

**Self-similar architectures for pressure-tolerant and mechanically durable
superamphiphobic coatings**

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Experimental section

Materials

TEOS (99.9 %) and PFDTES (97 %) were supplied by Gelest. Silica nanoparticles with a size range of 10-20 nm were obtained from Maikun Chemical Co. Ltd., Shanghai, China. The FSR adhesive was supplied by Shandong Xinna Superhydrophobic New Materials Co. Ltd., China. Other reagents such as CFC-113a, anhydrous ethanol, methyl acetate, and ammonia (25-28 wt%) were purchased from China National Medicines Co. Ltd. The Al plates were purchased from Shanghai Haocheng Metal Material Co., Ltd., China.

Preparation of F-POS@silica nanoparticles

Firstly, silica nanoparticles (20 g, 10-20 nm) were dispersed in a mixture of 1.0 L of the ethanol/ammonia mixture containing 60 mL of ammonia solution, which was then mechanically stirred for 10 min followed by ultrasonication for 30 min. Subsequently, 30 mL of tetraethoxysilane (TEOS) and perfluorodecyltriethoxysilane (PFDTES) were added, and then the mixture was stirred for 2 h to form a uniform suspension containing F-POS@silica nanoparticles. The suspension was subsequently washed using butyl acetate for three times and finally centrifugated at 4000 rpm for 10 min to obtain the semi-solid F-POS@silica nanoparticles.

Preparation of FSR/F-POS@silica superamphiphobic coatings

The FSR adhesive (4.2 g) was dissolved in 14.4 mL of butyl acetate by stirring for 30 min. Afterwards, 10.0 g of the above semi-solid F-POS@silica particles were uniformly dispersed in the FSR solution by 1 h stirring. Subsequently, phase separation of the FSR adhesive occurred when trichlorotrifluoroethane (CFC-113a) was gradually added into the FSR/F-POS@silica suspension under vigorous stirring. Finally, the FSR/F-POS@silica superamphiphobic coatings were fabricated by spraying the phase-separated FSR/F-POS@silica suspension (3.0 mL) on the Al plates (~12 cm²) and then curing at certain temperature (25-250 °C) for 10 min.

Mechanical, chemical, and environmental stability tests

The mechanical durability of the coatings was examined by a Taber abrasion tester (Dongguan Yaoke Instrument Equipment Co., Ltd.) with CS 10 grinding wheel under 125g load (ASTM D4060). The mechanical durability of the coatings was also examined by the tape peeling test (ASTM D3359). The tape (3M, Scotch 600) was placed onto the surface of the

coating for 10 s at a load of 0.2 kg and subsequently quickly peeled off.

The chemical stability of the coating was evaluated by immersing in 1 M HCl solution, 1 M NaOH solution and 3.5 wt% NaCl solution. The environmental stability of the coating was tested by UV irradiation (ASTM G154), keeping at high temperature or outdoor conditions for a period.

The CA and SA of water and soybean oil on the coatings were measured at pre-determined intervals of the tests.

Characterization

The CA and SA of water and oil (10 μL) were measured by a Contact Angle System OCA20 (Dataphysics, Germany) equipped with a tilting table. All the tests were performed three times, and the average values with standard deviations were provided. The bounce times, solid-liquid contact time and bounce height in the first impact/bounce cycle of the coatings were recorded using a high-speed video camera (FASTCAM, Mini UX100) at 4000 fps. The surface structure of the samples was observed by field emission scanning electron microscopy (SEM, JSM-6701F, JEOL) and a field emission transmission electron microscope (TEM, JEM-1200EX, JEOL). The surface chemical composition of the samples was analyzed by X ray photoelectron spectrometry (XPS, ESCALAB 250Xi) with Al $K\alpha$ X-ray radiation source. The FTIR spectra of samples were collected with a Thermo Nicolet NEXUS TM spectrophotometer (Thermo, Madison, USA) from 4000 cm^{-1} to 400 cm^{-1} using KBr pellets.

Anti-icing performance tests

The anti-icing performance was investigated utilizing a custom-made refrigeration system. For the freezing delay time, the droplet (60 μL) freezing processes on the samples in the environment of different temperatures (-10 $^{\circ}\text{C}$ ~ -40 $^{\circ}\text{C}$) and 60% RH were recorded by a CCD camera. The ice adhesion strength was assessed by injecting 1.0 mL of water into a glass column on the sample surface and was frozen completely for 3 h. Then, the ice column was displaced from the surface using a digital push-pull meter. Thus, the ice adhesion strength (τ , kPa) can be determined using the equation: $\tau = F/A$, where F (N) is the tensile force, and A (m^2) is the effective cross-sectional area of the ice column and substrate.

