Graphitic Carbon Nitride doped SnO₂ 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 $(\alpha \nu)^{1/2}$ 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 deposited on the SnO$_2$ and G-SnO$_2$, (b) the relationship of $(\alpha hv)^{1/2}$ 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-C$_3$N$_4$ 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.
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<tr>
<th>Sample</th>
<th>$\tau_1$ (ns)</th>
<th>$A_1$ (%)</th>
<th>$\tau_2$ (ns)</th>
<th>$A_2$ (%)</th>
<th>$\tau_{ave}$ (ns)</th>
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Table S2. The parameters of PSCs based on bare SnO$_2$.

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<th>Device</th>
<th>$V_{oc}$ (V)</th>
<th>$J_{sc}$ (mA/cm$^2$)</th>
<th>FF</th>
<th>PCE(%)</th>
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Table S3. The parameters of the PSCs based on optimal G-SnO$_2$.

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<tr>
<th>Device</th>
<th>$V_{oc}$ (V)</th>
<th>$J_{sc}$ (mA/cm$^2$)</th>
<th>FF</th>
<th>PCE(%)</th>
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<tr>
<td></td>
<td>Bare SnO$_2$</td>
<td>1mg/ml G-SnO$_2$</td>
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<tr>
<td>electron mobility</td>
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<tr>
<td>(cm$^2$ V$^{-1}$ s$^{-1}$)</td>
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Table S4. Electron mobility of SnO$_2$ with different g-C$_3$N$_4$ doping concentration.
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<td>FTO/bl-SnO₂/mp-SnO₂/MAPbI₃/Spiro-/Au</td>
<td>humidity 20% temperature 25 °C</td>
<td>90% 3000 h</td>
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<tr>
<td>FTO/SnO₂ nanosheet/C₆₀/MAPbI₃/Spiro-/Au</td>
<td>humidity 20% temperature 25 °C</td>
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<td>ITO/Sb:SnO₂/MAPbI₃/Spiro-/Au</td>
<td>in a desiccator</td>
<td>95% 21d</td>
<td>3</td>
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<tr>
<td>ITO/SnO₂/C₆₀/CsFAMA/Spiro-/Au</td>
<td>humidity 15-20% temperature 25 °C</td>
<td>92% 90d</td>
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<tr>
<td>ITO/SnO₂-RCQs/CsFAMA/Spiro-/Au</td>
<td>humidity 40%-60% temperature 25 °C</td>
<td>95% over 1000h</td>
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</tr>
<tr>
<td>ITO/G-SnO₂/CsFAMA/Spiro-/Au (our work)</td>
<td>humidity 60% temperature 25 °C</td>
<td>90% 1500h</td>
<td>-</td>
</tr>
</tbody>
</table>

**References**


