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

Supporting Information

Graphitic Carbon Nitride doped SnO_2 Enabling Efficient Perovskite Solar Cells Exceeding 22%

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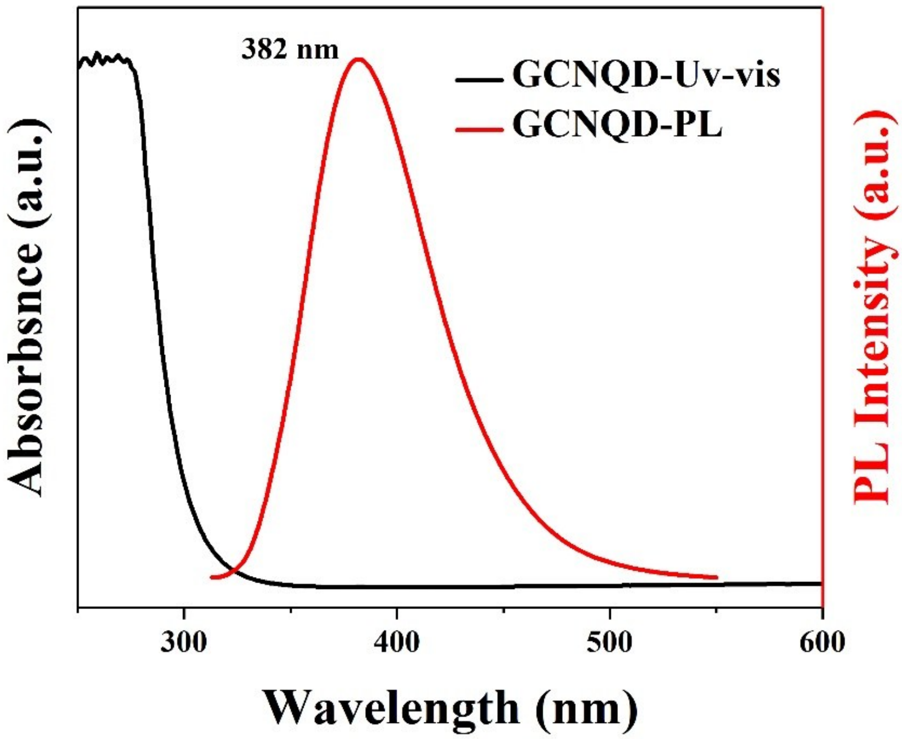

Fig. S1. The absorption and PL spectra of g-CNQD.

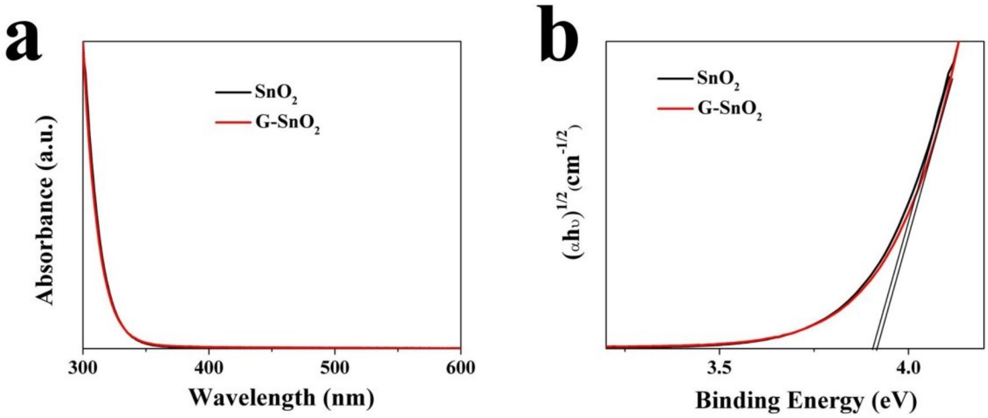

Fig. S2. (a) UV−vis absorption spectrum of the SnO_2 and G-SnO_2, (b) the relationship of $(\alpha h\upsilon)^{1/2}$ vs energy for SnO_2 and G-SnO_2.

