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Supporting Information

Waterborne, non-fluorinated and durable anti-icing superhydrophobic coatings based on diatomaceous earth

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Materials

Hexadecyltrimethoxysilane (HDTMS, 98%) and tetraethoxysilane (TEOS, 99.9%) were purchased from Gelest. DE powder was purchased from Sigma-Aldrich. The waterborne PU solution was provided by Haosheng Engineering Plasticization Co. Ltd., China. Before use, the waterborne PU solution was diluted with deionized water (1:1, v/v). Glass slides (24 mm × 50 mm, Menzel, Braunschweig, Germany) were used as the main substrates. AZ31B magnesium (Mg) alloy plates (30 mm × 30 mm) were purchased from Dongguan Feitai Metal Products Co., China. 1060 aluminum (Al) plates (30 mm × 30 mm) were purchased from Dongguan Wangcheng Metal Products Co., China. HCl and all the other reagents were obtained from China National Medicines Co. Ltd. All the chemical reagents used are analytical grade and were used as received without further purification. All solutions were prepared with deionized water.

Measurement of wettability

The water (10 μL) CA and SA of various coatings were measured using a Contact Angle System OCA20 (Dataphysics, Germany) equipped with a tilting table (0~70°). A minimum of five readings at different positions were recorded for each coating, and the average values with standard errors were reported.

Durability tests

The mechanical, chemical and environmental durability of the coatings were tested by water jetting, soaking in corrosive liquids and UV irradiation, respectively.

(i) The water jetting test means that the water jet at certain pressure (25 kPa or 50 kPa) scoured the 45° tilted surface from a height of 20 cm for a period of time.

(ii) The chemical stability tests were carried out by soaking the coatings in various corrosive liquids, including 1 M HCl(aq), 1 M NaOH(aq), saturated NaOH(aq), and saturated NaCl(aq) for a period of time (1 h or 24 h).

(iii) UV irradiation: the coatings were kept in a UV testing machine (ZN-P, Shanghai Xinlang Electronic Technology Co., Ltd) and irradiated with UV light (280~315 nm, 320 W) with a distance of 35 cm at 25 °C for 72 h.

After all the stability tests, the changes in the water CA and SA were recorded to evaluate stability of the coatings.

Characterization

Fourier transform infrared (FTIR) spectra of samples were recorded on a Thermo Nicolet NEXUS TM spectrophotometer using KBr pellets in the range of 400~4000 cm^{-1}. The micrographs of the samples were taken using a field emission scanning electron microscope (SEM, JSM-6701F, JEOL). Before SEM observation, all samples were fixed on Al stubs and coated with gold (~7 nm). The X-ray photoelectron spectra (XPS) of samples were obtained using a VG ESCALAB 250 Xi spectrometer equipped with a Monochromated Al Kα X-ray radiation source and a hemispherical electron analyzer. The spectra were recorded in the constant pass energy mode with a value of 100 eV, and all binding energies were calibrated using the C 1s peak at 284.6 eV as the reference.

