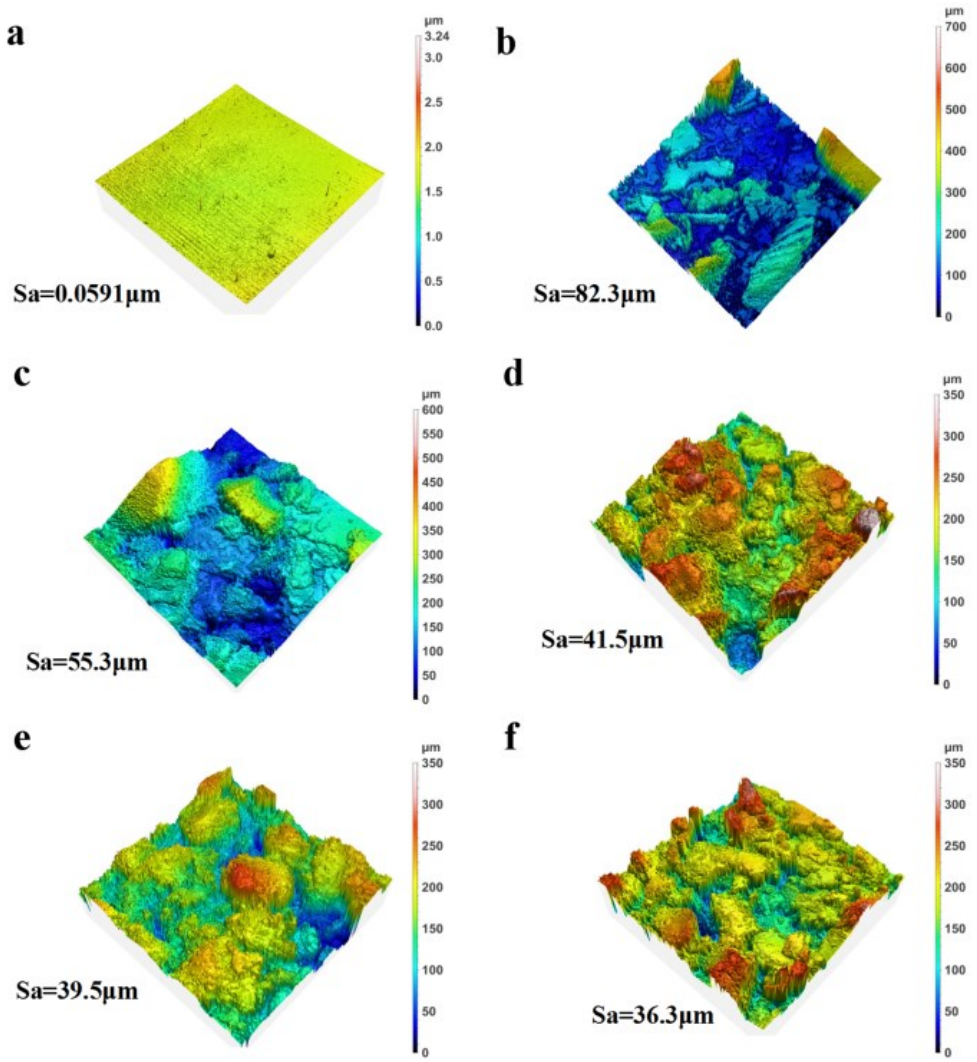


Figure S10. LSCM images of (a) EP adhesive layer and (b-f) HA-CEPs with different sizes, ranging from (b) 0.038-0.9 mm, (c) 0.038-0.45 mm, (d) 0.038-0.3 mm, (e) 0.038-0.2 mm, (f) 0.038-0.15 mm.

