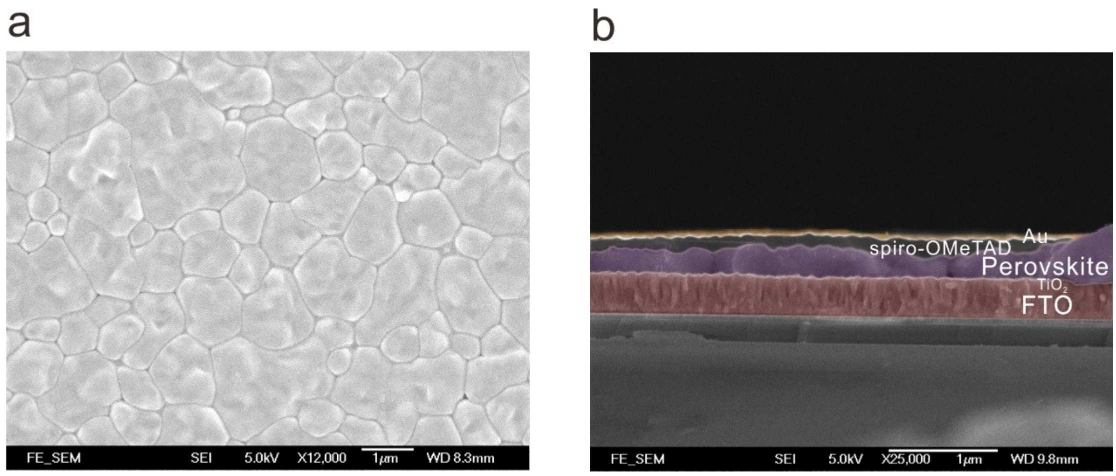
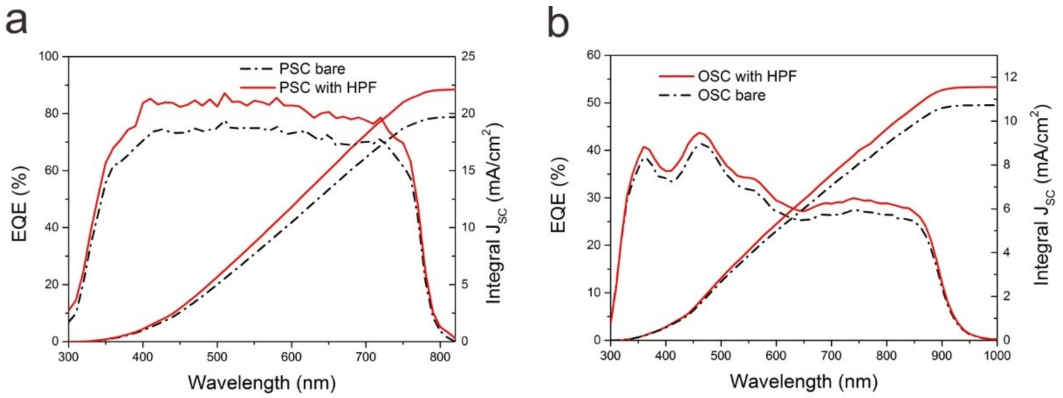
Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supplementary information

Supplementary Figures



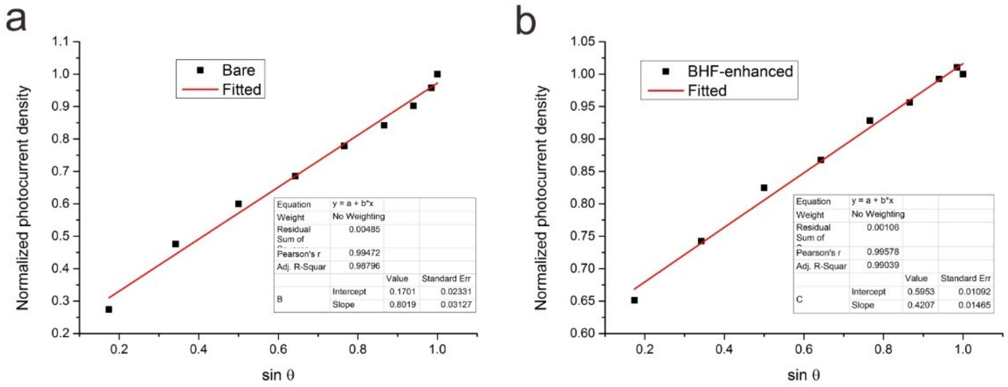
Supplementary Figure 1. FE-SEM image of (a) perovskite film and (b) cross-sectional image of the perovskite solar cell.



