A comprehensive review on the detection capability of inorganic ions by graphene quantum dots-based platforms

Prashant Dubey

Centre of Material Sciences, Institute of Interdisciplinary Studies (IIDS), University of Allahabad, Prayagraj-211002, Uttar Pradesh (INDIA)

Email: pdubey@allduniv.ac.in, pdubey.au@gmail.com, ORC id: 0000-0001-8159-6528

Table S1. GQDs, modified-GQDs, and GQDs-involved with other counterparts for Fe^{3+} and Fe^{2+} sensing application.

GQD-based sensor	Synthesis condition	Size distribution/ average size (nm)[a]	QY (%)	Sensing process	LR (µM)	LOD (µM)	Ref.
Fe^{3+}							
Doped-/undoped GQDs							
N-GQDs	Electrolysis of 3D Graphene in $BMIMPF_6$/acetonitrile; Centrifugation; Dialysis	1–5/3	10	FL, Turn-off	0–80	7.22	[1]
N-GQDs	HT (CA/25wt% NH_3 in water, 200°C, 3h); pH adjusted to 8.0; Dialysis	1–8/3.5	30.7	FL, Turn-off	0–10	—	[2]
N-GQDs	HNO_3 vapor cutting of MOF-derived nitrogen rich porous carbon (ZIF-8C), 160°C, 5h; *In-situ* filtration	1.3–2.7/2	—	FL, Turn-off	1–70	0.08	[3][f]
N-GQDs	MW (Aspartic acid/NH_4HCO_3 in water, 560W, 10min); Dialysis	1.8–2.4/2.1	14	FL, Turn-off	0–50	0.26	[4]
N-GQDs	HT (GO/$NH_3.H_2O$ in water, 120°C, 6h); Filtration; HT (Supernatant/THF, 100°C, 2h); THF portion separated by adding $(NH_4)_2SO_4$, dried & dispersed in water	5–10/6	—	FL, Turn-off	0.2–30	0.06	[5][f]
N-GQDs	HNO_3 vapor cutting of mesoporous nitrogen/carbon/silica composite (N/C/SBA-15), 150°C, 3h; *In-situ* filtration	1.6–3.5/2.4	—	FL, Turn-off	0.5–40	—	[6][f]
N-GQDs	MW plasma CVD (C_{60}, 2.45GHz, 800W, 3kPa, 440°C, 15min, N_2)	2–6.5/4.5	7.4	FL, Turn-off	0–2	0.4	[7]
N-GQDs	Electrolysis of graphite rod in 0.1M NaOH/0.1M semicarbazide aqueous solution, 4h; Centrifugation; Dialysis	5–30/20	18.95	FL, Turn-off	0–200	0.87	[8]