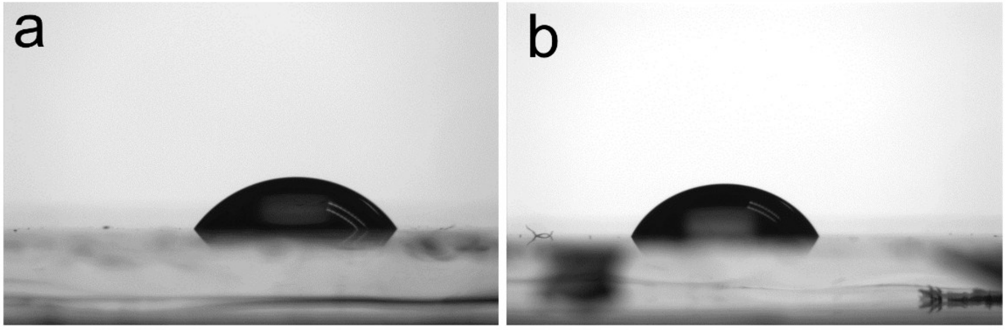

Fig. S3. Contact angle measurement for water on bare SnO_2 (a) and G-SnO_2 (b).

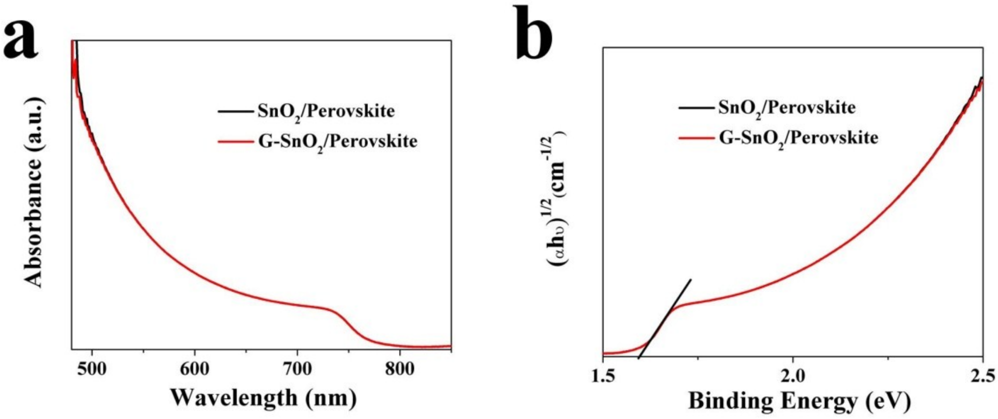

Fig. S4. UV−vis absorption spectrum of perovskite film deposite on the SnO_2 and G-SnO_2, (b) the relationship of $(\alpha h\upsilon)^{1/2}$ vs energy for perovskite film deposited on the SnO_2 and G-SnO_2.

