<table>
<thead>
<tr>
<th>Classification</th>
<th>Precursor(s)</th>
<th>Approach</th>
<th>Purification</th>
<th>CND Size</th>
<th>Surface functionality</th>
<th>CND role</th>
<th>Device architecture</th>
<th>$J_{SC}$ (mA cm$^{-2}$)</th>
<th>$V_{OC}$ (V)</th>
<th>FF</th>
<th>q (%)</th>
<th>Band edges (eV)</th>
<th>Optimized conditions</th>
<th>Explanation for performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GQDs</td>
<td>4-bromobenzoic acid, 4-bromobenzoic acid</td>
<td>SD CC</td>
<td>13.5 nm (DLS)</td>
<td>Triarylphenyl; single carbonyl group</td>
<td>Sensitizer</td>
<td>FTO/TiO$_2$, NP5/GQDs/1:7:Pt</td>
<td>0.20</td>
<td>0.48</td>
<td>0.58</td>
<td>0.06</td>
<td>3.8/5.3</td>
<td>No optimization</td>
<td>Low affinity of GQD functional groups for TiO$_2$</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td></td>
<td>SD CC</td>
<td>13.5 nm (DLS)</td>
<td>Triarylphenyl; single carbonyl group</td>
<td>Sensitizer</td>
<td>FTO/TiO$_2$, NP5/GQDs/1:7:Pt</td>
<td>-4.5</td>
<td>&gt;0.5</td>
<td>NR</td>
<td>NR</td>
<td>Tunable</td>
<td>No optimization</td>
<td>Addition of single carboxyl group resulted in higher sensitizer packing density due to edge-on alignment which produced more efficient electron transfer</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td>γ-butyrolactone</td>
<td>AD D (1 kDa)</td>
<td>3–15 nm</td>
<td>Carboxyl, alkyl sulfonic</td>
<td>Sensitizer</td>
<td>FTO/TiO$_2$, NP5/CQDs/1:7:Pt</td>
<td>0.53</td>
<td>0.38</td>
<td>0.64</td>
<td>0.13</td>
<td>-</td>
<td>No optimization</td>
<td>Emissive sites acting as recombination centers, inferior charge injection properties</td>
<td></td>
</tr>
<tr>
<td>CNDs</td>
<td>Melamine, glycerol</td>
<td>T D (1 &amp; 3.5 kDa)</td>
<td>0.8–3 nm</td>
<td>Hydroxyl, alkyld, amine, triazine</td>
<td>Sensitizer</td>
<td>FTO/TiO$_2$, NP5/CNDs/1:7:Pt</td>
<td>0.80</td>
<td>0.57</td>
<td>0.29</td>
<td>0.13</td>
<td>NR</td>
<td>No optimization</td>
<td>Two photon energy upconversion of N-doped CNDs enhanced harvesting of near-IR light. Low performance due to high recombination rates with CNDs and poor electron transfer.</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td>Graphite rods</td>
<td>EC CTFG</td>
<td>1–4 nm</td>
<td>Hydroxyl, alkyl, carboxylic acid</td>
<td>Sensitizer</td>
<td>Ti Foil/TiO$_2$, NTU/CQDs/1:7:Pt</td>
<td>0.02</td>
<td>0.58</td>
<td>0.35</td>
<td>0.04</td>
<td>Only bad gap (1.9) reported</td>
<td>No optimization</td>
<td>Showed feasibility as sensitizer; due to appropriate band alignment, photoexcited electrons easily injected into TiO$_2$</td>
<td></td>
</tr>
<tr>
<td>CNDs</td>
<td>γ-butyrolactone</td>
<td>AD D (MWCNT:CQD film)</td>
<td>NR (1–5 nm from TEM)</td>
<td>Carboxyl</td>
<td>Sensitizer</td>
<td>FTO/MWCNT:CQDs/1:7:Pt (not metal oxide based)</td>
<td>1.7–3.8</td>
<td>0.74–0.86</td>
<td>NR</td>
<td>Only highest reported (1.23%)</td>
<td>NR</td>
<td>No optimization</td>
<td>Depends on photodecay thickness. CQDs were covalently bound to CNTs via an ester linkage which allowed for more effective injection of the excited state electrons.</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNDs</td>
<td>Monkey grass</td>
<td>HT FLTR &amp; CTFG</td>
<td>2–6 nm</td>
<td>Carboxyl, hydroxyl, epoxy, amine, (pyridinic-N, pyrrolic-N, graphitic-N within core)</td>
<td>Sensitizer</td>
<td>FTO/TiO$_2$, NP5/CNDs/1:7:Pt</td>
<td>1.93 ± 0.07</td>
<td>0.49 ± 0.01</td>
<td>0.55 ± 0.02</td>
<td>0.53 ± 0.05</td>
<td>4.14/5.73</td>
<td>0.1 M I$_3$ (0.01 M I$_2$); (leq.) CND uptake not optimized</td>
<td>Aqueous I$_3^-$/I$_2$ vs. organic solvent resulted in stronger quenching of the CNDs by I$_2$ leading to enhanced utilization of the photoexcited electrons.</td>
<td></td>
</tr>
<tr>
<td>CNDs</td>
<td>CA, urea</td>
<td>MWV CTFG</td>
<td>NR (≤5 nm from TEM)</td>
<td>NR; presumably hydroxyl, carboxyl, and amine</td>
<td>Sensitizer</td>
<td>FTO/TiO$_2$, NP5/CNDs/1:7:Pt</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>Not optimized; only report EPC</td>
<td>CNDs could effectively inject electrons into TiO$_2$ displaying an electron injection rate and efficiency of 8.8 x 10$^7$ s$^{-1}$ and 91% which was attributed to strong intrinsic visible absorption and</td>
<td></td>
</tr>
</tbody>
</table>

In Tables S1-S5, the reference number within the parentheses corresponds to the reference number within the main text. A list of the acronyms used in the tables and their full names are provided in Table S6.

