

Electronic Supplementary Information

Polydopamine-filled Bacterial Nanocellulose as Biodegradable Interfacial Photothermal Evaporator for Highly Efficient Solar Steam Generation

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Experimental methods

Preparation of PDA/BNC

Gluconacetobacter hansenii (ATCC®53582) was cultured in test tubes containing 16 ml of #1765 medium at 30 °C under shaking at 250 rpm. The #1765 medium is composed of 2% (w/v) glucose, 0.5% (w/v) yeast extract, 0.5% (w/v) peptone, 0.27% (w/v) disodium phosphate, and 0.5% (w/v) citric acid. Polydopamine (PDA) particles were prepared using a method reported by Lu and co-workers.¹ To synthesize PDA particles with the size of 1 μm , ammonia solution (NH_4OH , 0.14 ml, 28–30%) was mixed with 31.5 ml of nanopure water ($\sim 18 \text{ M}\Omega\cdot\text{cm}$) and 14 ml of ethanol and the above mixture was shaken for 30 minutes. Dopamine hydrochloride solution (3.5 ml, 0.05 g ml^{-1}) was added into the above solution and then transferred to a petri dish. After 30 hours of mild shaking at room temperature, the PDA particles were collected by centrifugation (7000 rpm, 20 min) and washed with water for three times and dispersed in nanopure water (40 ml). Bacterial culture solution (3 ml, incubated 3 days) was added to #1765 medium (15 ml) to make a total 18 ml bacterial growth solution. The solution was subsequently transferred to a petri dish (diameter: 6 cm) and incubated at room temperature without disturbance. After 5 days, a thick BNC hydrogel ($\sim 4 \text{ mm}$) was obtained. PDA particle solution described above (40 ml) was centrifuged and dispersed in bacterial growth medium (7 ml) and was then added on top of the thick BNC hydrogel. After 12h, PDA particles formed on the BNC hydrogel and excess medium was removed. After another 12 h, a thin layer of PDA/BNC ($\sim 100 \mu\text{m}$) was formed on top of the prior thick BNC hydrogel. The bilayered hydrogel was then harvested and washed in boiling water for 2 hours, then dialyzed in nanopure water for one day. The purified PDA/BNC bilayer was then freeze-dried

overnight. For PDA/BNC with bigger size, above procedure were simply scaled up and performed in bigger containers.

Microstructure Characterization Methods

Scanning electron microscope (SEM) images were obtained using a FEI Nova 2300 Field Emission SEM. Transmission electron microscope (TEM) images were obtained using a JEOL JEM-2100F field emission microscopy. Dynamic light scattering (DLS) measurements were performed using Malvern Zetasizer (Nano ZS). Shimadzu UV-1800 spectrophotometer was employed for obtaining UV-vis extinction spectra and transmittance spectra. Reflectance spectra were obtained using a CRAIC micro spectrophotometer (QDI 302) coupled to a Leica optical microscope (DM 4000M) with 20× objective in the range of 450–800 nm with 10 accumulations and 100 ms exposure time in reflection mode. Raman spectra were obtained using a Renishaw inVia confocal Raman spectrometer mounted on a Leica microscope with 20 × objective and 785 nm wavelength diode laser as an illumination source. Thermogravimetric analysis (TGA) was performed using TA Instruments Q5000 IR Thermogravimetric Analyzer in air (at rate of 5 °C min⁻¹).

Thermal conductivity measurements of wet/dry PDA/BNC

The thermal conductivities of wet/dry PDA/BNC were measured by sandwiching the material between two glass microscope slides. The sandwich was placed between a hot plate and a glass slide with ice on top. The temperature distribution across the thickness was monitored by an IR camera (ICI 7320 USB camera). The emissivity coefficient of a glass slide and a sample was assumed to be 0.9 to obtain the temperature distribution.² Fourier equation was used to calculate the thermal conductivity of each sample:³

$$q' = K \frac{\Delta T}{\Delta X}$$

The heat flux (q') was calculated by assuming the thermal conductivity (K) of $1.05 \text{ W m}^{-1} \text{ K}^{-1}$ for glass slides. Because the glass slide and samples experience the same heat flux, the heat flux value obtained for glass slide was used to measure the thermal conductivity for PDA/BNC samples.