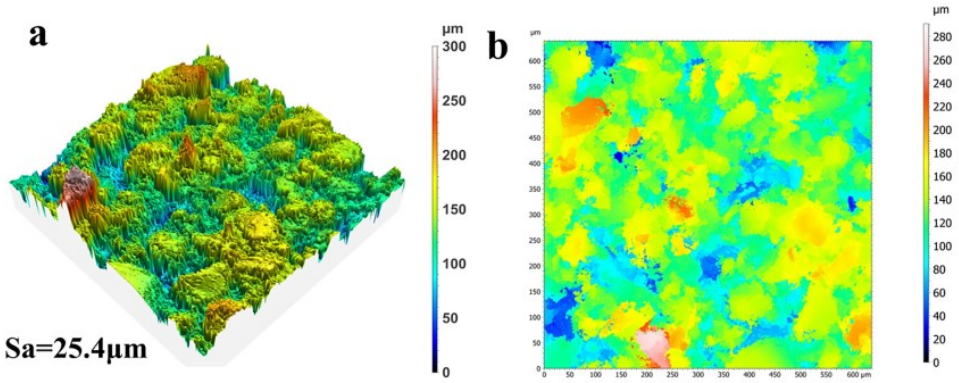


Figure S11. (a-b) LSCM images of HA-CEPs with the size ranging from 0.038-0.075mm.

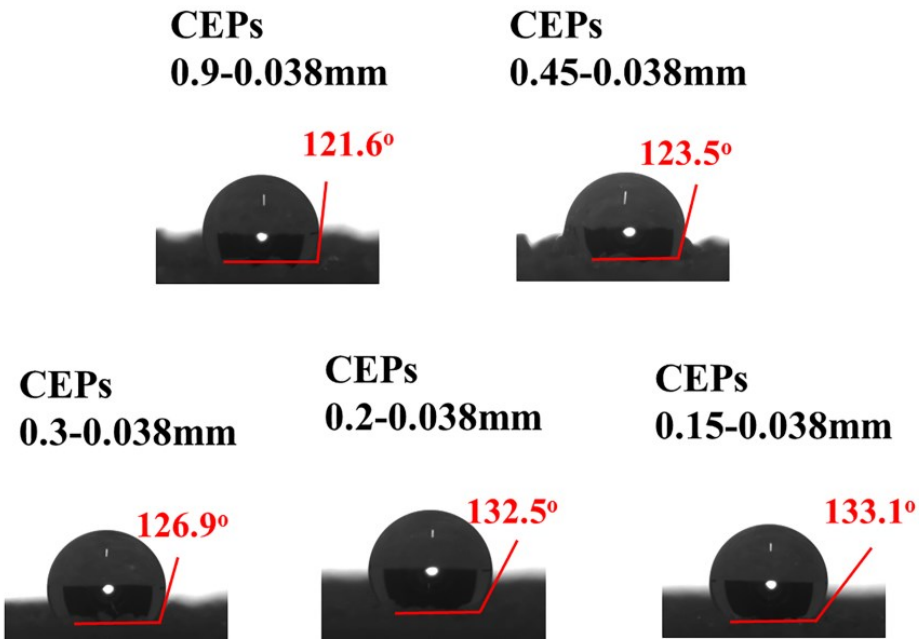


Figure S12. Water Contact angles of HA-CEPs with different sizes.