**Table S1** Sensitive (metal oxide-based) devices (Section 3.1)
CNDs

<table>
<thead>
<tr>
<th>CA, ionic formic acid</th>
<th>MWV</th>
<th>CTFG</th>
<th>0.5–2.5 nm</th>
<th>Sensitizer</th>
<th>Sensitizer</th>
<th>FTO/TiO₂ NPs/CNDs close to 1 /Pt</th>
<th>Sensitization conducted at pH 1 for 6–8 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA, uracil, ammonium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.99</td>
<td>Devices not directly optimized; Extent of N-doping in CO₃ optimized by varying precursor mass ratios (1:4 CA:CA)</td>
</tr>
</tbody>
</table>

CDs

<table>
<thead>
<tr>
<th>CA, ammonia</th>
<th>T</th>
<th>CTFG</th>
<th>7–15 nm</th>
<th>Sensitizer</th>
<th>Sensitizer</th>
<th>FTO/TiO₂ NPs/CDS close to 1 /Pt</th>
<th>Sensitization conducted at pH 1 for 6–8 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA, urea, formic acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.65</td>
<td>Devices not directly optimized; Extent of N-doping in CO₃ optimized by varying precursor mass ratios (1:4 CA:CA)</td>
</tr>
</tbody>
</table>

CQDs

<table>
<thead>
<tr>
<th>Strawberry powder</th>
<th>HT</th>
<th>None</th>
<th>1–4 nm</th>
<th>Sensitizer</th>
<th>Sensitizer</th>
<th>FTO/TiO₂ NPs/CQDs close to 1 /Pt</th>
<th>Sensitization conducted at pH 1 for 6–8 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA, ammonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.50</td>
<td>Devices not directly optimized; Extent of N-doping in CO₃ optimized by varying precursor mass ratios (1:4 CA:CA)</td>
</tr>
</tbody>
</table>

GQDs

<table>
<thead>
<tr>
<th>GO</th>
<th>AD</th>
<th>FLTR prior to PEG functionalization</th>
<th>0.5 nm</th>
<th>Sensitizer</th>
<th>Sensitizer</th>
<th>FTO/TiO₂ NPs/GQDs close to 1 /Pt</th>
<th>Sensitization conducted at pH 1 for 6–8 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>GO</td>
<td></td>
<td>D-(+) Glucosamine + Tris</td>
<td></td>
<td></td>
<td></td>
<td>6.65 ± 0.02 – 14.07 ± 0.02</td>
<td>Devices not directly optimized; Extent of N-doping in CO₃ optimized by varying precursor mass ratios (1:4 CA:CA)</td>
</tr>
</tbody>
</table>

GQDs

<table>
<thead>
<tr>
<th>GO</th>
<th>SCF</th>
<th>D (MWCO NR)</th>
<th>3–10 nm</th>
<th>Sensitizer</th>
<th>Sensitizer</th>
<th>FTO/TiO₂ NPs/GQDs close to 1 /Pt</th>
<th>Sensitization conducted at pH 1 for 6–8 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>GO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.36–7.80</td>
<td>Devices not directly optimized; Extent of N-doping in CO₃ optimized by varying precursor mass ratios (1:4 CA:CA)</td>
</tr>
</tbody>
</table>

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Au@CDs

Pyrene

HT

D (3.5 kDa)

2-5 nm

MPA-capped through ligand exchange with dodecylamine; Bare GQDs: hydroxyl

Phosphodiester dopant/co-sensitizer

TIO$_2$/NPs/CdSe QDs/GQDs/ZnS film/SiO$_2$/film/Na$_2$S$_2$/Cu$_2$S-brass

15.11–15.88

0.605–0.662

0.614–0.659

6.02 t

0.05–0.63 s

0.04

NR

GdSe QDs coated first following by GQDs (0.5 g L$^{-1}$ solution with 3 h adsorption time)

increased charge mobility of both polymer-based composites.

Depends on coating sequence, GdSe stock concentration, and length of adsorption time. GQDs function as an energy barrier suppressing charge recombination.

(Cu(II)–Il-) [218]

CDs

Carbon soot

(AOD) (MWCO NR)

2-8 nm

Carbonyl

Phosphodiester dopant/co-sensitizer

FTO/TiO$_2$/CD grafts

11.65–13.71

0.56–0.58

0.58–0.62

4.04–4.69

~3.8”±5.5

2.0 wt% CD grafted graphene

Larger pores afforded increased sensitizer uptake; graphene networks acted as bridge between TiO$_2$ NPs increasing electron transport and decreasing recombination; CDs hindered graphene agglomeration and acted as co-sensitizer transferring photoscropted electrons to graphene.

Depends on mass of GQDs (10, 20, 33.3, and 50 mg) incorporated into PANI-GQDs composites. Varying GQD concentration changes compatibility between the LUMO of the donor PANI chains and CB of the GQD acceptors and changes morphology of composite from flakes (10 & 20 mg) to rods in a mixture of both. Interaction between PANI and GQDs produce BDTs on the molecular level which facilitate charge carrier separation.

Increased roughness factor of TiO$_2$ NPs allowing higher dye uptake; faster extraction of photogenated electrons; reduced recombination

Au@CDs

Glucose, HAuCl$_4$

HT

CTFG

130–250 nm

Hydroxyl, epoxy

Electron acceptor

FTO/ZnO Nanorods/TiO$_2$/Au@CD$_x$/I$_2$-

11.71

0.68

0.78

6.22 NR

No optimization

Au@CDs promoted electron transfer and transport by accepting electrons from dye and shifting them to ZnO and/or FTO; plasmonic nature of Au nanostructures and FRET from ZnO to dye both enhanced excited state electron charge transfer resistance, increasing electron mobility, and charge carrier separation.

Depends on coating sequence, GdSe stock concentration, and length of adsorption time. GQDs function as an energy barrier suppressing charge recombination.

(Cu(II)–Il-) [218]

GQDs

GO

SCF

D (MWCO NR)

0.8–2.6 nm

Polyaniline functionalized; Bare GQDs: hydroxyl, carboxyl

Phosphodiester dopant/electron acceptor

FTO/PANI-GQDs/N719h$_1^1$–/ME

5.24–7.35

0.63–0.65

0.470–0.654

1.57–3.12

Cite GQD CB (3.47) from ref. [81]

33.3 mg GQDs in composite

Depends on coating sequence, GdSe stock concentration, and length of adsorption time. GQDs function as an energy barrier suppressing charge recombination.