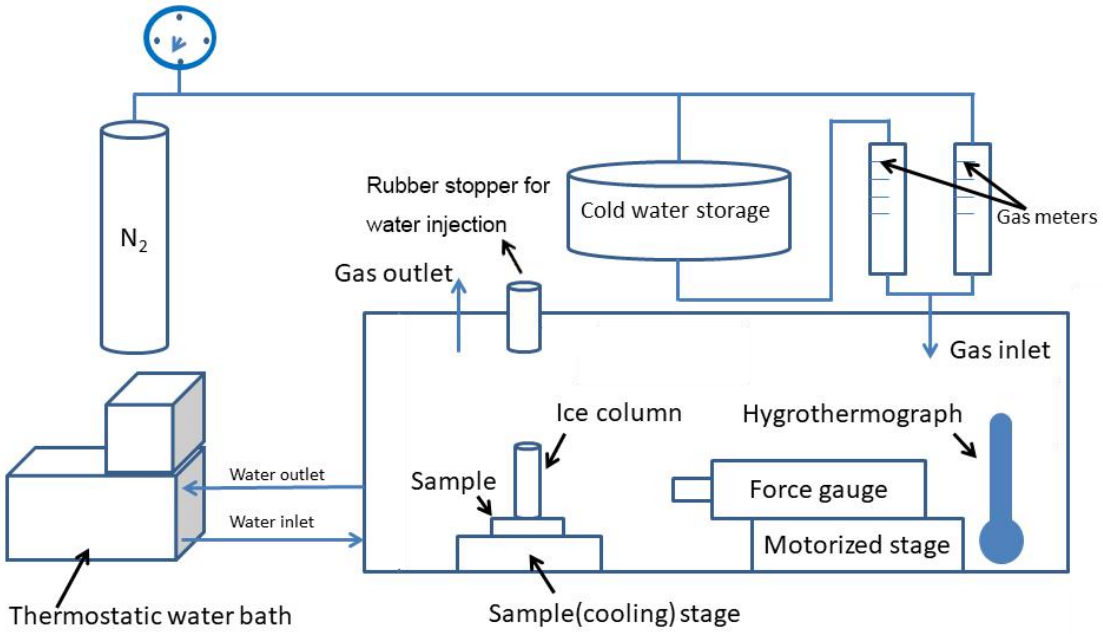

Fig. S1 Schematic illustration of the custom setup for the measurement of water freezing time and ice adhesion strength.

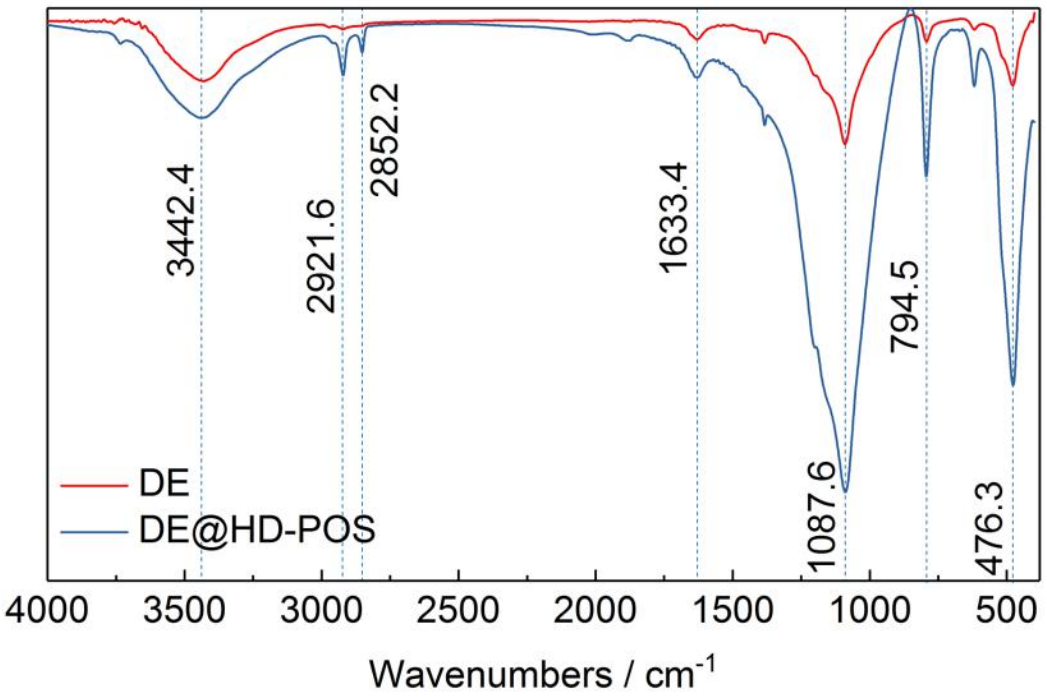

Fig. S2 FTIR spectra of DE and DE@HD-POS.

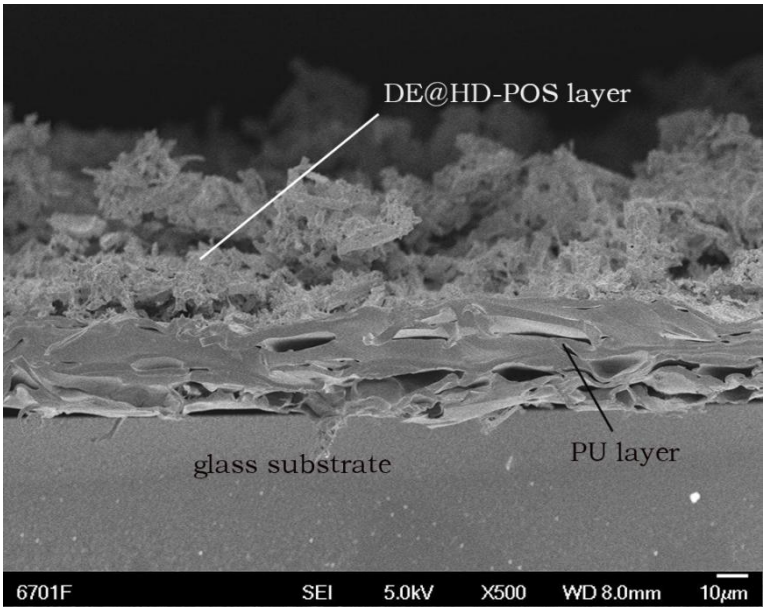

Fig. S3 Cross-sectional SEM image of the PU/DE@HD-POS coating.