N-GQDs	HT (DA.HCl in water, 180°C, 24h); Filtration; Dialysis; Centrifugation	2–5.5/3.4	34	FL, Turn-off	0–80	0.063	[9][f]
N-GQDs	Electrolysis of NG@CC in NaOH/H_2O/ethanol electrolyte solution, 24h; Dialysis	1.2–4.2/3.1	10	FL, Turn-off	10–1000	0.19	[10][f]
N-GQDs	Ar/DC microplasma treatment of *chitosan* in 35mM HCl electrolyte (pH: 2.57), 1h; Purification	2–5.2/3.79	4.68	FL, Turn-off	1–300	0.0667	[11][f]
N-GQDs	ST (GO in DMF, 200°C, 8h); Centrifugation	1–3/2	31.2	FL, Turn-off	0–0.9	0.017	[12][f]
N-GQDs	Acid oxidation of *lignin* with 17.5% HNO_3 under reflux (80°C, 8h); Centrifugation; HT (above solid residue in 0.2M NaOH aqueous solution, 200ºC, 12h); Filtration; Dialysis	1.5–5.5/~3.3	28	FL, Turn-off	0–500	1.49	[13][f]
N-GQDs	Pyrolysis (ACTB, 180°C, 4h); Dispersed in water	2–4/2.99	14.4	FL, Turn-off	0–1000	0.016	[14][g]
N-GQDs	HT ($CA.H_2O/NH_3$ in water, 200°C, 6h); Dissolved in water & pH adjusted to 7.0; Centrifugation; Dialysis	4–6/—	19.1	FL, Turn-off	0–100	0.74	[15]
B-GQDs	HT (TNP/borax in 0.125M NaOH aqueous solution, 200°C, 6h); Dialysis	< 5/2	16.8[c]	FL, Turn-off	0.05–220, 220–420	0.0312	[16][f]
N,S-GQDs	HNO_3 vapor cutting of polythiophene-derived carbon, 180°C, 1h; *In-situ* filtration	3.9–6.3/4.7	2.35	FL, Turn-off	0–130	0.07	[17][f]
N,S-GQDs	Pyrolysis (CA/L-cysteine, 200°C, 5min); Mixed in water; Centrifugation; Dialysis	3–11/7	74.5[c]	FL, Turn-off	0.01–3	0.0033	[18][f]
N,P-GQDs	ST (CA/PNCT in alcohol, 180°C, 48h); Centrifugation; Dialysis	1–6/3.4	34.8	FL, Turn-off	0–0.15	0.146	[19][h]
N,Fe-GQDs	HT (Ammonium iron citrate/urea in water, 180°C, 6h); pH adjusted to 7.0; Centrifugation; Dialysis	2–8/4.5	30.57	FL, Turn-off COL, Turn-on	10–110 0–450	3.21 1.34	[20][f]
Mn^{2+}–B,N-GQDs	HT ($CA/urea/borax/MnCl_2.4H_2O$ in water, 180°C, 8h); Centrifugation; Dialysis	1.5–6.5/3.7	30.52	FL, Turn-off	10–100, 100–800	0.78, 9.08	[21]
GQDs	HNO_3 vapor cutting of ordered mesoporous carbon/silica (C/SBA-15), 160°C, 5h; *In-situ* filtration	2.5–5.2/3.6	—	FL, Turn-off	3–60	0.3	[22][f]
GQDs	Acid oxidation of carbon black with 6M HNO_3 under reflux (130°C, 24h); Centrifugation; Drying & dissolution in water	5–10/—	—	FL, Turn-off	0–60	0.45	[23]
GQDs	Chemical oxidation of GO with $KMnO_4$ under MW-ultrasonication (400W, 90°C, 0.5h); Centrifugation; Filtration; Dialysis	1–6/2	23.8	FL, Turn-off	10–120	10	[24]
GQDs cluster	MW (CA/urea/zinc precursor in water); Dialysis	—/10	18	FL, Turn-off	0–10	0.03914	[25]
GQDs	Electrochemical trimming of GO aqueous dispersion, 5h; Filtration; Dialysis	0.5–6/2	6.6	FL, Turn-off	0.1–20	0.23	[26]