(Cu(II)–Il-) [218]

GQDs

CNFs

AOD

(3 kDa)

~15 nm (DLS)

NR; presumably oxygen containing moieties

Electron shuttle/electron acceptor

FTO/TiO$_2$/NF$_x$/GQDs/N719$_1^1$–/Pt

11.72

0.68

0.78

6.22 NR

No optimization

Increased roughness factor of TiO$_2$ NPs allowing higher dye uptake; faster extraction of photogenated electrons; reduced recombination

Au@CDs

Glucose, HAuCl$_4$

HT

CTFG

130–250 nm

Hydroxyl, epoxy

Electron acceptor

FTO/ZnO Nanorods/TiO$_2$/Au@CD$_x$/I$_2$-

11.71

0.61

0.58

4.10

3.89.0 (Au@CD)

No optimization

Au@CDs promoted electron transfer and transport by accepting electrons from dye and shifting them to ZnO and/or FTO; plasmonic nature of Au nanostructures and FRET from ZnO to dye both enhanced excited state electron generation of dye

(Cu(II)–Il-) [218]

CDs

L- ascorbic acid

T

CC

10–30 nm

NR; presumably oxygen containing moieties

Electron donor; co-sensitizer

FTO/TiO$_2$/NP$_x$/Phb:GQDs:hydroxyl, carboxyl

17.07 ± 0.19

0.690 ± 0.004

0.411 ± 0.004

4.84 ± 0.13

3.78/4.39

No optimization

Due to co-mingling of sensizers and appropriate band alignments, conductive CDs enhance electron propagation between QDs and TiO$_2$ resulting in fast electron transport and slow recombination; CDs provide minute sensitizer effect Depends on oxidation temperature and mass of GQDs loaded; Upconversion properties of GQDs results in FRET to dye enhancing the photocurrent

(Cu(II)–Il-) [218]

GQDs

CNFs

AOD

CTFG (SSPPT)

5–40 nm

PEG functionalized

Electron donor

FTO/TiO$_2$/NF$_x$/QDs/D719$_1^1$–/Pt

14.15–15.20

0.764–0.766

0.740–0.75

7.31–7.95 NR

80 °C acid oxidation with 2.6 mg GQD loading

Depends on coating sequence, GdSe stock concentration, and length of adsorption time. GQDs function as an energy barrier suppressing charge recombination.

(Cu(II)–Il-) [218]

GQDs

Graphite rods

EC

CTFG

5–10 nm

Not directly reported; inferred that they are li-

Electrolyte dopant

FTO/TiO$_2$/NP$_x$/N719$_1^1$–/CD$_x$/I$_2$/Pt

1.94–6.64

0.57–0.66

0.47–0.67

0.59–2.71 NR

CDs (0.5 mm) [219]

Due to co-mingling of sensizers and appropriate band alignments, conductive CDs enhance electron propagation between QDs and TiO$_2$ resulting in fast electron transport and slow recombination; CDs provide minute sensitizer effect Depends on oxidation temperature and mass of GQDs loaded; Upconversion properties of GQDs results in FRET to dye enhancing the photocurrent

(Cu(II)–Il-) [218]

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stabilized since ILs were exfoliation electrolyte

GQDs
Vulcan XC-72 carbon black
AO CTFG ~10 nm
Hydroxyl, carbonyl
CE dopant FTO/TiO₂, NPv/NT19/t, 1/4/Ppy:GQDs
11.41–14.36 0.70–0.74 0.48–0.57 4.46–5.24 NR
10% (v:v) GQDs:PPy
Depends on GQD content in CE; optimized conditions comparable to Pt CE; GQD doping increased porosity of film introducing more active sites and thereby increasing charge transfer.

GDs
Glucose MWV D (1 kDa)
~3.5 nm NR; presumably oxygen containing moieties
CE dopant FTO/TiO₂, NPv/NT19/Electrolyte/GDs/PEDOT:PSS
12.82–14.23 0.67–0.72 0.60–0.70 5.14–7.20 NR
30 v% GDs in PEDOT:PSS solution
Depends on v% of GDs; Produces rougher surface morphology of CE film resulting in enhanced electrocatalytic activity and reduced R_CT which translates to higher J_SC and \( \eta \).

GQDs
Carbon black AO/MWV NR
Carboxyl, carbonyl, hydroxyl, epoxy
CE dopant FTO/TiO₂, NPv/NT19/t, 1/4/GQDs:Carbon aerogel
11.36 0.79 0.67 5.97 NR
Devices not optimized; GQD:carbon aerogel thickness optimized (1.2 µm) with CV
Inclusion of GQDs into carbon aerogel increased catalytic efficiency at the CE compared to neat carbon aerogel due to nanoscale nature of GQDs that possess higher percentage of more energetic, catalytically active edge carbons

CNDs
CA CA HT CTFG
Oxygen-rich functional groups, specifically carbonyl
CE dopant FTO/TiO₂, NPv/NT19/t, 1/PANI:CNDs
10.3–13.8 0.76–0.78 0.67–0.72 5.71–7.45 NR
5 wt% CNDs in PANI
CNDs acted as nuclei for PANI polymerization leading to a more homogeneous nucleation to produce films with higher porosity, surface roughness, conductivity, and electrocatalytic activity. Depends on CND wt%; 1 wt% not enough to produce highly porous film giving only slight improvement, while 10 wt% led to supersaturation and subsequent aggregation of nuclei which hindered homogenous polymerization, resulting in poorer performance. Optimized (5 wt%) CE comparable to Pt CE.

GQDs
CA, thiourea HT CTFG 1.0–5.0 nm
Hydroxyl, carbonyl, amine/amide, sulfur moieties
CE dopant FTO/TiO₂, NPv/NT19/t, 1/PANI:GQDs
5.39–9.30 0.38–0.44 0.329–0.497 0.754–1.603 NR
PANI-GQD CE electropolymerized at a scan rate of 10 mV s⁻¹
Inclusion of GQDs led to mace-like morphology compared to spherical NPs when electropolymerizing neat PANI, which enhanced surface area and conductivity. Performance depends on scan rate used for electropolymerization; scan rates of 30, 50, 80, and 100 mV s⁻¹ led to lower \( \eta \) and FF producing a lower PCE.

\( \mu \)mol LiI⁻, increased continuous illumination stability.