Solar steam generation experiment

In a typical test, a circular bilayer of PDA/BNC with 3 cm diameter and 2.1 mm thickness was floated on water in a 100-ml beaker. The solar beam from a solar simulator (Newport 66921 Arc Lamp) was directly or concentrated using a magnifying lens illuminated onto the PDA/BNC. The power density of the solar beam on the sample surface was controlled to be 1 and 3 kW m^{-2} . Each sample was illuminated for 45 min and the weight loss over the entire duration was recorded. For the cycling experiments, a $1 \text{ cm} \times 1 \text{ cm}$ sample with 4 mm thickness floating on water in a plastic cuvette with dimensions of 12.5 mm (W) \times 12.5 mm (D) \times 49 mm (H) was used. The power density of the solar beam at the sample surface for cycling was controlled to be 7 kW m^{-2} (7 sun) for 15 min illumination duration. The temperature was measured using an IR camera and the weight change from evaporation was measured using an electronic mass balance with an accuracy of 0.1 mg. It is assumed that the steam was generated at $100 \text{ }^\circ\text{C}$. The evaporation efficiency (η) is given by: ⁴

$$\eta = \frac{\dot{m}h_{LV}}{I}$$

Where η is evaporation efficiency, \dot{m} is the evaporation rate, h_{LV} is the total enthalpy of sensible heat (294 J g⁻¹, from 25 °C to 100 °C with specific heat 4.2 J g⁻¹ K⁻¹) and phase change of liquid to water (2256 J g⁻¹), and I is the incident illumination power density.

Supporting figures

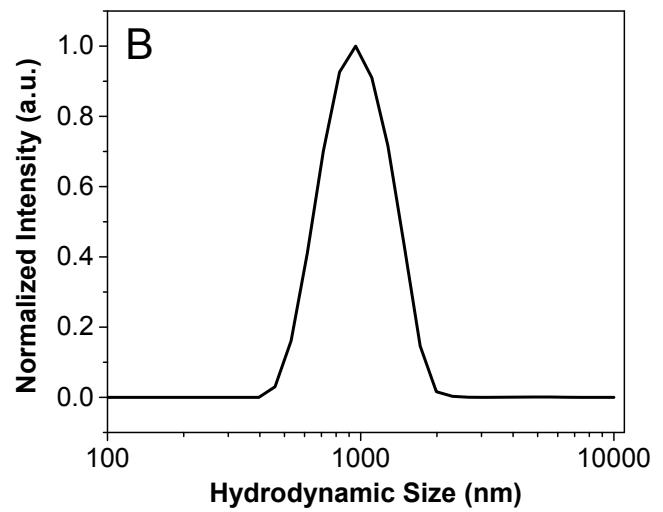
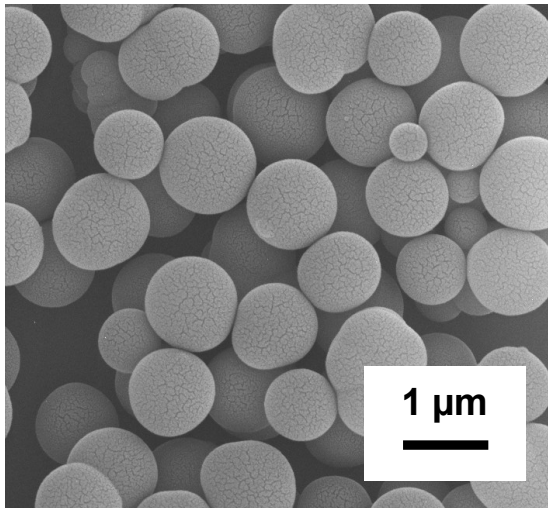


Fig. S1. (A) SEM image of PDA particles (B) Hydrodynamic size of PDA particles measured by DLS.