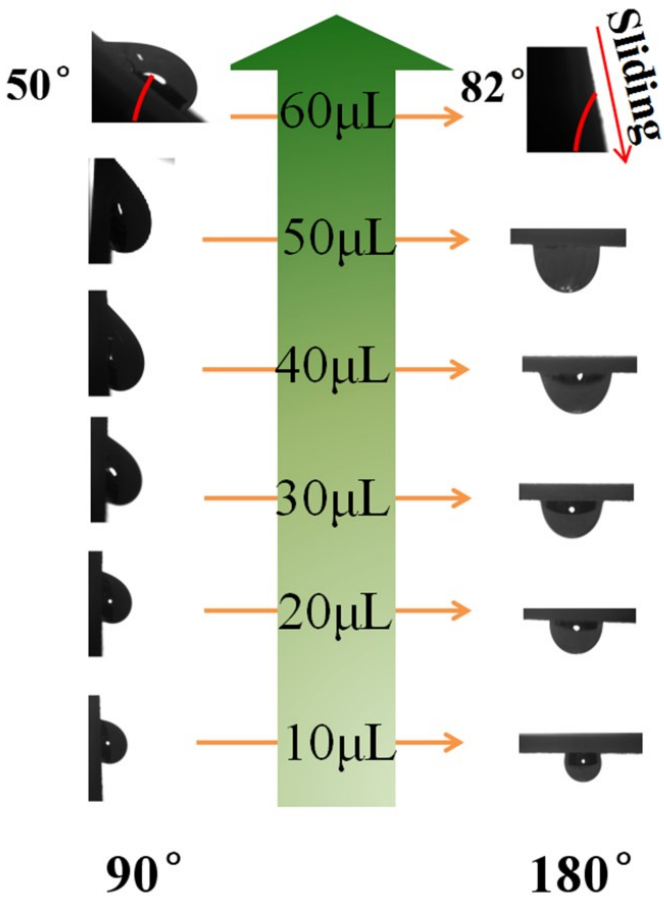


Figure S13. Water droplets storage with different volumes on HA-CEPs.

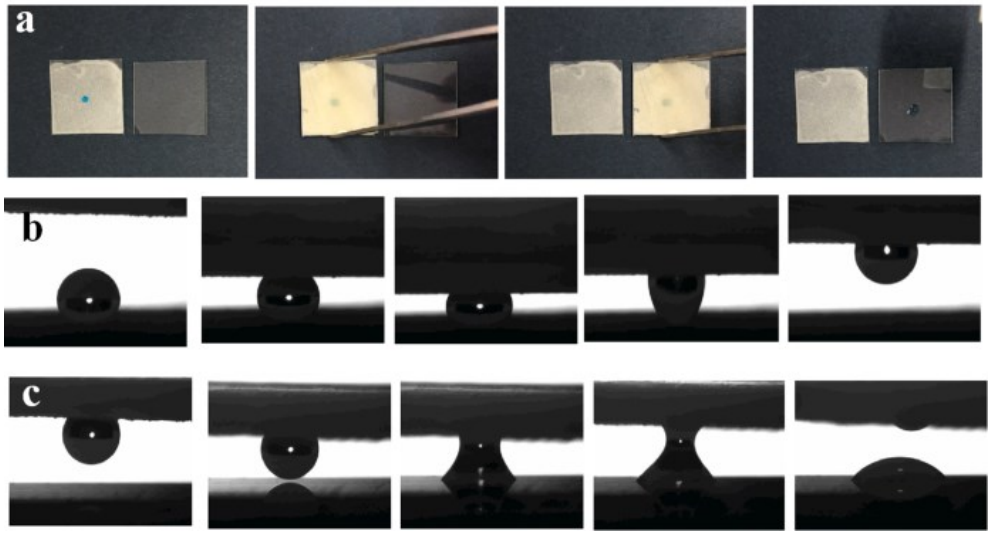


Figure S14. (a) Transporting the water droplet by HA-CEPs. (b) Water droplets were transfered from superhydrophobic surface with low water adhesion to HA-CEPs. (c) Water droplets were transfered from HA-CEPs to hydrophilic glass plate.