GQDs	Pyrolysis (*Spent tea leaves*, 500°C, 3h); ST (Biochar/oxone in DMF, 250°C, 12h); Filtration; Dialysis	1.25–4.75/3	—	FL, Turn-off	0.5–6	0.29	[27][f]
GQDs	Pyrolysis (*Eucalyptus tree leaves* extract, 300°C, 8h); Filtration	1–5/3	6.9	FL, Turn-off	1–6[d]	—	[28]
Fluorine-rich GQDs	HT (HFG/30% H_2O_2 in water, 180°C, 1h); Centrifugation	1.3–2.4/—	2.9	FL, Turn-off	0–90	1.93	[29]
GQDs	ST (*Spent tea leaves* dispersed in ethanol, 200°C, 12h); Filtration; Dialysis	0.75–4.25/2.3	21	FL, Turn-off	1–6	0.5	[30]
Functionalized GQDs							
GL–N-GQDs	Thermolysis (GL in ethylene glycol, 190°C, 20min); Dialysis	1.8–4.6/3.24	16.2	FL, Turn-off	0.5–500	0.1	[31][f]
BCP–GQDs	Acid oxidation of carbon black with HNO_3:H_2O (1:1.5) under reflux (100°C, 48h); Centrifugation; Filtration; Covalently modified with BCP (P7AC-*b*-PNIPAAm)	12–44/26.6	—	FL, Turn-off	0–50	—	[32]
AL–GQDs AS–GQDs GL–GQDs	Reflux (DMF dispersion of GO in dichlorosulfoxide, 80°C, 36h); Centrifugation; Reflux with AL/AS/GL (80°C, 48h); Filtration, Dialysis	2.9–6.1/4.5 3.5–5.3/4.1 3.6–6.3/5.3	12.67 11.27 10.92	FL, Turn-off ″ ″	0.05–7.5, 10–400 0.5–200 0.5–200	0.05 0.1 0.1	[33][f]
GSH–GQDs	Pyrolysis (*Lime oil* extract/glutathione, 260°C, 5min); Dissolved in 0.25M NaOH	—	—	FL, Turn-off	1–150	0.1	[34][f]
CD–sl-GQDs	HT (CA/CD in water, 160ºC, 6h); Centrifugation	3.5–6.5/4.8	5.34	FL, Turn-off	0–85	0.26	[35][f]
PEG–GQDs	HT (*Cane molasses* in water, 190°C, 24h); Filtration; Non-covalently modified with PEG-200	1.5–3.5/2.5	21.32	FL, Turn-off	8–24	5.77	[36][f]
Modified–GQDs	Pyrolysis (*Spent tea*, 500°C, 3h, N_2); Acid oxidation of biochar with HNO_3 under MW-reflux (500W, 100°C, 2h); Diluted with water; Filtration; pH adjusted to 7.0; HT (200°C, 8h); Filtration; Dialysis	0.5–3.5/1.6	23	FL, Turn-off	1–50	2.5	[37]
Luminol–GQDs	Pyrolysis (CA, 200°C, 5min); Mixed in 4 mg/mL NaOH solution; pH adjusted to 7.0; Filtration; Dialysis; Functionalized with luminol under HT condition (180°C, 8h); Filtration	6–18/~12	—	FL, Turn-off	50–300	0.08	[38]
Luminol–GQDs	Pyrolysis (CA, 200°C, 25min); Mixed in 10 mg/mL NaOH solution; pH adjusted to 7.0; Filtration; Dialysis; Functionalized with luminol under HT condition (180°C, 8h); Filtration	—/20	—	FL, Turn-off	50–400	1.5	[39][f]
GQDs-involved with other counterparts							
PS-AER/GQDs	Acid oxidation of graphite with HNO_3:H_2SO_4 (1:3) under ultrasonication (3h) & HT (120°C, 24h); Filtration & pH adjusted to 7.0; Non-covalent attachment on PS-AER.	< 10/—[b]	—	FL, Turn-off	1–7	0.65	[40]

Chitosan/OH-GQDs/ Au@glass slip	OH-GQDs purchased from ASC Material; Spin coated along with the chitosan on Au-modified glass slip	—	—	SPR, Change in resonance angle	0–1[e], 1–10[e]	0.5[e]	[41]
GQDs/poly(AM-*co* -AA) hydrogel	Pyrolysis (CA, 200°C, 20min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0; Centrifugation; *In-situ* incorporated in poly(AM-co-AA) hydrogel	2.7–4.8/3.62[b]	—	FL, Turn-off	10–160	—	[42]
Fe^{2+}							
GSH–GQDs/H_2O_2	Pyrolysis (*Lime oil* extract/glutathione, 260°C, 5min); Dissolved in 0.25M NaOH	—	—	FL, Turn-off	1–150	0.1	[34][f]
B,N-GQDs	MW (CA/urea/boric acid, 720W, 180°C 15min); Dispersed in water; Centrifugation	5–10/—	30.2	FL, Turn-off	0–200[e]	—	[43][f]