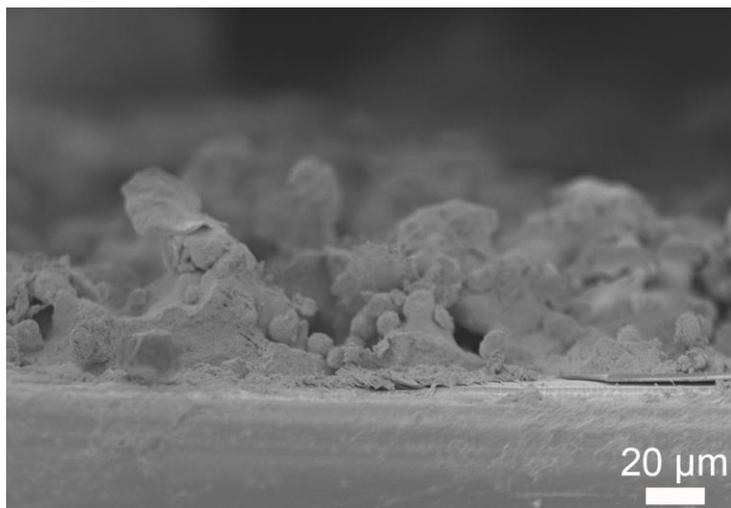


Fig. S1 Cross-sectional SEM images of the FSR/F-POS@silica coating at magnification of $\times 500$.

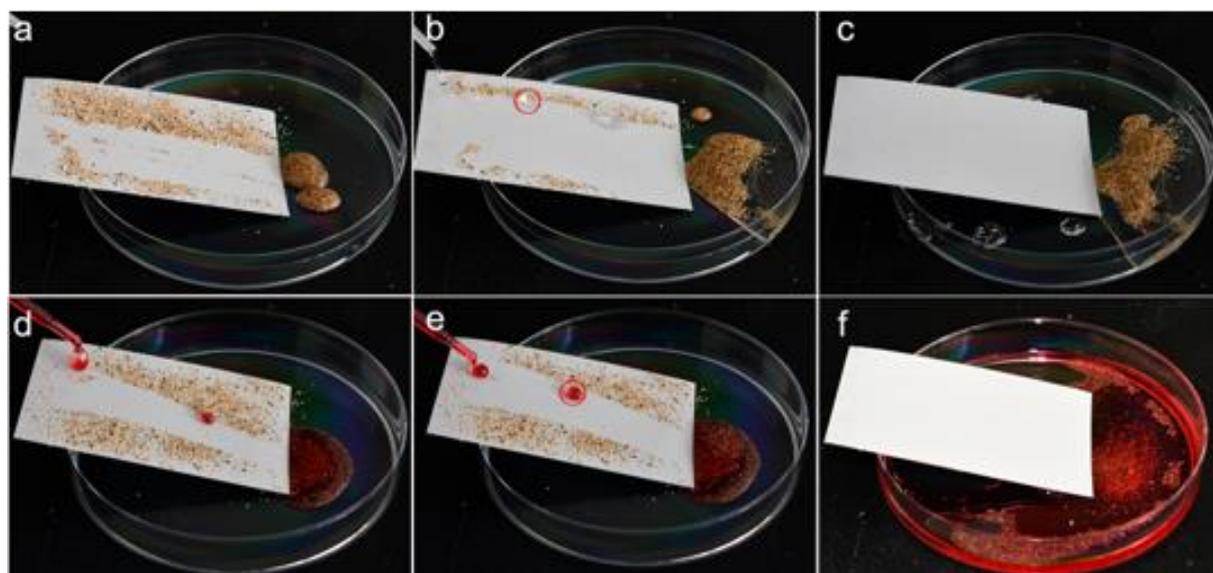


Fig. S2 Removal of sand particles on the PSR/F-POS@silica coating by falling (a-c) water droplets and (d-f) soybean oil droplets

