ADVANCED MATERIALS INTERFACES
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Supporting Information

for *Adv. Mater. Interfaces*, DOI 10.1002/admi.202301048

Using Paper as a Biomimetic Fog Harvesting Material

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Using paper as a biomimetic fog harvesting material

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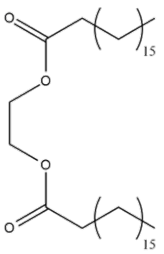
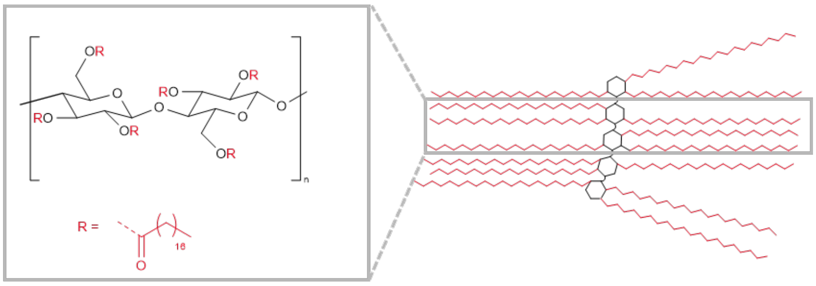
SI-1: Composition of superhydrophobic paper coating

Structure of ethylene glycol distearate (EGDS) and cellulose stearoyl ester (CSE) with a degree of substitution of DS = 3.



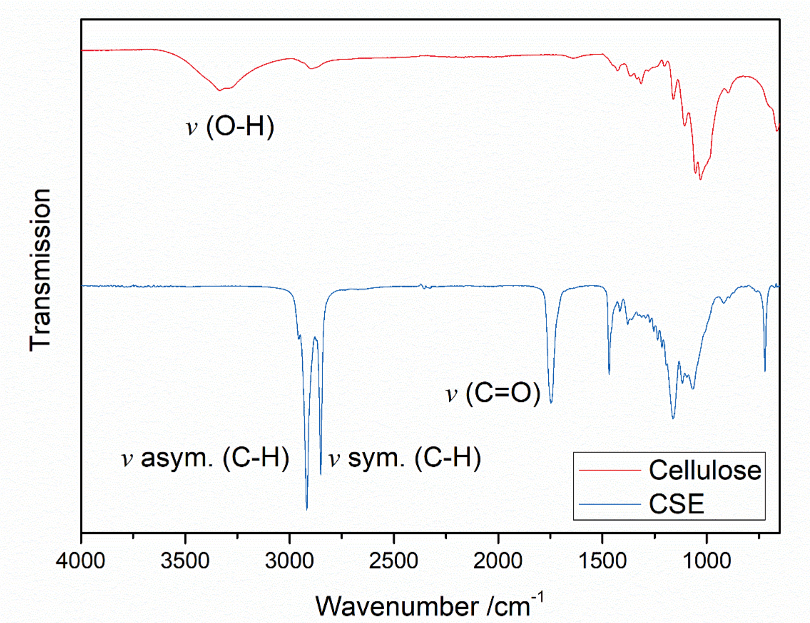
EGDS



CSE

SI-2: FT-IR spectra of CSE confirms degree of substitution (DS) of 3:

FT-IR measurements were conducted on a FTIR-ATR spectrometer *Spectrum One* from Perkin-Elmer (Perkin Elmer GmbH, Uberlingen, Germany) between 4000 and 650 cm^{-1}. The comparison of cellulose and CSE shows a complete functionalization (degree of substitution DS = 3) of cellulose with stearoyl moieties. The -OH band of cellulose at ~3500–3200 cm^{-1} completely disappears in the CSE spectra, while the asymmetrical and symmetrical C-H stretching vibrations of the methylene groups at 2916 and 2849 cm^{-1} as well as the C=O stretching vibrations of ester bonds at 1745 cm^{-1} indicate the covalent binding of stearoyl groups.