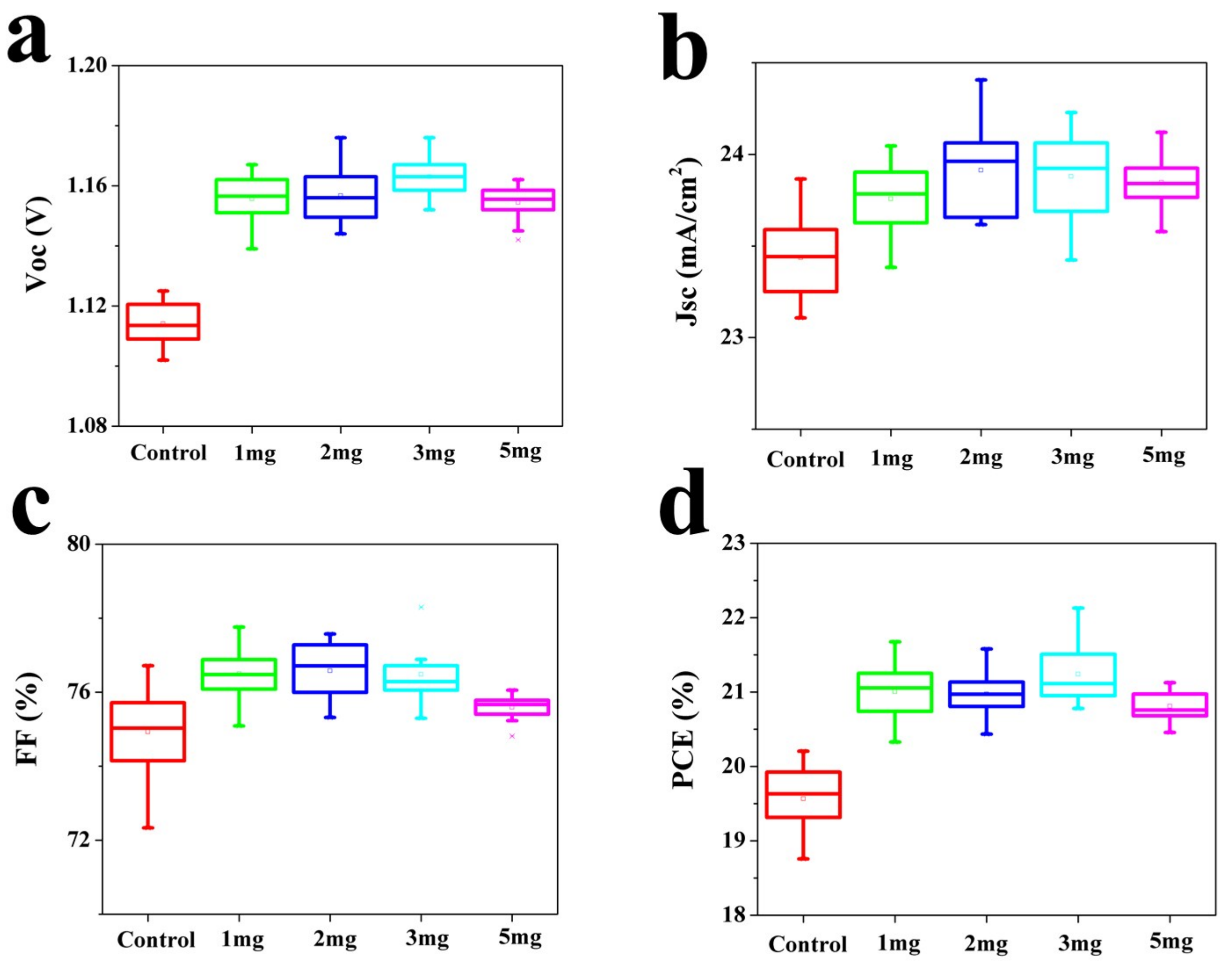

Fig. S5. Statistics parameters of V_{oc} (a), J_{sc} (b), FF (c), and PCE (d) SnO_2 and G-SnO_2 with different doping concentration PSCs.