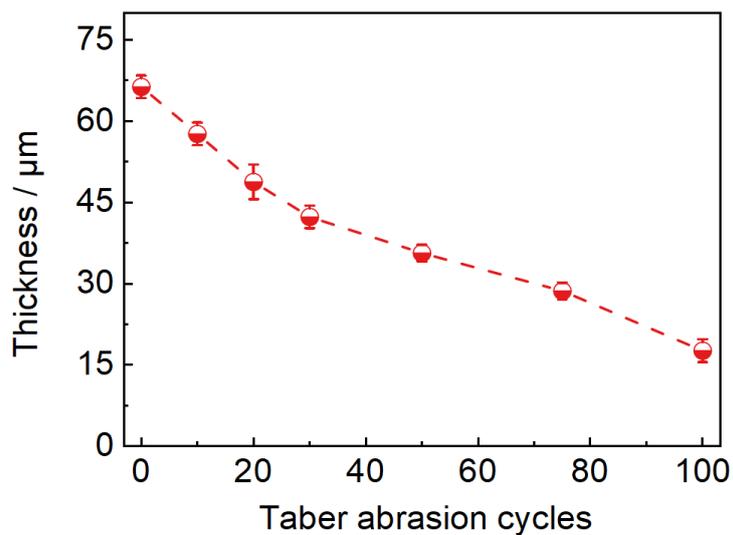


Fig. S3 Change in thickness of the FSR/F-POS@silica coating during the Taber abrasion test.

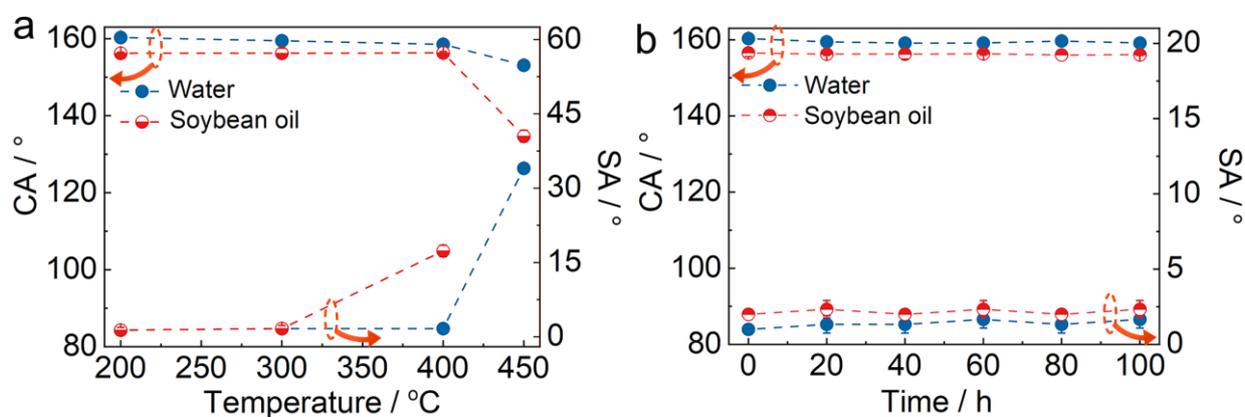


Fig. S4 Variations of CA and SA of water and soybean oil of the PSR/F-POS@silica coating (a) after heat treatment at different temperature for 1 h and (b) after heat treatment at 200 $^{\circ}\text{C}$ for a period. The data are shown as mean \pm SD, n = 5.

Table S1. Comparison of mechanical robustness of various superamphiphobic coatings.

Substrates	Test conditions	Loads	Abrasive parameters	Results	Refs.
Al sheet	Taber abrasion	125 g	CS10	After 75 cycles, $CA_{\text{Soybean oil}} = 151.6^\circ$, $SA_{\text{Soybean oil}} = 27.8^\circ$	This work
Glass	Sandpaper abrasion	4.5 kPa	Cotton fabric	After 50 cycles, $CA_{\text{water}} > 150^\circ$, $SA_{\text{water}} < 50^\circ$	[1]
Glass	Sandpaper abrasion	250 g	2000- grit	After 20 cycles, $CA_{n\text{-Decane}} = 149^\circ$, $SA_{n\text{-Decane}} = 24^\circ$	[2]
Glass	Sandpaper abrasion	50 g	2000-grit	After 100 cm, $CA_{\text{ethylene glycol}} > 150^\circ$, $SA_{\text{ethylene glycol}} < 10^\circ$	[3]
Tinplate sheet	Sandpaper abrasion	50 g	1000-grit	After 50 cycles, $CA_{\text{water}} > 150^\circ$, $SA_{\text{water}} < 15^\circ$	[4]
Glass	Sandpaper abrasion	100 g	600-grit	After 280 cm, $CA_{\text{sunflower oil}} > 150^\circ$, $SA_{\text{sunflower oil}} < 20^\circ$	[5]
Al sheet	Sandpaper abrasion	200 g	1000-grit	After 40 cycles, $CA_{\text{water}} = 152^\circ$, $SA_{\text{water}} = 11^\circ$	[6]

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