Supplementary Information

Photonic Crystal Concentrator for Efficient Output of Dye-sensitized Solar Cells

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Experimental Section

Fabrication of the photonic crystal (PC) concentrators. The PC concentrators were fabricated from mono-dispersed polymer latex spheres of poly(styrene-methyl methacrylate-acrylic acid) (Poly(St-MMA-AA)) with a concentration of 0.25 wt% at 80ºC and 80% relative humidity for *ca.* 24 h by vertical deposition method. Here, the substrates were concave watch glasses with diameter of 6 cm. The latex spheres with diameters of 173, 191, 216 and 280 nm were synthesized by our previous method[1].

Characterization of the PCs. The surface morphology of the PCs was determined using a field emission scanning electron microscope (SEM) (JEOL JSM-6700F) at 10 kV. The photographs of the PC concentrators were taken with a digital camera (Canon Powershot A75). UV-vis spectra of the PCs were obtained with a U-4100 UV-vis Spectrometer (Hitachi, Japan). The relative irradiance of the light at the focal point of the PC concentrator was obtained with the Fiber Optic Spectrometer (AvaSpec-2048-USB2).

Preparation and characterization of DSSCs. DSSCs were prepared according to our previous method[2], where, N719 dye (Ru(2,2'-bipyridine-4,4'-dicarboxylic acid)$_2$(NCS)$_2$) was used. The photo-electric conversion efficiency of DSSCs was obtained by an electrochemical analyzer (CHI630A, Chenhua Instruments Co., Shanghai) under solar simulator illumination (CMH-250, Opt Photoelectric Technology Co. Ltd, Beijing) at room temperature.

Photocurrent action spectrum. The incident photon-to-current conversion efficiency (IPCE) was analyzed under light intensity of 100 mW cm^2 (AM1.5). IPCE was calculated by equation:

$$\mathrm{IPCE}(\lambda) = \frac{1240 \times J[\mathrm{uA/cm^2}]}{\lambda(\mathrm{nm}) \times P[\mathrm{W/m^2}]}$$

Where, J is the photocurrent density generated by monochromatic light with wavelength λ and intensity P.

The I-V characteristics of the DSSC in the presence or absence of PC concentrators. The photovoltalic system containing PC concentrator included DSSC and solar simulator, the PC concentrator was used as light-harvesting module. The area of the PC concentrator was 28.26 cm^2 with diameter of 6 cm and focal length of 2.86 cm. The area of the cell was 0.2 cm^2. The light intensity was measured with an irradiatometer (FZ-A, Opt Photoelectric Technology Co. Ltd, Beijing). The maximum incident light intensity on the concentrator surface was 38.2 ± 3 mW cm^{-2} due to the limitation of solar simulator. The control experiment was done under same conditions (i.e., DSSC, light tensity) in the absence of PC concentrator.

The durability of the DSSC in the presence of the PC concentrators or Al film concentrator. The I-V characteristics, such as, J_{sc}, P_{max}, V_{oc}, *ff* of DSSC were determined when continuously working under the PC or Al-film concentrator for 11h, respectively. The Al-film concentrator was prepared by depositing the Al-film with thickness of 50 nm upon concave watch glass substrate (with diameter of 6 cm, focal length of 2.86 cm, magnification of 15 ×) under ~ 4×10^{-4} Pa at a rate of ~ 1 A s^{-1} using a VPC-260 F Vacuum Deposition Equipment (ULVAC).

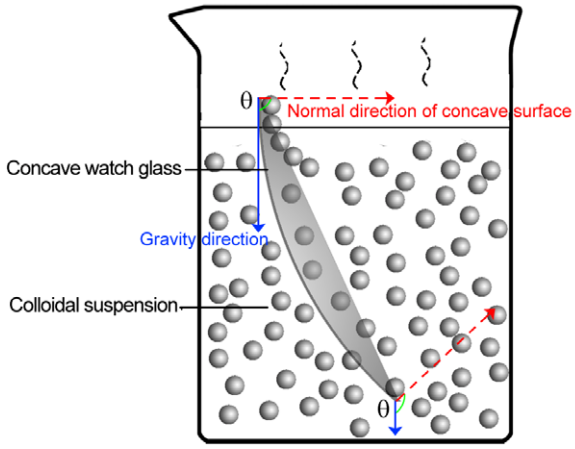

Fig. S1. The scheme of self-assembly procedure for the concave photonic crystal (PC). The angles between normal direction of the concave surface and gravity direction should be no less than 90º to ensure well assembly of the latex spheres upon the concave watch glass surface.