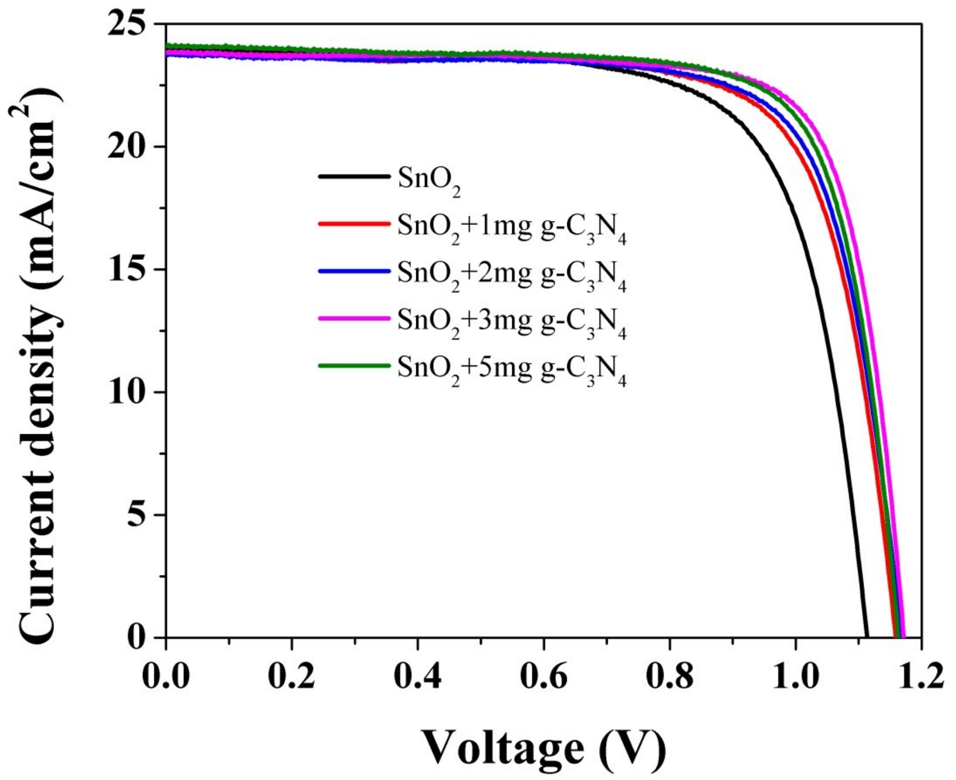

Fig. S6. The *J*–*V* curves of the SnO_2 and G-SnO_2 with different g-CNQD concentration PSCs

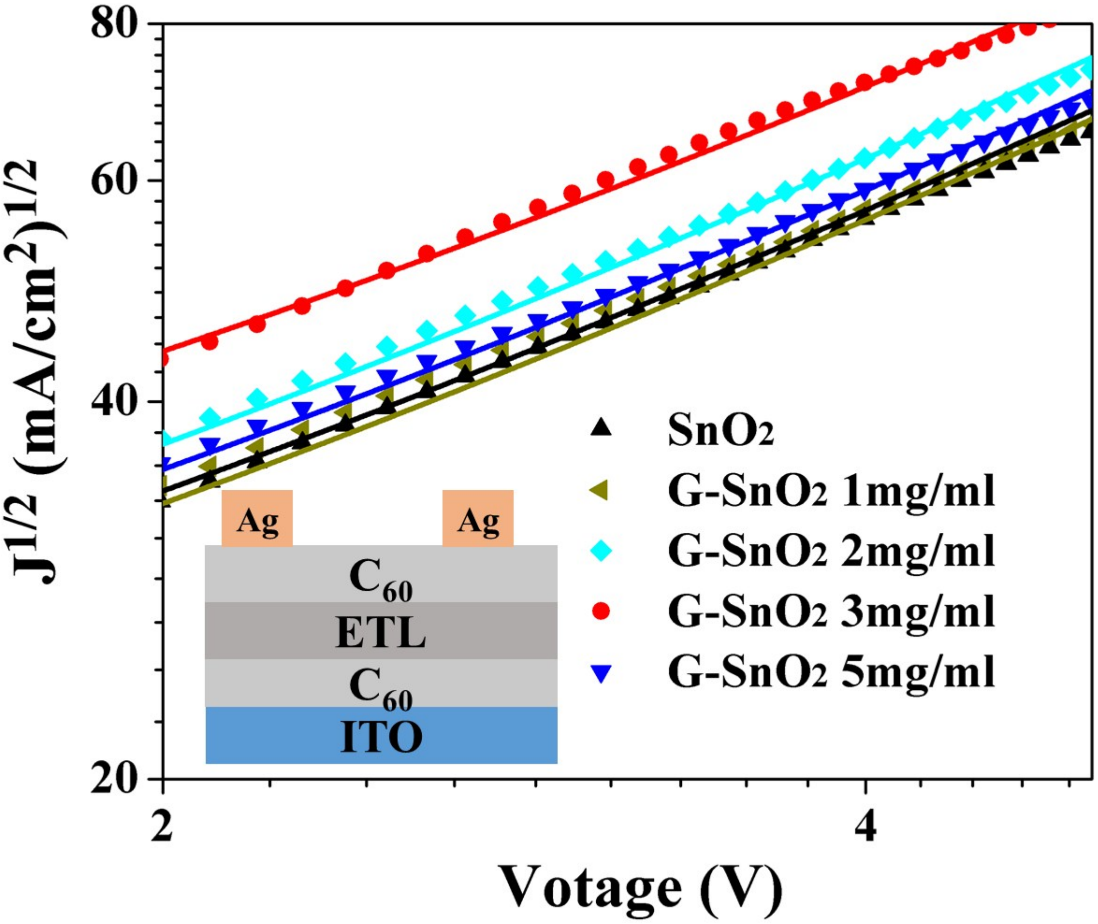

Fig. S7. The current J-V curves based on SnO_2 and G-SnO_2 films fitting with the Mott-Gurney law.