*Value calculated by authors; *Multiple devices characterized per each condition and/or for all device architectures (including controls)
<table>
<thead>
<tr>
<th>Classification</th>
<th>Precursor(s)</th>
<th>Approach</th>
<th>Purification</th>
<th>CND Size</th>
<th>Surface functionality</th>
<th>CND role</th>
<th>Device architecture</th>
<th>JSC (mA cm⁻²)</th>
<th>VOC (V)</th>
<th>FF</th>
<th>η (%)</th>
<th>Band edges (eV)</th>
<th>Optimized conditions</th>
<th>Explanation for performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GQDs</td>
<td>GS</td>
<td>HT</td>
<td>D (3.5 kDa)</td>
<td>5–15 nm</td>
<td>Carboxylic; subsequent functionalization with amine</td>
<td>Electron acceptor</td>
<td>ITO/PEDOT:PPS/P3HT:GQDs/LiF/Al</td>
<td>0.36–5.31</td>
<td>0.58–6.62</td>
<td>0.47–5.53</td>
<td>0.12–1.14</td>
<td>3.55/5.38</td>
<td>1 wt% GQDs</td>
<td>Depends on GQD wt%; Appropriate band alignment, improved optical properties and morphology (i.e., nanoscale phase separation) of composite film.</td>
</tr>
<tr>
<td>GQDs</td>
<td>Graphene film</td>
<td>EC</td>
<td>D (8–14 kDa)</td>
<td>3–5 nm</td>
<td>Hydroxyl, carboxyl</td>
<td>Electron acceptor</td>
<td>ITO/PEDOT:PPS/P3HT:GQDs/LiF/Al</td>
<td>0.92–6.33</td>
<td>0.67–0.77</td>
<td>0.27–0.3</td>
<td>0.19–0.28</td>
<td>4.2/4.4</td>
<td>Annealed device (140 °C for 10 min)</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td>GO</td>
<td>D (3.5 kDa)</td>
<td>5–20 nm</td>
<td>NR (<strong>5</strong> nm from TEM)</td>
<td>Carbon, hydroxyl, epoxy</td>
<td>Electron acceptor</td>
<td>ITO/PEDOT:PPS/P3HT:PCBM/GQDs/</td>
<td>15.2–26.11</td>
<td>0.733–0.74</td>
<td>0.604– 0.676</td>
<td>7.11–7.60</td>
<td>0.5 wt% GQDs reduced for 5 h</td>
<td>Depends on GQD wt%; and whether the as-synthesized GQDs or dots that were reduced for 5 or 10 h are employed; non-reduced (GQDs, i.e., highly oxygenated) show higher absorptivity while fully reduced (10 h) GQDs show higher conductivity; partially reduced (5 h) GQDs provides an optimum balance of optical absorptivity and electrical conductivity.</td>
<td></td>
</tr>
<tr>
<td>CNDs</td>
<td>CA, oleylamine</td>
<td>SFTP/T</td>
<td>CTGF</td>
<td>1–4.5 nm</td>
<td>Aldoxide, hydroxyl, oleylamine</td>
<td>Electron acceptor</td>
<td>ITO/PEDOT:PPS/P3HT:CNDs/LiF/Al</td>
<td>0.29</td>
<td>1.59</td>
<td>48.5</td>
<td>0.23</td>
<td>2.80–3.86/6.30</td>
<td>No optimization</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td>D-glucose, ODA</td>
<td>CC</td>
<td>1–4 nm</td>
<td>Alkyl</td>
<td>Electron acceptor</td>
<td>ITO/PEDOT:PPS/PFO-OBT:CQDs (or ZnO/CQDs)</td>
<td>6.0–14.8</td>
<td>0.80–0.88</td>
<td>0.26–0.30</td>
<td>1.5–3.9</td>
<td>4.1/0.8 (20°C)</td>
<td>40 mg mL⁻¹ active layer, 1:1 PFO-OBT:ZnO/CQDs (or CQDs)</td>
<td>Increased roughness of film, which led to formation of charge transport channels; large surface area of GQDs resulted in increased heterojunction interfaces reducing recombination; 20% improved charge carrier mobility and conductivity.</td>
<td></td>
</tr>
<tr>
<td>CQDs</td>
<td>Double-walled CNTs</td>
<td>OFCT (3 kDa)</td>
<td>3–5 nm</td>
<td>NR; presumably oxygen containing moieties</td>
<td>Co-electron acceptor</td>
<td>ITO/PEDOT:PPS/P3HT:PCBM/CQDs/LiF/Al</td>
<td>11.80–26.46</td>
<td>0.56–0.60</td>
<td>0.28–0.30</td>
<td>2.05–3.54</td>
<td>2.44/3.75</td>
<td>10.6 wt% GQDs at 0.05 mg mL⁻¹</td>
<td>Depends on P3HT:PCBM ratio; GQD concentration not optimized, held constant; Improvement from enhanced absorption of blended film and appropriate band alignment.</td>
<td></td>
</tr>
<tr>
<td>GQDs</td>
<td>GO</td>
<td>HT</td>
<td>D (3.5 kDa)</td>
<td>27–38 nm</td>
<td>Carboxylic, hydroxyl, epoxy</td>
<td>Co-electron acceptor</td>
<td>ITO/MoO₃/P3HT:PCBM/GQDs/LiF/Al</td>
<td>10.8 ± 0.02</td>
<td>12.79 ± 0.04</td>
<td>0.601 ± 0.001</td>
<td>0.002–0.002</td>
<td>5.5 ± 0.07–0.04</td>
<td>4.7 (work function)</td>
<td>0.08 wt% GQDs*</td>
</tr>
<tr>
<td>GQDs</td>
<td>GO</td>
<td>AO</td>
<td>D (3.5 kDa)</td>
<td>&gt;5 nm</td>
<td>Hydroxyl, carboxyl</td>
<td>Co-electron acceptor</td>
<td>ITO/PEDOT:PPS/P-DTS/P3HT:GQDs/Ca/Al</td>
<td>13.35–13.58</td>
<td>0.748–0.754</td>
<td>0.60–0.63</td>
<td>5.94–6.40</td>
<td>0.84/0.75</td>
<td>1 wt% GQDs</td>
<td>Depends on GQD wt%; and whether the as-synthesized GQDs or dots that were reduced for 5 or 10 h are employed; non-reduced (GQDs, i.e., highly oxygenated) show higher absorptivity while fully reduced (10 h) GQDs show higher conductivity; partially reduced (5 h) GQDs provides an optimum balance of optical absorptivity and electrical conductivity.</td>
</tr>
<tr>
<td>CQDs</td>
<td>Polystyrene</td>
<td>T</td>
<td>OE</td>
<td>NR</td>
<td>NR</td>
<td>Active layer</td>
<td>ITO/TiO₂/P3HT:PCBM/GQDs</td>
<td>12.28–13.61</td>
<td>0.86–0.87</td>
<td>0.56–0.58</td>
<td>5.98–7.05</td>
<td>NR</td>
<td>0.06/2 wt% GQDs*</td>
<td>Depends on GQD wt%; in active layer; introduction of CQDs led to strong light scattering by GQDs increased optical path length; nanoscale GQDs led to favorable morphology and phase separation of film enhancing current density and reducing charge transfer resistance.</td>
</tr>
</tbody>
</table>

Table S2 Bulk Heterojunction Organic Photovoltaics (Section 3.2)
GQDs: T- ST (2 kDa) D (3–6 nm) 0.74 ± 0.02 – 11.3 ± 0.01 0.252 ± 0.0004 – 6.10 ± 0.002 3.40 ± 0.02 – 5.90 ± 0.02 NR 3 wt% CNP

GQDs: HEL 15.5 ± 0.05 – 7.22 ± 0.0 ± 0.0 ± 0.0 ± 0.5

Inclusion of GQDs resulted in enhanced light absorption and improved electron transport; photoexcited electrons transferred from GQDs to PCBM via FRET and in-turn stacking interactions between GQDs and PCBM induced efficient charge transport. Depends on GQD wt% in HEL and whether rGQDs are included in the active layer.
Carbon fibers; rGQDs: GO
carboxyl, epoxy; rGQDs: same but much smaller amount
dopant; rGQDs: active layer dopant
M:\(\pm \text{GQDs})/\text{ITO}/\text{Al}
17.3 \pm 0.03 0.012–0.748 \pm 0.002 0.0019–0.718 \pm 0.0002 0.08–8.67 \pm 0.10 0.02 wt% rGQDs in active layer\nm active layer. Inclusion of GQDs improved film morphology; negatively charged GQDs increase size of PEDOT-rich cores (grain size) and spread out grain boundaries more evenly which improves current pathways and charge conductance. GQDs also extended light scattering and light confinement; however higher wt% likely decrease light penetration negatively affecting devices. Inclusion of rGQDs in active layer decreased resistance owing to conductivity of rGQDs. Taking advantage of both improvements leads to synergistic effect, resulting in highest performance.