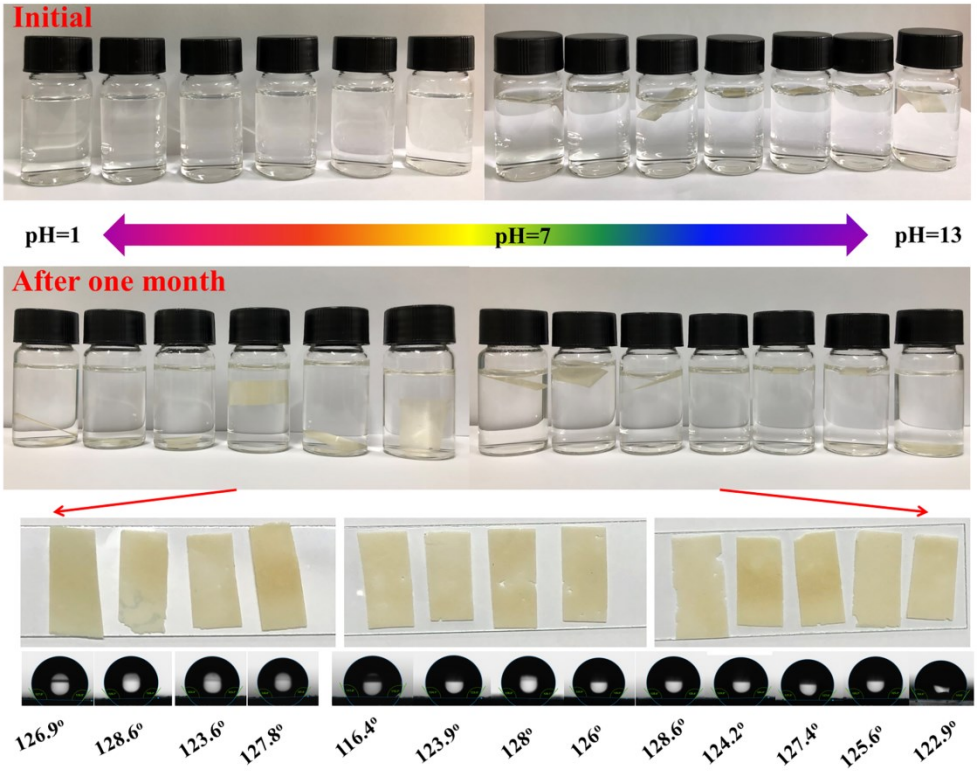


Figure S15. Acid and alkali corrosion resistance test, HA-CEPs remained and without change after one month.

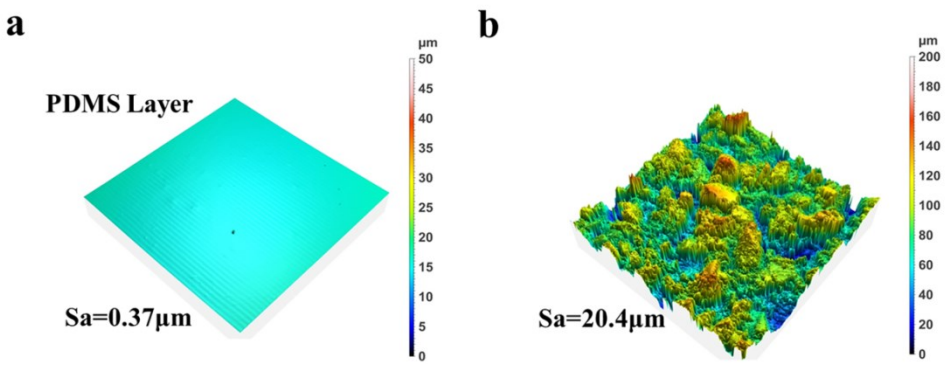


Figure S16. LSCM images of (a) PDMS layer and (b) LA-CEPs.

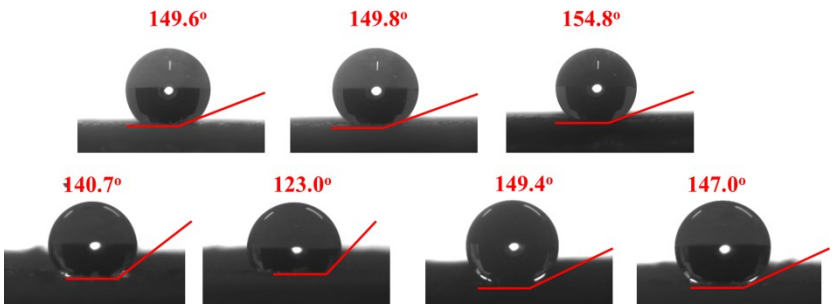


Figure S17. The water contact angles of coating prepared by unsaturated polyester resin, glass fiber reinforced EP, carbon fiber reinforced EP, PE, phenolic resin, rubber powder and melamine formaldehyde resin, respectively.