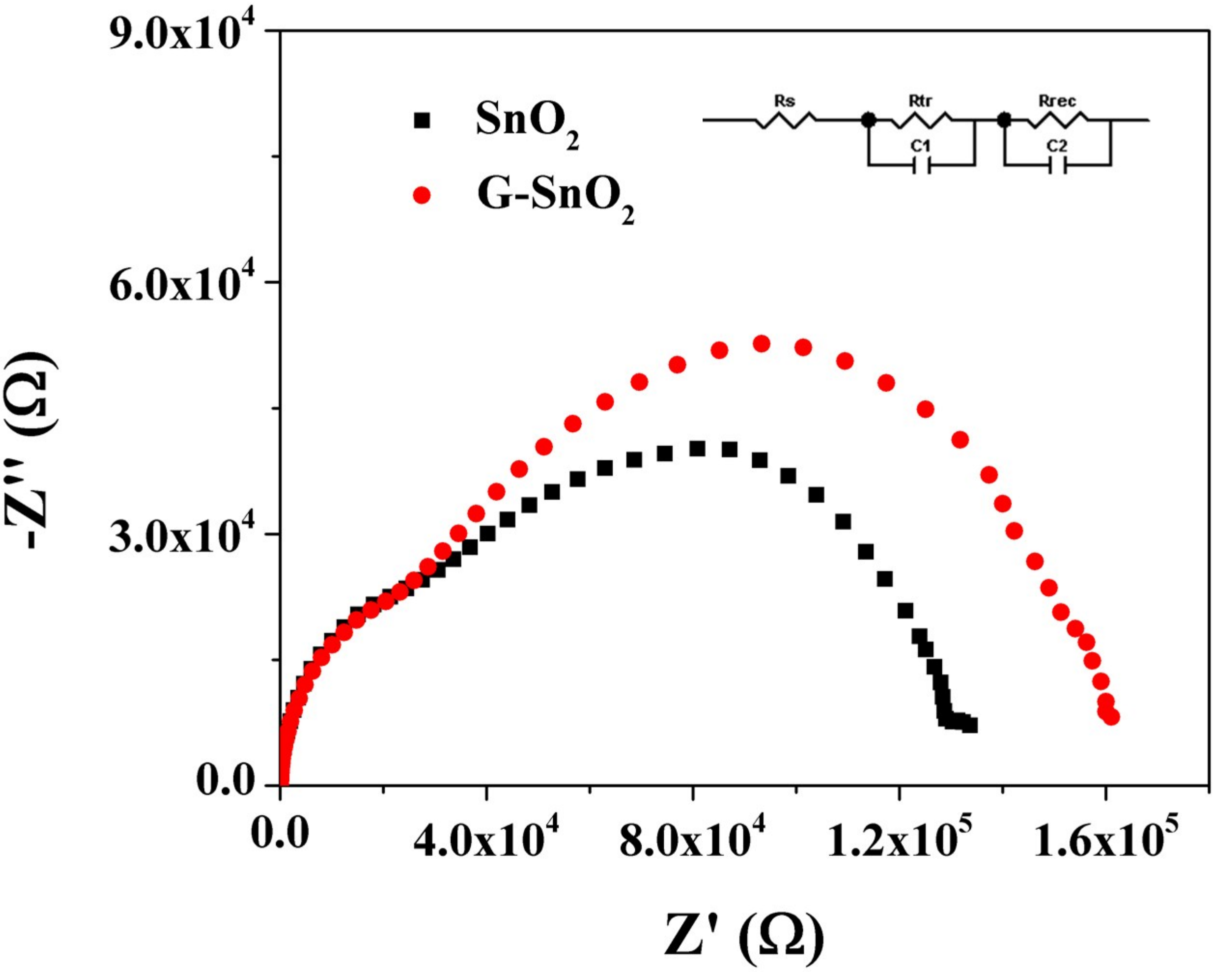

Fig. S8. EIS of planar-type PSCs with SnO_2 and G-SnO_2 ETLs, the insert picture is the fitting model.