Supplementary Figure 2. EQE spectra and calculated J_{SC} of (a) PSC and (b) OSC. The J_{SC} is calculated by the equation:

$$J_{SC} = \int_{\lambda_{min}}^{\lambda_{max}} \frac{q}{hc} S_{Solar}(\lambda) S_{EQE}(\lambda) \lambda d\lambda$$

where q is elementary charge, h is Planck constant, c is velocity of light, $S_{Solar}(\lambda)$ is specific solar spectrum at wavelength λ, and $S_{EQE}(\lambda)$ is EQE at λ. The integral curves were plotted in the graphs, indicating a remarkable increase of current density when the device is attached with BHF. The calculated J_{SC} of bare PSC and OSC were 19.7 and 10.7 mA/cm^2 respectively. After equipped with the BHF, the current density values of PSC and OSC enhanced to 22.1 and 11.6 mA/cm^2.



Supplementary Figure 3. Photocurrent-incident angle curves of bare PSC and BHF-enhanced PSCs. It is assumed that the solar power density remains unchanged during the daytime, and 2 sets of PSCs (one with BHF and the other without BHF) are placed at the same position parallel to the horizon. The photocurrent densities of bare PSC and BHF-enhanced PSC at normal incident angle are 20 mA/cm^2 and 22.5 mA/cm^2, respectively. For simplification, we consider the situation of spring equinox (or autumnal equinox), when the sunshine duration is the same for most of the area on the earth. The normal incident of sunlight is defined as 90°, and $\sin\theta = \cos\left(\frac{t-12}{12}\pi\right)\cos\varphi$, where θ is the incident angle, t is the daytime (ranging from 0 to 12 on spring equinox or autumnal equinox day) and φ is the latitude. The photocurrent densities of bare PSC and BHF-enhanced PSC at any sunshine time are:

$$I_{Bare} = f(t) = 20 \times (0.17 + 0.8\cos\left(\frac{t-12}{12}\pi\right)\cos\varphi), \quad (1)$$

$$I_{BHF} = g(t) = 22.5 \times (0.6 + 0.42\cos\left(\frac{t-12}{12}\pi\right)\cos\varphi). \quad (2)$$

The total energy generated by the bare PSC and BHF-enhanced PSC during the daytime can be calculated as:

$$E_{Bare} = UIt = U\int_0^{12} f(t)\cdot tdt, \quad (3)$$

$$E_{BHF} = UIt = U\int_0^{12} g(t)\cdot tdt, \quad (4)$$

where U is the output voltage of the PSC, which is ~ 1V for our devices (According to our results, the V_{OC} and FF of BHF-enhanced PSCs show very small shift when varying the incident angle. On the contrary, the V_{OC} of bare

PSCs will drop dramatically at 0° incidence. Hence, the actually E_{BHF}/E_{Bare} ratio should be even larger than our calculated results).

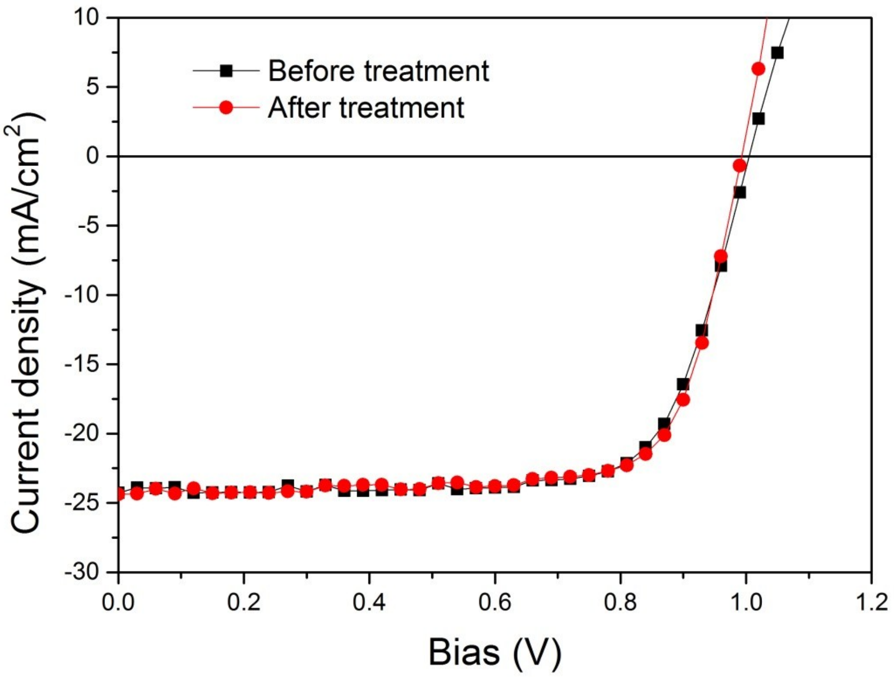
As a result, $E_{Bare} = 122 + 234\cos\varphi\ (J/m^2)$,