GQDs CFs AO D (2 kDa) 20–30 nm NR; presumably oxygen containing moieties Hole extraction layer ITO:GQDs/P3HT:PC\(_{61}\)BM or DR/TBTD:PC\(_{71}\)BM/Al/NF/AE
9.77–11.36 0.50–0.92 0.502–0.652 2.57–6.82 4.9 (work function) 1.5–2 nm layer of GQDs\n
Depends on donor acceptor pair and layer thickness of GQD HEL; high conductivity and homogenous morphology of GQD films afforded efficient HEL.

GQDs Vulcan VXC-72 carbon black AO FLTR \(\leq 4\) nm Mainly carboxyl; some hydroxyl, epoxy Hole extraction layer ITO:GQDs/P3HT:PC\(_{61}\)BM or PCDTBT:PC\(_{71}\)BM/Al/NF/A
10.65–15.20 0.75–0.89 0.67–0.69 6.30–7.91 5.26 (work function) No optimization

Depends on donor acceptor pair; large amount of carboxyl functionality increased GQD work function affording good ohmic contact with the donor polymers which improved hole extraction and suppressed recombination; high transmittance of homogeneous GQD film allowed for increased light collection. Depends on wt% of GQDs added; GQDs electrostatically interacted with PEDOT chains forming core-shell like nanostructure; reorientation of the PEDOT dimers improved charge hopping pathways (i.e., enhanced conductivity).

GQDs CNFs AO CNTGs (SSPPT): D 8–10 nm NR; presumably oxygen containing moieties co-hole extraction layer ITO:PEDOT-PSS/GQDs/P3HT:PC\(_{61}\)BM/Al/NF/A
14.59–16.08 0.58–0.59 0.48–0.50 4.08–4.74 5.0 (work function) 20 vol% GQDs in hole extraction organogel

Depends on CND concentration (0.10, 0.15, 0.20 mg mL\(^{-1}\)), spin casting speed (1500, 2300, 3200 rpm), and annealing time (5 or 10 min). Incorporation of CND film lowers work function of active layer, decreasing energy barrier and promoting hole extraction, generates a rougher surface for increased reflected and scattered light, decreased current leakage, and improved hole mobility producing more balanced charge transport. At optimized concentration CNDs uniformly disperse in interfacial layer to give better phase separation and interfacial contact increasing conductivity. Low spinning speeds (1500 rpm) provided thin poorly conducting films. Higher speeds produce thin poorly conducting films.

CNDs CA, Urea MWW NR 2–5 nm NR; presumably oxygen and amine containing moieties Buffer layer/hole extraction layer ITO/PCD-TBT:PC\(_{61}\)BM/CNDs/M oDio/Ag
13.70 \pm 0.07–14.71 \pm 0.07 0.86 \pm 0.01–0.87 \pm 0.05 0.5465 \pm 0.0002–0.5603 \pm 0.003 6.51 \pm 0.11–7.22 \pm 0.13 NR 0.15 mg mL\(^{-1}\) CND solution spin-coated at 2300 rpm and annealed for 5 min. \n
Depends on BHJ architecture employed; in all cases incorporation of CNDs as buffer layer showed enhanced parameters over no or conventional buffer layer due to improved ohmic contact, reduced current leakage, more balanced charge transport, reduced charge recombination, higher exciton dissociation, and increased

CDs CA, EDA HT D (1 kDa) 1–2 nm Hydroxyl, carboxyl, amine Buffer layer ITO:PEDOT-PSS/DR/TBTD:PC\(_{71}\)BM (or P3HT:PC\(_{61}\)BM)/CNDs/Al
9.86–13.32 0.608–0.905 0.52–0.64 3.15–7.67 NR 0.1–0.5 mg mL\(^{-1}\) CD solution for film deposition depending upon device architecture\n
PV parameters depend on BHJ architecture employed; in all cases incorporation of CNDs as buffer layer showed enhanced parameters over no or conventional buffer layer due to improved ohmic contact, reduced current leakage, more balanced charge transport, reduced charge recombination, higher exciton dissociation, and increased

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### CQDs

| CQDs | Acetylene | CVG | FLTR | 2–7 nm | Mostly alkyl; some hydroxyl/carboxyl | Buffer layer | ITQ/PEDOT:PPS/P3HT:PC71BM(or PTB7:PC71BM; PTB7-Th:PC41BM)/CQDs/Al | 9.44–16.26 | 0.630–0.792 | 0.50–0.67 | 2.97 ± 0.10–8.18 ± 0.03 | 3.84 ± 0.70 | 0.05–0.1 mg mL⁻¹ | CQD solution for film deposition regardless of BHJ architecture* | 241 |

### GQDs

| GQDs | Vulcan VXC-72 carbon black | AD | FLTR | < 4 nm | TMA functionalized | Buffer layer; labeled as cathode interlayer (CI) | ITQ/PEDOT:PPS/PC61BM(or PTB7-Th:PC71BM)/GQDs(or Ca, LiF, ZnO)/Al | 9.42–17.39 | 0.76–0.91 | 0.643–0.711 | 5.41–8.80 | NR | 3–7 nm GQD layer (don’t show results) with Al cathode* | 242 |

### GQDs

| GQDs | CA, ammonia | HT | D (3 kDa) | 2–8 nm | NR; likely oxygen and nitrogen containing moieties | Buffer layer; labeled as cathode interlayer (CI) | ITQ/PEDOT:PPS/GQDs/P3HT:PC71BM | 6.61–8.95 | 0.58–1.15 | 0.49–0.61 | 3.15–3.72 | 4.9 eV (work function?; not discussed) | No optimization | 243 |