SI-3: Calculation of required droplet volumes for roll-off from surfaces

Roll-off angles for different droplet volumes on glass, polyethylene (PE) and superhydrophobic paper were measured. The fit functions are given in equation (1) – (3).

$$y_{\text{glass}} = 4423.76 \cdot x_{\text{glass}}^{-1.14} \quad (1)$$

$$y_{\text{PE}} = 372.19 \cdot x_{\text{PE}}^{-0.64} \quad (2)$$

$$y_{\text{superh. paper}} = 19.69 \cdot x_{\text{superh. paper}}^{-0.70} \quad (3)$$

Using these fit functions with x = V and y =φ, the required droplet volumes for roll-off from surfaces with given orientations can be calculated via equations (4) – (6)

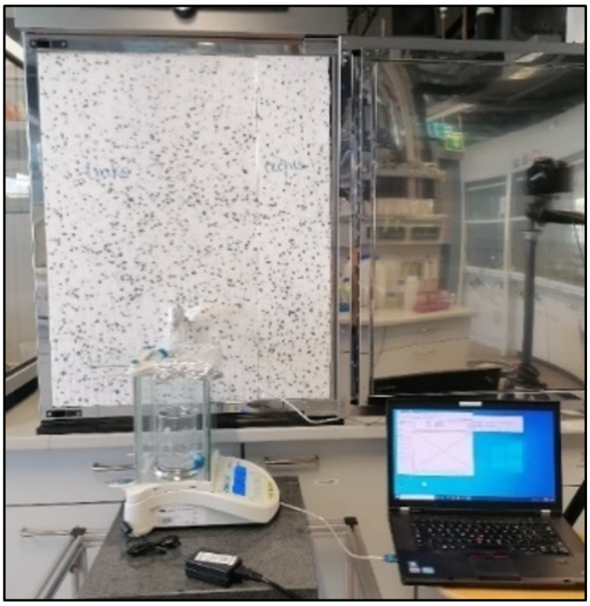
$$V_{\text{drop, glass}} = \left(\sqrt[1.14]{\varphi_{\text{glass}} \cdot (4423.76)^{-1}}\right)^{-1} \quad (4)$$

$$V_{\text{drop, PE}} = \left(\sqrt[0.64]{\varphi_{\text{PE}} \cdot (372.19)^{-1}}\right)^{-1} \quad (5)$$

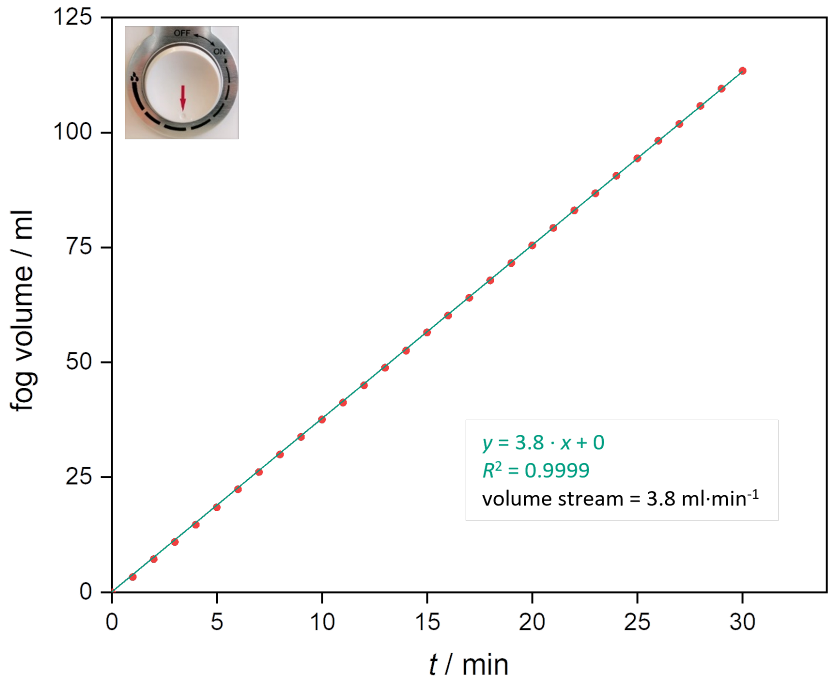
$$V_{\text{drop, superh. paper}} = \left(\sqrt[0.70]{\varphi_{\text{superh.paper}} \cdot (19.69)^{-1}}\right)^{-1} \quad (6)$$

SI-4: Setup of the Fog Harvesting test station

For laboratory scale measurement of fog harvesting, control of temperature is essential. Therefore an ultrasonic humidifier is placed into an isolated closed oven and is befogging the samples (5.0 x 5.0 cm) with a volume flow of 3.8 ml·min^{-1} from a distance of 5 cm. Documentation of the collected water quantity is carried out gravimetrically with an automatically recording balance.