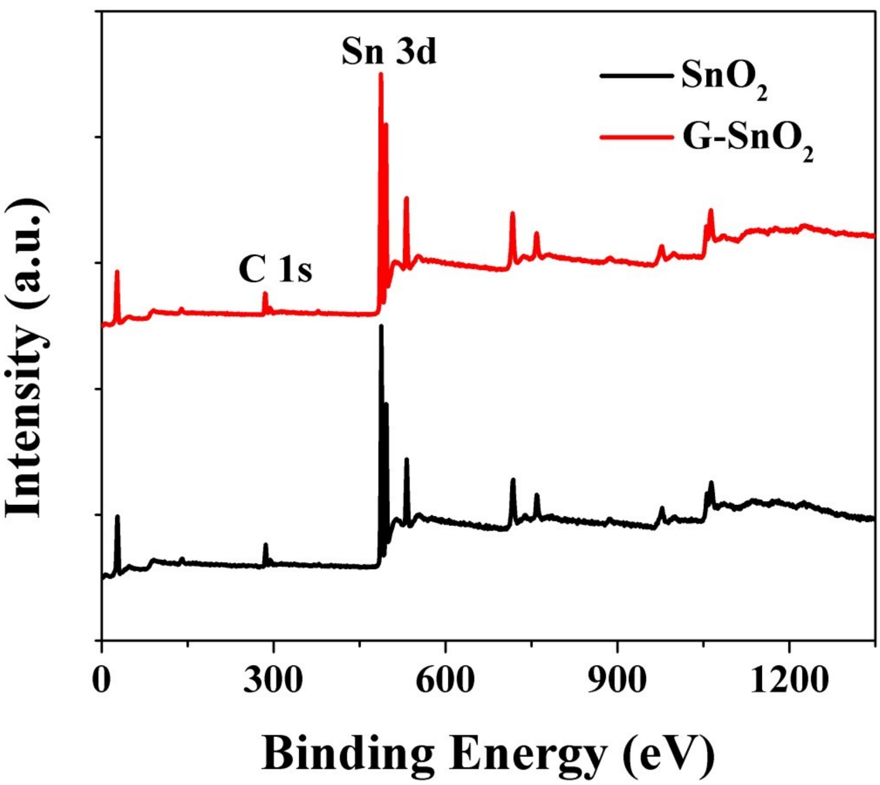

Fig. S9. XPS survey scans of bare SnO_2 and G-SnO_2.

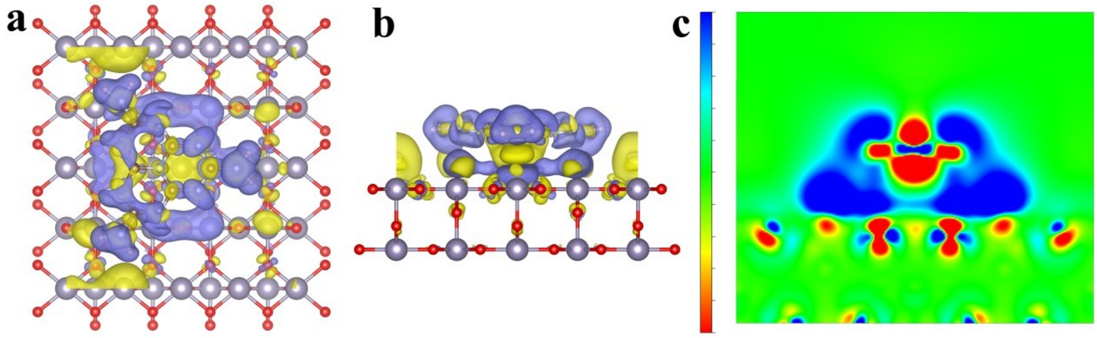

Fig. S10. (a) the top view of the charge density difference of G-SnO_2. (b) the side view for the charge density difference of G-SnO_2, the cyan and yellow areas indicate electron accumulation and depletion, respectively. (c) the corresponding 2D view, the blue and yellow indicate electron accumulation and depletion, respectively.

Table S1. The TRPL fitting parameters of perovskite film on SnO_2 and G-SnO_2.

Sample	τ_1 (ns)	A_1 (%)	τ_2 (ns)	A_2 (%)	τ_{ave} (ns)
SnO_2	42.05	11.3	323.8	88.70	291.96
G-SnO_2	12.7	13.2	364.8	86.80	318.32

Table S2. The parameters of PSCs based on bare SnO_2.