### GQDs

| GQDs | CA, L-cysteine | HT | NR | 0.5–3.5 nm | NR; likely oxygen and sulfur containing moieties Carbonoyl, hydroxyl, epoxyether, thioether | Buffer layer dopant | ITQ/GQDs-CaCO₃/P3HT:PCBM/V₂O₅/Au | 9.04 | 0.585 | 0.6 | 3.17 | Only bad gap [3] reported | No optimization | 244 |

### GQDs

| GQDs | CA, L-cysteine | HT | NR | <5 nm | Buffer layer dopant | ITQ/GQDs-CaCO₃/P3HT:PCBM/V₂O₅/Au | ~5.0–9.2 | 0.510–0.585 | 0.35–0.60 | ~0.90–3.23 | 4.04/7.34 (GQDs-CaCO₃) | 50% GQDs in a buffer layer annealed at 120 °C | 245 |

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Charge collection efficiency; CQDs also lowered work function of Al electrode and led to more (air) stable devices. PV parameters depend on BHJ architecture employed; in all cases incorporation of CQDs as buffer layer showed enhanced parameters over no or conventional buffer layer due to improved electron-extracting, hole-blocking ability, and reduced interfacial resistance. CQD devices showed improved thermal stability due to reduced molecular diffusion. More hydrophilic CQDs showed poorer performance due to increased surface defects that hindered charge transport.

Depends on device architecture and cathode selection: PCDTBT gives higher V_OC while PTB7-Th gives higher J_SC (and PCE); Cathode performance - Al>Ag>Au. All GQD included devices show improvement over controls and conventional buffer layers (CI) in part from conductivity of GQDs which reduced series resistance. GQDs form interfacial dipole at metal cathode interface lowering the work function creating an ohmic contact and increasing the built-in potential across the active layer which improves charge carrier selection/extraction and suppresses charge recombination. Increasing the alkyl chain length on the functional groups from methyl to ethyl to n-butyl gradually decreases performance possibly due to decreased conductivity from more insulating functionality.

Inclusion of GQDs into CaCO₃ buffer layer promoted exciton dissociation at the P3HT/buffer interface enhancing electron transfer and hole blocking; due to wide bandgap and appropriate energy alignments.

Depends on GQD concentration and slightly on annealing temperature; at higher concentrations insulating nature of oxidized GQDs plagues device performance; Optimized conditions results in excellent electron-selective buffer (i.e., hole-blocking ability) that
GQDs
GNSs
LA/HT
CTFG (nothing after HT treatment)
3.5–6.0 nm
Nrf, presumably oxygen containing moieties
Buffer layer dopant
FTO/ITO,
NPV-GQDs/P3HT/PEDOT:PSS/Pt

3.5–6.0 nm
NR; presumably oxygen containing moieties

Buffer layer dopant
FTO/ITO,
NPV-GQDs/P3HT/PEDOT:PSS/Pt

3.78 ± 0.18
0.757 ± 0.009
0.52 ± 0.02
3.16 ± 0.06
3.47±5.94
No optimization

GQDs provide better conduits for photoexcited charge transfer and suppressed recombination; GQDs reduced energy offset between donor (P3HT) and acceptor (TiO₂) which promoted charge carrier propagation

CNDs
CA, urea
MWV
CTFG
1–5 nm
Hydroxyl, carboxyl, amine
Buffer layer dopant
ITO/PEI:CNDs/PCDTBT:PC₇₀BM/Mo
O₃/Ag

12.34 ± 0.11–14.84 ± 0.19
0.86 ± 0.01–0.87 ± 0.01
0.4717 ± 0.01–0.5854 ± 0.03
5.01 ± 0.11–7.26 ± 0.20
4.4 (work function)
1.0 wt% CNDs in PEI buffer layer

Incorporation of CNDs led to higher surface roughness and better morphology of the film which resulted in improved interfacial contact; CNDs improved built-in potential and charge mobility/transport properties and decreased recombination; slightly enhanced light absorption due to improved scattering of composite film.

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*Multiple devices characterized per each condition and/or for all device architectures (including controls)
Table S3: Solid-state Solar Cells (Section 3.3)