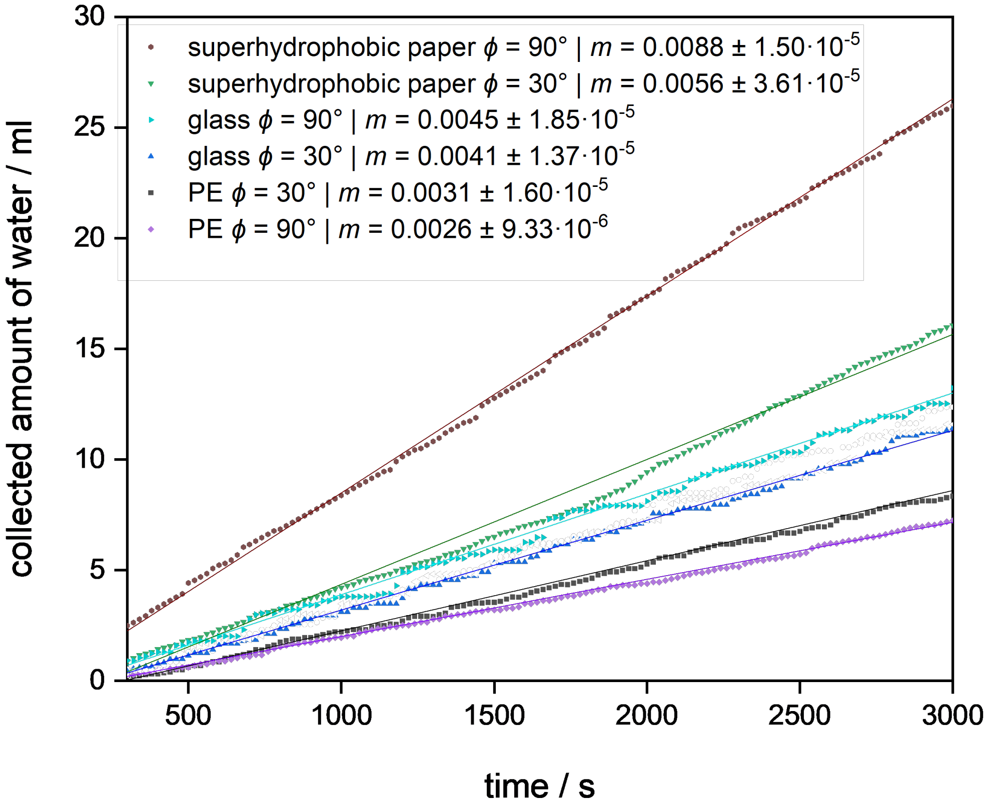


Prior to the measurements, the fog volume flow of the device is measured for the selected configuration by gravimetrically measuring the ejected water amount at selected time intervals and determining the volume flow stream as the slope of the linear regression.



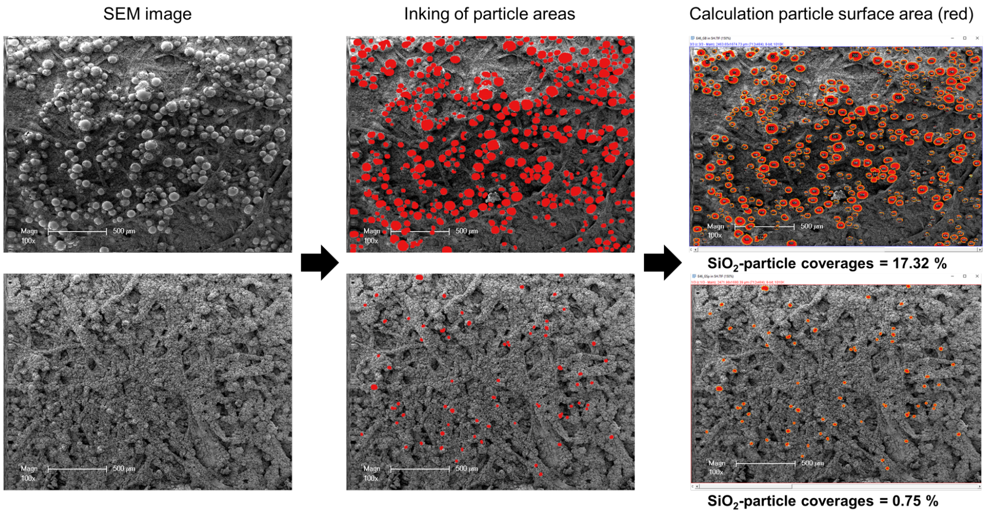
SI-5: Fog harvesting measurements of superhydrophobic paper, PE, glass