Device	V_{oc} (V)	J_{sc} (mA/cm^2)	FF	PCE(%)
1	1.106	23.26	0.7662	19.71
2	1.119	23.46	0.7672	20.14
3	1.118	23.72	0.7620	20.21
4	1.125	23.39	0.7624	20.06
5	1.120	23.37	0.7596	19.88
6	1.121	23.59	0.7566	20.00
7	1.124	23.29	0.7532	19.72
8	1.125	23.42	0.7576	19.97
9	1.121	23.55	0.7492	19.78
10	1.109	23.59	0.7514	19.66
11	1.112	23.53	0.7559	19.78
12	1.111	23.87	0.7553	20.03
13	1.109	23.35	0.7459	19.32
14	1.105	23.22	0.7513	19.28
15	1.102	23.61	0.7441	19.36
16	1.108	23.15	0.7355	18.86
17	1.114	23.11	0.7287	18.76
18	1.116	23.24	0.7404	19.21
19	1.113	23.20	0.7483	19.33
20	1.114	23.20	0.7471	19.31
21	1.124	23.61	0.7388	19.60
22	1.109	23.57	0.7397	19.33
23	1.103	23.64	0.7234	18.87
24	1.111	23.52	0.7425	19.40
Average	1.114	23.44	0.7493	19.57

Table S3. The parameters of the PSCs based on optimal G-SnO_2.

Device	V_{oc} (V)	J_{sc} (mA/cm^2)	FF	PCE(%)
1	1.159	23.48	0.7671	20.87
2	1.162	23.42	0.7689	20.93
3	1.158	23.68	0.7672	21.04
4	1.162	23.50	0.7663	20.92
5	1.164	23.50	0.7629	20.86
6	1.157	23.66	0.7604	20.82
7	1.154	23.69	0.7599	20.78
8	1.156	23.85	0.7608	20.97
9	1.152	23.94	0.7625	21.03
10	1.168	24.20	0.7657	21.64
11	1.163	24.21	0.7534	21.21
12	1.167	24.23	0.7628	21.57
13	1.166	24.17	0.7607	21.44
14	1.167	24.15	0.7622	21.49
15	1.163	23.82	0.7631	21.14
16	1.169	23.89	0.7660	21.40
17	1.163	24.05	0.7571	21.18
18	1.161	23.99	0.7530	20.98
19	1.162	23.94	0.7555	21.02
20	1.165	23.78	0.7611	21.09
21	1.176	24.03	0.7830	22.13
22	1.171	24.07	0.7775	21.92
23	1.169	23.93	0.7814	21.86
24	1.158	23.91	0.7775	21.53
Average	1.163	23.88	0.7648	21.24

Table S4. Electron mobility of SnO_2 with different g-C_3N_4 doping concentration.

	Bare SnO_2	**1mg/ml G-SnO_2**	**2mg/ml G-SnO_2**	**3mg/ml G-SnO_2**	**5mg/ml G-SnO_2**
electron mobility ($cm^2\ V^{-1}\ s^{-1}$)	5.2×10^{-3}	5.67×10^{-3}	6.60×10^{-3}	7.5×10^{-3}	5.34×10^{-3}

Table S5. Device stability test of perovskite solar cells.

Device structure	Store condition	Stability	Reference
FTO/bl-SnO_2/mp-SnO_2/$MAPbI_3$/Spiro-/Au	humidity 20% temperature 25 °C	90% 3000 h	1
FTO/SnO_2 nanosheet/C_{60}/$MAPbI_3$/Spiro-/Au	humidity 20% temperature 25 °C	94% 500h	2
ITO/Sb:SnO_2/$MAPbI_3$/Spiro-/Au	in a desiccator	95% 21d	3
ITO/SnO_2 /C_9/ CsFAMA /Spiro-/Au	humidity 15-20% temperature 25 °C	92% 90d	4
ITO/SnO_2-RCQs/ CsFAMA /Spiro-/Au	humidity 40%-60% temperature 25 °C	95% over 1000h	5
ITO/G-SnO_2 / CsFAMA /Spiro-/Au (our work)	humidity 60% temperature 25 °C	90% 1500h	-

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