| Classification | Precursor(s) | Approach | Purification | CN3 Size | Surface functionality | CN3 role | Device architecture | $J_{sc}$ (mA cm$^{-2}$) | $V_{oc}$ (V) | FF | $\eta$ (%) | Band edges (eV) | Optimized conditions | Explanation for performance | Reference |
|----------------|-------------|----------|--------------|----------|----------------------|----------|---------------------|--------------------------|-------------|-----|-------------|----------------|----------------------|--------------------------|----------------------|-----------|
| GQDs           | GO          | HR       | NR           | 4–15 nm  | Hydroxy, carboxyl, epoxy | Sensitizer | A2O/ZnO/NiO/GOQDs/TiO$_2$/Au | 0.45 | 0.8 | 0.5 | 0.2 | 1.8–2.35/5.4–5.5 | No optimization | Insufficient hole collection due to small interfacial contact between GOQDs & TiO$_2$ | (46) |
| GQDs           | Glucose, chitin, chitosan | ST | CTF/G/FLTR | 2–14.1 nm (depends on precursor) | Hydroxy, carboxyl, epoxy, amine, amide | Sensitizer | FTO/ZnO Nanorods/GOQDs/CGQDs/GOQDs | 0.054–0.674 | 0.175–0.300 | 0.35–0.44 | 0.006–0.077 | NR | Mixture of chitin- and chitosan-derived CQDs | Depends on precursor employed to make CQDs (i.e., the surface functionality of the resultant dots) evidenced by variability in internal resistance; glucose-derived dots led to higher recombination; all devices poor performance due to low internal efficiency. | (44) |
| CQDs           | Glucose     | HT       | CTFG         | ~16 nm   | NR; likely oxygen moieties | Electron donor/accept or | FTO/ZnO/CdS QDs/2%ZnO/CdS/FTO/Na$_2$S/MWNT | 1.70–1.88 | 0.564–0.605 | 0.31–0.36 | 0.34–0.35 | NR/4.5 | No optimization | CQDs functioned as excellent electron conduits channeling current to collection layer due to high conductivity, nanoscale proximity to surrounding components, and favorable energy alignments; CQDs transfer electrons to CuPc via FRET which then cascade into the CQDs that shuttle them to FTO; liquid electrolyte gave higher performance. | (72) |
| CNDs           | Glucose     | HT       | CTFG         | ~20 nm   | Hydroxy, carboxyl, epoxy | HEL/EBL | In/Ga$_2$O$_3$/CGQDs | 18.0–25.9 | 0.47–0.50 | 0.47–0.63 | 4.6–6.2 | 2.15/5.95 | NR | Methylated Si; 80 nm layer of 2–6 nm GQD | Depends on CQD size & layer thickness; due to appropriate band alignment GQDs efficiently transported holes and reduced carrier recombination at anode. | (60) |
| CQDs           | Graphite Rods | EC | CTFG         | 2–8 nm   | Hydroxy, carboxyl, epoxy | HEL/EBL | In/Ga$_2$O$_3$/CGQDs | 17.6–30.1 | 0.34–0.51 | 0.31–0.59 | 2.6–9.1 | 2.26/5.56 | NR | Methylated Si; 23 nm layer of 2–6 nm CGOs | Depends on CQD size & layer thickness; due to appropriate band alignment GQDs efficiently transported holes and reduced carrier recombination at anode. | (79) |
| GQDs           | rGO         | AD       | D (2 kDa)    | NR       | Hydroxy, carboxyl, carboxyl | Downshifting layer | CGQDs/Ag/Si/1%ETM Emitter/Si wafer/BiF$_3$/Ni | 30.04–34.14 | 0.622–0.621 | 0.79–0.81 | 14.93–15.55 | NR | 30 nm x 1 coating speed (corresponds to 2.25 nm GQDs) |Coated on Si wafer, effective for interfacial contact. | (246) |
| CNDs           | CA, EDA     | HT       | D (0.5 kDa)  | 2–8 nm   | Hydroxy, carboxyl, epoxy, amine/amide (pyridinic-N, pyrrolic-N within core) | Downshifting layer | CNDs/CaPc/1%Si/25 nm Si wafer/electrode | 29.55 | 0.53 | 0.7 | 10.96 | NR | 2.0% volume ratio CNDs spin-coated 8 times (optimized by EQE) |Optimized coating absorbed UV light and via fluorescence converted energy to region better utilized by Si devices. | (247) |
| GQDs           | Graphite Rods | EC | CRMT         | NR (≤10 nm from TEM) | NR; likely hydroxyl, carboxyl, epoxy | Downshifting layer | CGQDs/P(VDF/HexaFluoronitrile)/CGQDs | 36.49–37.32 | 0.617–0.625 | 0.577–0.606 | 13.03 ± 0.58–14.06 | NR | CGQDs synthesized with: 50 mA current gave highest overall PCE; 20 mA current gave largest % increase in PCE | CGQDs can function as modest down-shifting layers (2-5% improvements in PCE over devices without layer); performance depends on size of GQD which was influenced by applied current [20–60 mA]; no correlation between CQD size and applied current was provided. | (250) |
| GQDs           | Oxidized    | HT       | 3–12 nm     | NR       | Hydroxy, carboxyl, epoxy | HEL/EBL | In/Ga$_2$O$_3$/Si wafer | 26.07–33.93 | 0.51–0.58 | 0.50–0.65 | 7.99–8.00 | 3–6 nm | 20 nm layer of 3–6 nm GQDs | Depends on GQD size (determined by length of sonication duration) | (248) |
GSs
hydroxy, carboxyl, epoxy
based on previous paper
ref (60)
GQDs
(methylated)/GQDs window of SiO₂/Au/graphene
12.35
2.96/6.56;
5–8 nm:
3.14/6.07;
6–12 nm:
3.74/6.01
GQDs
oxidation of GSs) and layer thickness (8, 20, 50 nm; determined by volume of GQDs deposited). Due to appropriate band alignment, (1)
photogenerated charge carriers diffuse to interface and are separated by built-in electric field of the heterojunction and (2) electrons prevented from transferring from Si to graphene, minimizing recombination (evidenced by increased minority carrier lifetimes).
Hole transport possibly occurs via tunneling or the existence of intermediate energy levels in GQDs. Change in GQD size affects band alignment while films thinner or thicker than 20 nm result in a nonuniform GQD layer or light-blocking effects and poor conductivity, respectively. Devices showed good stability for over 6 months (in air).
Doping of graphene film using HNO₃ vapor improved performance of all devices.

GQDs
Glucose
MWV
NR
2–4 nm
NR; hydroxyl, carboxyl, epoxy based on previous report
HEL dopant
Al/n-Si (top side pyramidal array)/PEDOT:PSS/GQDs/Ag
31.56–36.26
0.51–0.57
0.623–0.638
10.02–13.22
NR
0.5 wt% GQDs in PEDOT:PSS with back surface field treatment
0.6223–0.6387
0.5 wt% GQDs in PEDOT:PSS with back surface field treatment

GQDs
Glucose
MWV
NR
3–4 nm
NR; hydroxyl, carboxyl, epoxy based on previous report
Down-shifting layer
Ag/ITO/n-type a-Si:H/a-Si:H/n-type Si (micropyramidal)/a-Si:H/p-type a-Si:H/ITO/GQDs/Ag
36.05–37.47
0.61
0.7048–0.7251
15.60–16.55
NR
0.3 wt% GQDs

dependence on GQD wt% (0.1, 0.3, 0.5, 0.7, or 1). Inclusion of GQDs improves optical and electrical properties due to downconversion effect and conductivity of GQDs. GQD wt% higher than 0.5 decreases minority carrier lifetime and increases recombination likely due to GQD aggregation that forms trap sites. Higher amounts can also inhibit Si light absorption. Back surface field treatment by heavily doping the Si via a thermal diffusion of POCl₃ enhances all device parameters for all GQD wt% (0-1%).
GQDs downconvert UV photons to visible photons, which have longer extinction distances, increasing the probability of an absorption event and reducing power losses to defect induced recombination. All GQD concentrations (0.05, 0.1, 0.3, 0.7, 1.0, 2.0 wt%) improve performance over bare device although 0.7 wt% and higher begin to show decreased Jᵥ, FF, and PCE. Authors attribute this to poorer conductivity typically associated with thicker GQD layers; however, based on the understood device architecture this should not play a role here and would more likely result from decreased transmittance due to a thicker GQD film.