The raw data and linear regression of gravimetrically determined water amount per time collected during fog harvesting measurements are shown of three different surfaces (superhydrophobic paper, PE, glass) with tilt angles of 30 and 90 degrees respectively.



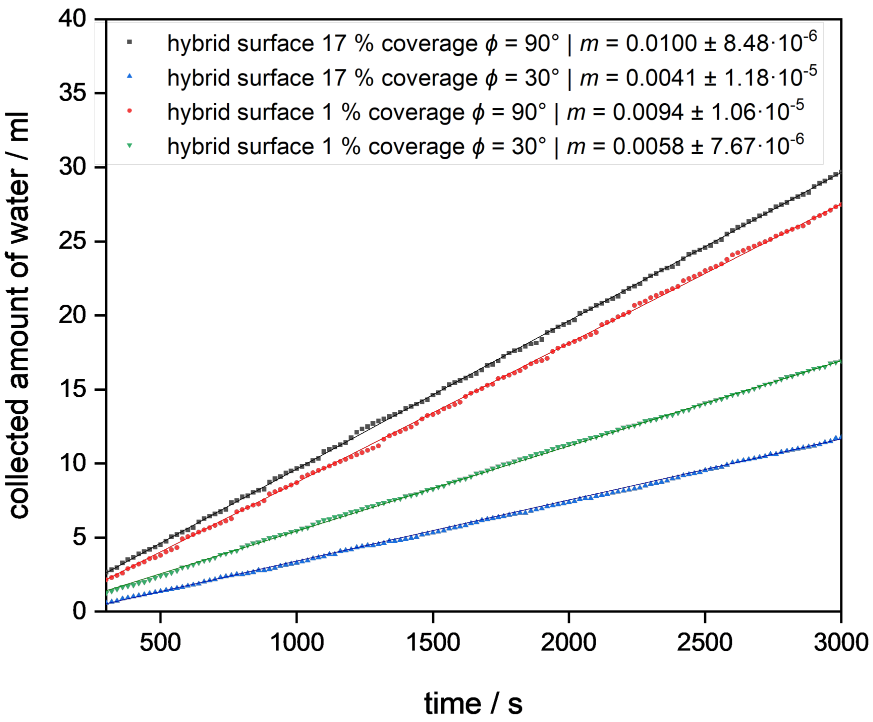
SI-6: Determination of surface coverage with silica particles

The smooth areas on the SEM images of hybrid surfaces were marked in red using GNU Image Manipulation Program 2.10. The pixels of the red areas were calculated using ImageJ and referred to the total amount of pixels, which lead to a surface coverage in percent. Two hybrid surfaces with different SiO2-particle coverages of 0.75 % (approx. 1 %) and 17,32 % (approx. 17 %) were prepared for this studies.



SI-7: Fog harvesting measurements of hybrid paper surfaces

The raw data and linear regression of gravimetrically determined water amount per time collected during fog harvesting measurements are shown of four hybrid paper materials with superhydrophobic background and 1 % or 17 % coverage of glass with surface tilt angles of 30 and 90 degrees respectively.



SI-7: Temperature profiles of the surfaces measured with a thermographic camera

The assessment of temperature profiles of superhydrophobic coated paper compared to hybrid paper was investigated wit a set-up from PTS Heidenau, using a photonic high performance test set up XGA with a thermographic camera with high thermal resolution of < 30 mK. The partially superhydrophobic (left area) and hybrid (right area) coated paper is fogged from a distance of 5 cm with the ultrasonic nebulizer used for the fog harvesting experiments (**Fehler! Verweisquelle konnte nicht gefunden werden.**7, A), and the temperature evolution of this surface is detected according to defined time intervals (**Fehler! Verweisquelle konnte nicht gefunden werden.**7, B).