$E_{BHF} = 405 + 115\cos\varphi (J/m^2)$.

Obviously, E_{BHF}/E_{Bare} is larger when the latitude is higher.

For example, the latitude of Hong Kong is ~ 22°,

Thus, $E_{Bare} = 339\ J/m^2 = 94\ mWh/m^2$, and the output energy of BHF-enhanced PSC $E_{BHF} = 512\ J/m^2 = 142\ mWh/m^2$, which is 51% larger than that of bare PSC. For high latitude area such as Moscow (φ ~ 55°), $E_{Bare} = 256\ J/m^2 = 71\ mWh/m^2$, and $E_{BHF} = 471\ J/m^2 = 131\ mWh/m^2$. In other word, the BHF-enhanced PSC generates 85% more electricity than that of bare PSC.



Supplementary Figure 4. The *J-V* curves of BHF-enhanced PSC before and after the durability test of BHF. The durability test consists of the UV, acid and thermal treatment of the BHF. Firstly, the BHF was irradiated by UV lamp (Spectroline MODEL SB-100PA/F) for 1 h. Afterwards, the BHF was immersed in 0.1M HCl solution for 1 day, and then dried at 80 °C for another day to finish the acid and thermal durability test. The *J-V* results indicate stable optical characteristics of the BHF under UV/acid/high temperature.

Supplementary Table 1

Supplementary Table 1: Comparison of optical haze and transmittance for some typical haze matrials reported previously

Materials	Haze value @400-800nm	Total Transmittance
ZnO:Al[35]	~30%	N.A.
Nanofibrillated cellulose+Ag nanowire[30]	63~70%, 65% on average	~90%
Nanostructured paper[23]	~60%	~96%
TiO_2[17]	55%~75%	N.A.
Pyramidal type SnO_2:F (FTO) [36]	5%~30%,18% on average	N.A.
w-Textured SnO_2:F (FTO) [36]	50%~85%,70% on average	N.A.
Alumina nanowire bundles A[24]	92%	~85%
Alumina nanowire bundles B[24]	85%	~91%
Alumina nanowire bundles C[24]	75%	~93%
Wood composites[25]	~80%	~90%
BHF PDMS (this work)	**>75%**	**~97%**

Supplementary Table 2: Summary of the photovoltaic performances of 10 randomly selected PSCs with and without BHF. The average PCE enhancement by BHF is 12.3%.

Device No.	*BHF*	*V_{OC} (V)*	*J_{SC} (mA/cm^2)*	*FF (%)*	*PCE (%)*	*Enhancement (%)*
1	w	0.94	20.2	75.8	14.4	
	w/o	0.94	22.6	78.0	16.6	15.3
2	w	0.93	19.8	76.5	14.1	
	w/o	0.93	22.7	76.1	16.1	14.2
3	w	0.98	20.3	74.9	15.1	
	w/o	0.99	22.4	75.1	16.7	10.6
4	w	0.99	20.3	75.9	15.3	
	w/o	0.99	22.0	77.0	16.8	9.8
5	w	1.05	20.2	73.2	15.5	
	w/o	1.05	22.2	74.0	17.2	11.0
6	w	1.05	20.9	70.9	15.6	
	w/o	1.06	22.7	71.3	17.2	10.3
7	w	1.00	21.3	73.0	15.5	
	w/o	1.02	22.7	74.0	17.1	10.3
8	w	0.98	21.2	70.0	14.5	
	w/o	0.98	23.2	71.5	16.3	12.4
9	w	1.05	17.0	69.3	12.4	
	w/o	1.05	18.9	71.0	14.1	13.7
10	w	1.03	20.8	77.6	16.6	
	w/o	1.03	24.5	75.9	19.2	15.6

Supplementary References:

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