*Multiple devices characterized per each condition and/or for all device architectures (including controls).
### Table S4 Bio-inspired Devices (Section 3.4)

<table>
<thead>
<tr>
<th>CQDs</th>
<th>Precursor(s)</th>
<th>Approach</th>
<th>Purification</th>
<th>CND Size</th>
<th>Surface functionality</th>
<th>CND role</th>
<th>Device architecture</th>
<th>J_{SC} (mA cm(^{-2}))</th>
<th>V_{OC} (V)</th>
<th>FF</th>
<th>η (%)</th>
<th>Band edges (eV)</th>
<th>Optimized conditions</th>
<th>Explanation for performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CQDs</td>
<td>Graphite rods</td>
<td>EC</td>
<td>FLTR/CTFG</td>
<td>4–30 nm</td>
<td>Hydroxyl, carboxyl, epoxide</td>
<td>Electron acceptor/donor</td>
<td>FTO/TiO(_2) NPs/RhB/CQDs/(\gamma)-Pt</td>
<td>~6.4</td>
<td>~0.5</td>
<td>NR</td>
<td>0.147</td>
<td>NR</td>
<td>No optimization</td>
<td>CQDs act as electron/energy transfer bridge between RhB and TiO(_2), mimicking processes involved in photosynthesis; CQDs enhanced absorbance of RhB and acted as one-way bridge, effectively separating the charge carriers and suppressing recombination. Nonscale dimension of CQDs (i.e., increased surface area) creates more intimate contacts with the thylakoid membranes affording increased direct electron transfer; due to well-aligned absorbance and fluorescence properties, CQDs absorb unused photons and convert them to photosynthetic relevant wavelengths.</td>
</tr>
<tr>
<td>CQDs</td>
<td>Graphite rods</td>
<td>EC</td>
<td>CC</td>
<td>126 ± 8 by 77 ± 7 nm</td>
<td>NR; presumably oxygen containing moieties</td>
<td>Electron donor</td>
<td>Carbon paper/Thylakoid membranes/CQDs/Si thin film</td>
<td>3.1 ± 0.9</td>
<td>0.62 ± 0.02</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>No optimization</td>
<td>No optimization</td>
</tr>
<tr>
<td>CQDs</td>
<td>Acetic acid, EDCE</td>
<td>MMW</td>
<td>OE</td>
<td>1–2 nm</td>
<td>Hydroxyl, carboxyl, amine</td>
<td>Electron donor</td>
<td>No device made</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>No optimization</td>
<td>CQDs promoted photosynthesis by enhancing the electron transfer process; chloroplasts absorbance profile overlaps with CQDs emission profile (390 nm excitation) resulting in electron transfer from CQDs to chloroplasts.</td>
</tr>
</tbody>
</table>

*Multiple devices characterized per each condition and/or for all device architectures (including controls)*

### Table S5 Perovskite-based Devices (Section 3.5)

<table>
<thead>
<tr>
<th>CQDs</th>
<th>Precursor(s)</th>
<th>Approach</th>
<th>Purification</th>
<th>CND Size</th>
<th>Surface functionality</th>
<th>CND role</th>
<th>Device architecture</th>
<th>J_{SC} (mA cm(^{-2}))</th>
<th>V_{OC} (V)</th>
<th>FF</th>
<th>η (%)</th>
<th>Band edges (eV)</th>
<th>Optimized conditions</th>
<th>Explanation for performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GQDs</td>
<td>Graphite rod</td>
<td>EC</td>
<td>D (3.5 kDa)</td>
<td>5–10 nm</td>
<td>Carboxyl, hydroxide (GQDs were treated with hydrazine)</td>
<td>Electron acceptor/donor</td>
<td>FTO/TiO(<em>2)/GQDs/CH(</em>{3})/NH(_3)/PbI(_3)/Spiro-OMeTAD/Au</td>
<td>15.20 ± 0.78–16.81 ± 0.83</td>
<td>0.589 ± 0.032–0.618 ± 0.031</td>
<td>0.58 ± 0.030</td>
<td>0.6</td>
<td>0.54–0.76</td>
<td>4.2/6.8</td>
<td>TiO(_2) loaded with 0.5 mg mL(^{-1}) GQD(^{a})</td>
</tr>
<tr>
<td>CQDs</td>
<td>CA, p-phenylenediamine</td>
<td>HT</td>
<td>CTFG</td>
<td>2–4 nm</td>
<td>NR; likely amines, carbonyl</td>
<td>HEL</td>
<td>FTO/TiO(<em>2)/CH(</em>{3})/NH(_3)/PbI(_3)/CQDs/Au</td>
<td>7.83</td>
<td>0.515</td>
<td>0.74</td>
<td>3</td>
<td>2.07/5.12</td>
<td>No optimization</td>
<td>No optimization</td>
</tr>
</tbody>
</table>

*Multiple devices characterized per each condition and/or for all device architectures (including controls)*

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\(^{a}\) Reference numbers for the explanation of performance are provided in the respective tables.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD</td>
<td>Acid dehydration</td>
</tr>
<tr>
<td>AO</td>
<td>Acid oxidation</td>
</tr>
<tr>
<td>AUC</td>
<td>Analytical ultracentrifugation</td>
</tr>
<tr>
<td>A2O</td>
<td>Aluminum-doped zinc oxide</td>
</tr>
<tr>
<td>Bmim</td>
<td>1-Butyl-3-methylimidazolium</td>
</tr>
<tr>
<td>BSSF</td>
<td>Back surface field</td>
</tr>
<tr>
<td>CA</td>
<td>Citric acid</td>
</tr>
<tr>
<td>CB</td>
<td>Conduction band</td>
</tr>
<tr>
<td>CC</td>
<td>Column chromatography</td>
</tr>
<tr>
<td>CD</td>
<td>Carbon dot</td>
</tr>
<tr>
<td>CE</td>
<td>Counter electrode</td>
</tr>
<tr>
<td>CF</td>
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<tr>
<td>CNF</td>
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<tr>
<td>CNP</td>
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<tr>
<td>CNT</td>
<td>Carbon nanotube</td>
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<tr>
<td>CND</td>
<td>Carbon nanodot</td>
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<tr>
<td>CQD</td>
<td>Carbon quantum dot</td>
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<td>CROMT</td>
<td>Chromatography</td>
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<td>Cyclic voltammetry</td>
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<td>Di-tetrabutylammonium cis-bis(isothiocyanato)bis(2,2′-bipyridyl-4,4′-dicarboxylato)ruthenium(II)</td>
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<tr>
<td>DLS</td>
<td>Dynamic light scattering</td>
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<tr>
<td>EBL</td>
<td>Electron blocking layer</td>
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<td>EC</td>
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<tr>
<td>EDA</td>
<td>Ethylenediamine</td>
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<tr>
<td>EDIE</td>
<td>Ethyleneimine ethoxylated</td>
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<td>EOE</td>
<td>External optical efficiency</td>
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<td>FLTR</td>
<td>Filtration</td>
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<td>FREC</td>
<td>Förster resonance energy transfer</td>
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<td>FTO</td>
<td>Fluorine doped tin oxide</td>
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<td>g-(\text{C}_3\text{N}_4)</td>
<td>Graphitic carbon nitride</td>
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<td>LUMO</td>
<td>Lowest unoccupied molecular orbital</td>
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<td>MW</td>
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<td>MWNTs</td>
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<td>PCBM</td>
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<td>Poly(4,8-bis((2-ethylhexyl)oxy)benzo[2,1,3]thiophene-2,5-diyl)-3-fluorothieno[3,4-b]thiophene-2-carboxylic acid)</td>
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References


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