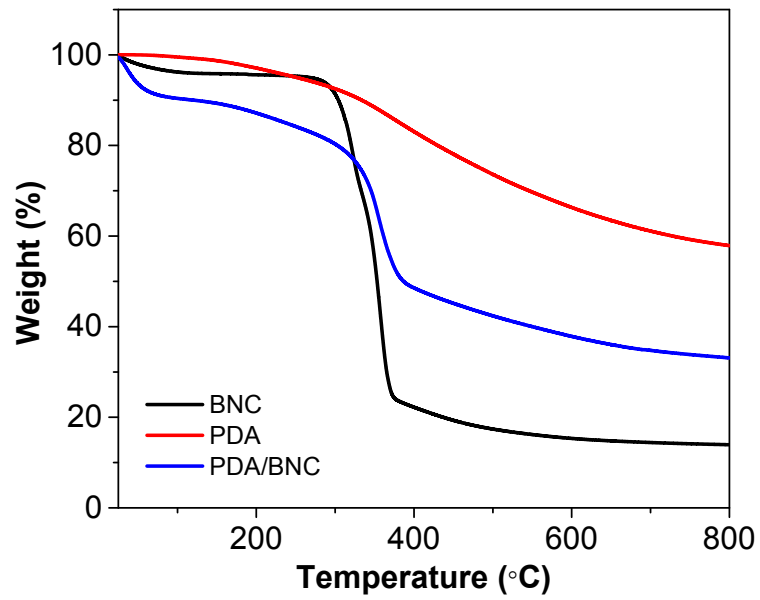


Fig. S2. TGA of pristine BNC, pristine PDA and PDA/BNC.

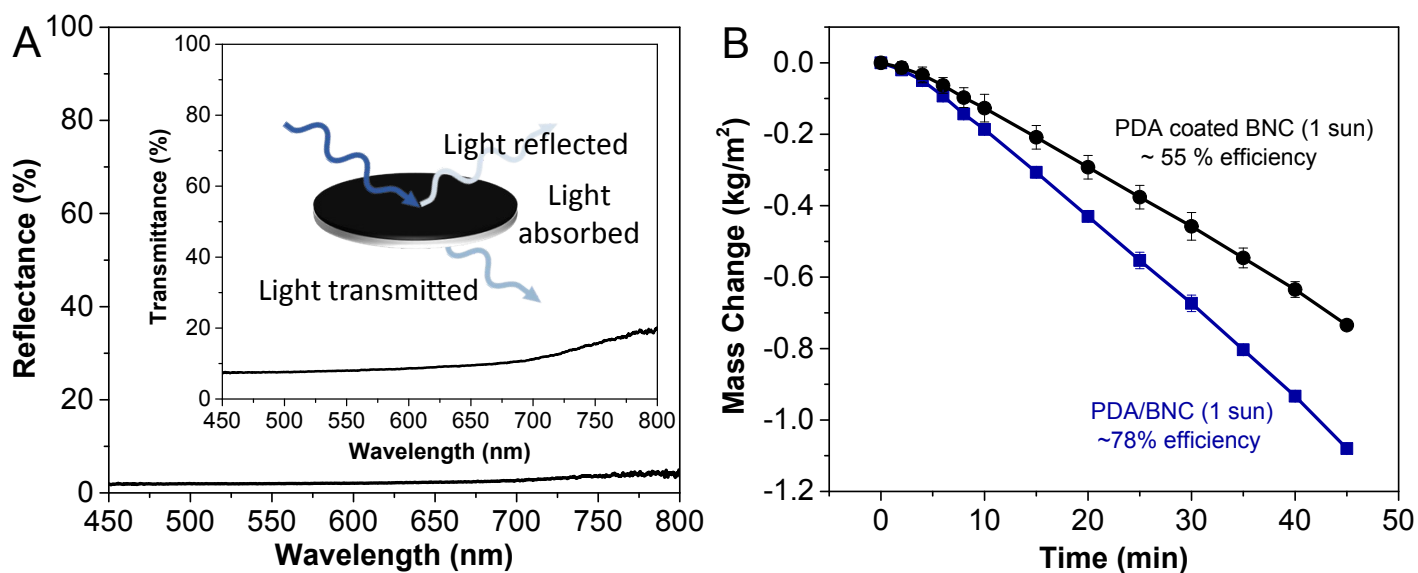


Fig. S3. (A) Transmittance and reflectance spectra of PDA coated BNC hydrogel. (B) Solar steam generation performance of PDA coated BNC compared with PDA/BNC via *in situ* growth method.

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3. Q. Jiang, L. Tian, K.-K. Liu, S. Tadepalli, R. Raliya, P. Biswas, R. R. Naik and S. Singamaneni, *Advanced Materials*, 2016, **28**, 9400-9407.
4. H. Ghasemi, G. Ni, A. M. Marconnet, J. Loomis, S. Yerci, N. Miljkovic and G. Chen, *Nat Commun*, 2014, **5**.