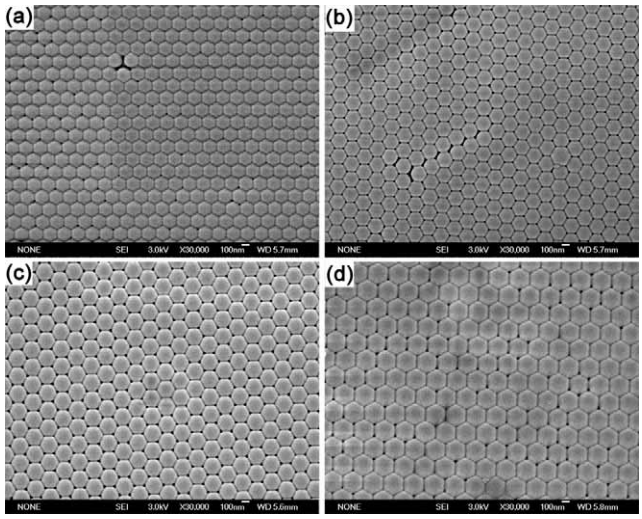

Fig. S2. Typical SEM images of the PC concentrators assembled from latex spheres with different diameters of 173(a), 191(b), 216(c) and 280(d) nm. The scale bar is 100 nm. The well-ordered assembly of latex spheres could be clearly shown.

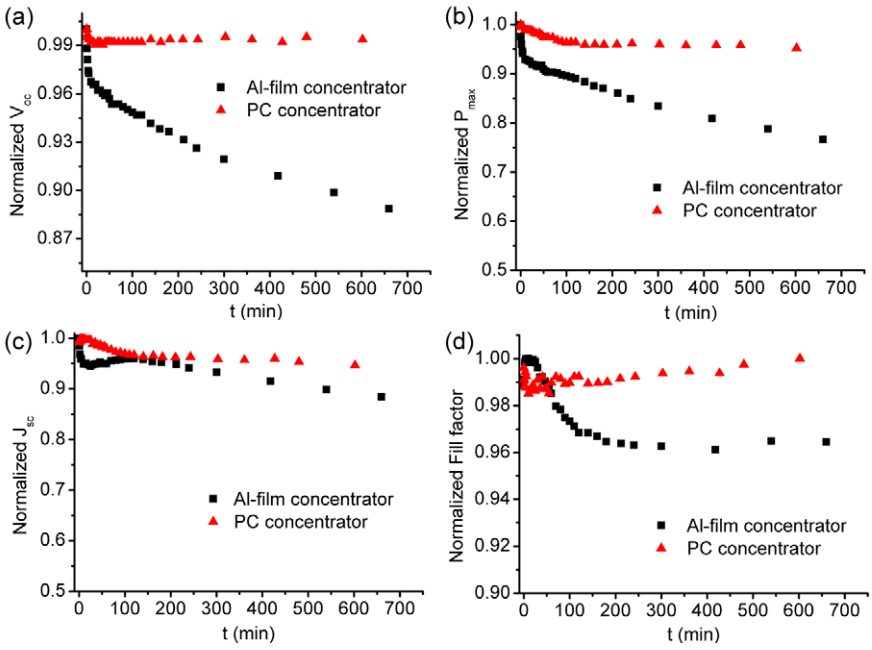

Fig. S3. Normalized comparison of the stability for various DSSC parameters under concentrators of Al-film and PC (with the stopband of 530 nm). (a) photovoltages, (b) output powers, (c) photocurrent densities; (d) fill factors. Generally, a rapid decrease of I-V characteristics with increasing irradiation time could be clearly observed when concentrated by concave Al-film, which indicated that the application of Al-film concentrator would accelerate dye degradation. In contrast, the cell performance kept stable when using the PC concentrator, which implied that the PC concentrator could effectively prevent dye from degrading and promote the output of the DSSC.

Table S1. DSSC characterization results in the presence of PC concentrators

	J_{sc} (mA cm^{-2})	V_{oc} (V)	*ff* (%)	P_{max} (mW cm^{-2})	η (%)
1	3.92	0.659	80.9	2.09	5.49
2	9.09	0.692	76.2	4.79	8.87×10^{-2}
3	14.25	0.714	72.4	7.37	1.36×10^{-1}
4	10.12	0.696	75.7	5.33	9.87×10^{-2}
5	24.89	0.730	62.7	11.42	2.11×10^{-1}

Note: **1** is the control sample which is directly exposed to the solar simulator; **2**, **3**, **4** and **5** are results under PC concentrators with the stopbands of 644, 448, 475 and 530 nm, respectively.

J_{sc}: the photocurrent density measured at short circuit.

V_{oc}: the open circuit photo-voltage.

ff: the fill factor of the DSSC.

I_{in}: the intensity of the light of the system, it was 38.2 ± 3 mW cm^{-2}

P_{max}: maximum output power density of the DSSC. P_{max} was calculated by the equation:

$$P_{max} = J_{sc} \times V_{oc} \times ff$$

η: the total-light-to-electricity conversion efficiency. η was calculated by the equation:

$$\eta = P_{max} \times A_{cell} / (I_{in} \times A_{PC})$$

A_{cell}: the area of the cell, it was 0.2 cm^2 in this work.

A_{PC}: the area of the PC concentrator, it was 28.26 cm^2 in this work.

References

1 J. X. Wang, Y. Q. Wen, H. L. Ge, Z. W. Sun, Y. M. Zheng, Y. L. Song and L. Jiang, *Macromol. Chem. Phys.,* 2006, **207**, 596.

2 Y. Zhao, J. Zhai, S. X. Tan, L. F. Wang, L. Jiang and D. B. Zhu, *Nanotechnology,* 2006, **17**, 2090.