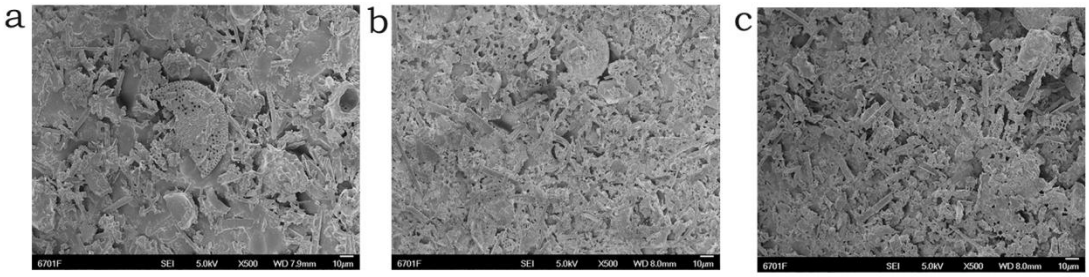

Fig. S4 SEM images of the PU/DE@HD-POS coatings with a C_{DE} of (a) 10, (b) 20 and (c) 40 g L^{-1}.

Fig. S5 Photographs the PU/DE@HD-POS coatings after soaked in various corrosive liquids for 1 h.

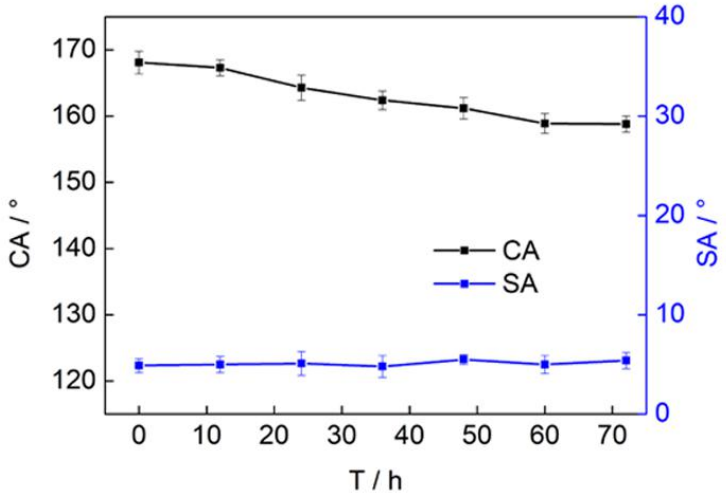

Fig. S6 Variation of water CA and SA of the PU/DE@HD-POS coating with UV irradiation time.

Table S1. Surface chemical composition of the PU/DE@HD-POS coating.

Elements	Contents / at.%
C	51.6
O	23.5
Si	24.9

Table S2. Surface chemical composition of the PU/DE@HD-POS coating after water jetting at 50 kPa for 30 min.

Elements	Contents after water jetting / at.%
C	59.6
O	25.1
Si	15.3

Table S3. Water freezing time of superhydrophobic coatings on different substrates.

Substrates	Temperature / °C	RH	Freezing time / s	Ref.
Glass slide	-15	60%	516.0	This work
Mg alloy plate	-15	60%	361.0	This work
Al plate	-15	60%	315.0	This work
Al plate	-15	unspecified	222.0	[1]
Glass slide	-15	60%	508.0	[2]
Monoliths	-10	unspecified	302.0	[3]
Ti_6Al_4V titanium alloy	-10	5%	15.5	[4]
Al plate	-10	unspecified	23.0	[5]
Al plate	-15	unspecified	276.3	[6]

Movie S1. Horizontal moving of a water droplet on the surface of the PU/DE@HD-POS coating.

Movie S2. Repeated vertical squeezing of a water droplet on the surface of the PU/DE@HD-POS coating.

Movie S3. Impact/bounce of a water droplet on the surface of the PU/DE@HD-POS coating. The high-speed videos were recorded at 4000 fps using a high-speed video camera (FASTCAM Mini UX100, Photron, Japan).

References

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