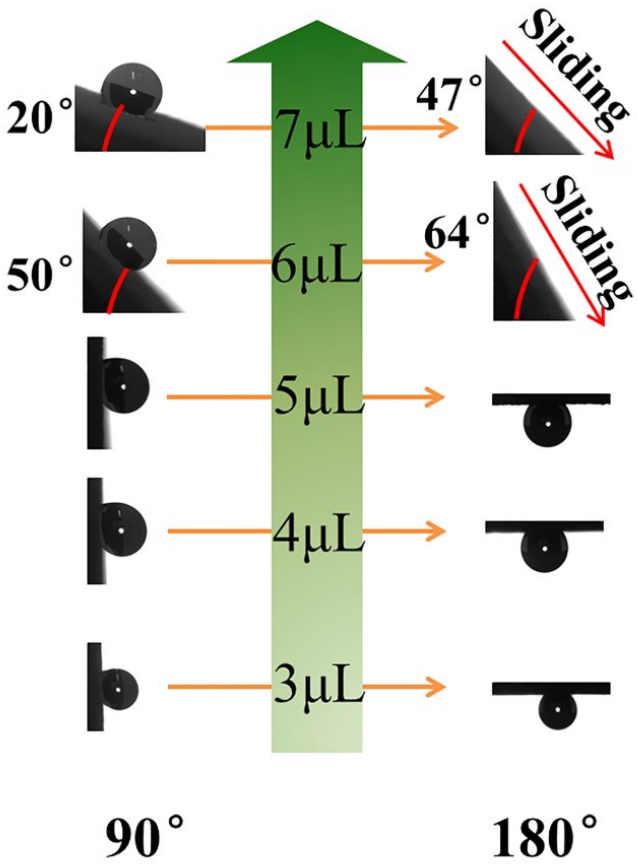


Figure S18. Water droplets storage with different volumes on LA-CEPs.

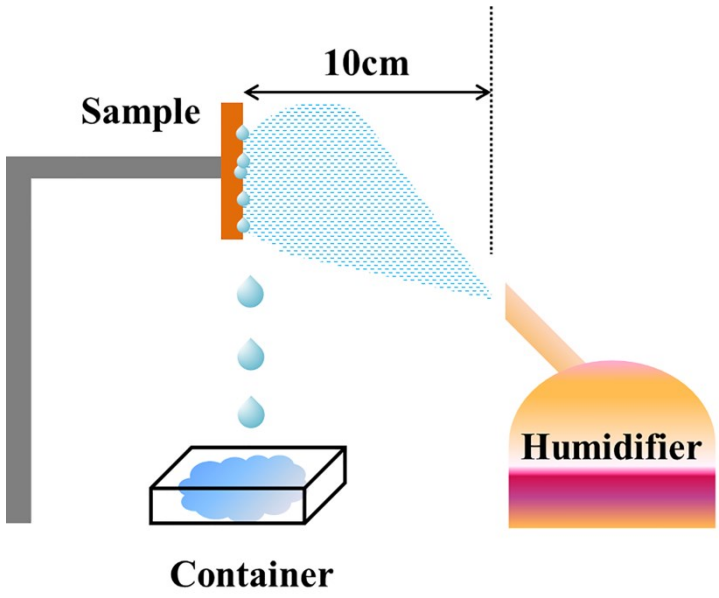


Figure S19. Schematic diagram showing the equipment for water collection from fog.

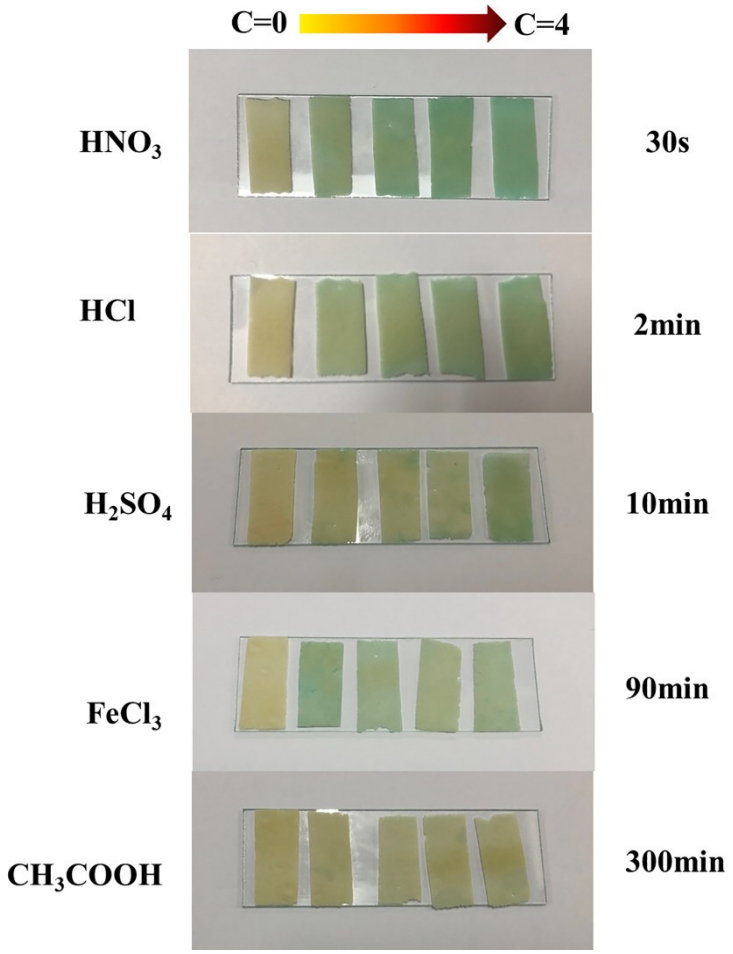


Figure S20. Identification of different acids, CEPs coatings were immersed in different acid solutions and the time of discoloration were recorded. From left to right, the concentration of acid solutions was 0, 1, 2, 3 and 4 mol/L, respectively.

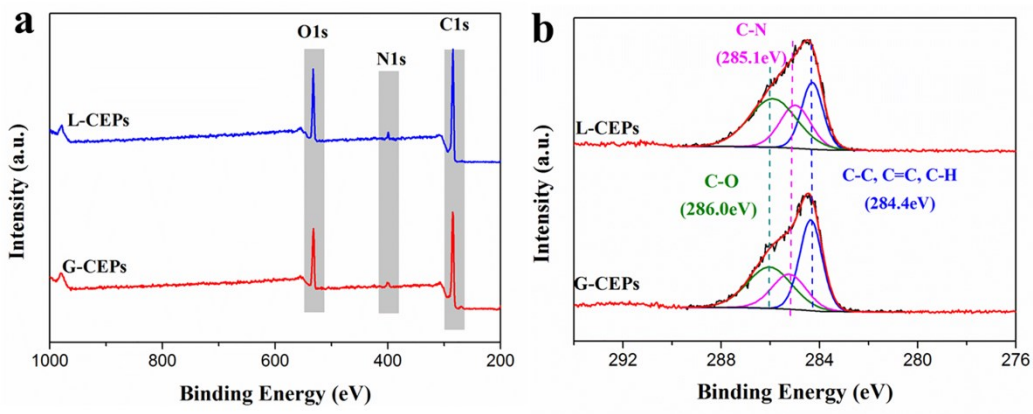


Figure S21. (a) Survey spectra and (b) high-resolution C 1s spectra of L-CEPs and G-CEPs.