Abbreviations: GL: glycine, BCP: block copolymer, AL: L-alanine, AS: asparagine, GSH: glutathione, CD: β-cyclodextrin, sl: single-layered, PEG: polyethylene glycol, PS-AER: polystyrenic anion-exchange resin, poly(AM-*co*-AA): poly(acrylamide-*co*-acrylic acid), $BMIMPF_6$: 1-butyl-3-methylimidazolium hexafluorophosphate, HT: hydrothermal, CA: citric acid, MOF: metal organic framework, MW: microwave, GO: graphene oxide, THF: tetrahydrofuran, CVD: chemical vapour deposition, DA.HCl: dopamine hydrochloride, NG: nitrogen-doped nanomesh graphene, CC: carbon cloth, Ar: argon, DC: direct current, ST: solvothermal, DMF: dimethylforamide, ACTB: ammonium citrate tribasic, TNP: 1,3,6-trinitropyrene, PNCT: phosphonitrilic chloride trimer, HFG: hydroxylated fluorographene, P7AC-*b*-PNIPAAm: poly(7-(4-(acryloyloxy)butoxy)coumarin)-b-poly(N-isopropylacrylamide), QY: quantum yield, FL: fluorometric, COL: colorimetric, SPR: surface plasmon resonance, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: size distribution/average size of GQDs used with other counterparts, [c]: absolute QY, [d]: dynamic concentration range, [e]: LR/LOD in ppm, [f]: analytical ability in real water/biological fluid/supplement samples, [g]: paper-based sensing capability, [h]: analytical ability in living cells.

Table S2. GQDs, modified-GQDs, and GQDs-involved with other counterparts for Hg^{2+} sensing application.

GQD-based sensor	**Synthesis condition**	**Size distribution/average size (nm)**[a]	**QY (%)**	**Sensing process**	**LR (μM)**	**LOD (μM)**	**Ref.**
Hg^{2+}							
Undoped/doped-GQDs							
GQDs	Pyrolysis (CA, 200°C, 30min); Dissolved in 10 mg/mL NaOH solution & pH adjusted to 7.0	7–14/10.5	—	FL, Turn-off	0–60[g]	3.36[g]	[44]
GQDs	Acid oxidation of graphene with HNO_3/H_2SO_4 under ultrasonication (12h); Drying; Diluted with water; Filtration; Centrifugation	< 15/—	—	FL, Turn-off	0.8–9	0.1	[45]
GQDs	Pyrolysis (CA, 190°C, 45min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 8.0	—	—	FL, Turn-off	1–10	0.09	[46]
Red-fluorescent GQDs	ST (*Psidium guajava* leave extract in ethanol, 180°C, 18h); Filtration	—	—	FL, Turn-off	60–380	82	[47]
GQDs	Pyrolysis (CA, 200°C, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0	15–25/—	4.54	FL, Turn-off	2.5–45	0.23	[48]
N-GQDs	Pyrolysis (CA/glycine, 200°C, 20min); Dissolved in 10 mg/mL NaOH solution & pH adjusted to 7.5	0.5–4/2.2	28.1	FL, Turn-off	0–5	0.032	[49][i]
N-GQDs	HT (CA/NH_3 in water, 200°C, 3h); Dialysis	1.3–2.93/2.03	—	FL, Turn-off	0.02–1	0.0047	[50][i, j]
N-GQDs	N-GQDs purchased from JCNANO Technology	1.5–4.5/2.7	—	FL, Turn-off	2.5–800[g]	2.5[g]	[51][i]
N-GQDs	HT ($GO/NH_3.H_2O$ in water, 150°C, 7h); Filtration; Dialysis	4–6/5	8.16	FL, Turn-off	0–4.31, 4.31–12.32	0.023	[52][i]
N-GQDs	HT (CA/ethylenediamine in water, 180°C, 10h); Dialysis	2–10/5	—	FL, Turn-off	0–0.01, 0.1–1	0.00045, 0.0673	[53]
N-GQDs	HT (1,3,6-trinitropyrene/L-tryptophan in 125mM NaOH solution, 200°C, 6h); Filtration; Dialysis	1.5–3/2.1	24.8[d]	FL, Turn-off	0.05–15	0.019	[54][i]
N-GQDs	Acid oxidation of nitrogen-doped graphene with piranha under reflux (80°C, 1.5h); Diluted with water & pH adjusted to 4.0; Filtration; Dialysis	2.2–4/2.9	7.43	FL, Turn-off	0.0005–0.11	0.00008	[55][i]
N-GQDs/Filter paper	Infrared-assisted pyrolysis (CA/urea 260°C, 10min); Dispersed in water; Drop coated on cellulose filter paper	—/~4	—	FL, Turn-off	0–6[h], 6–10[h]	0.5[h]	[56]

N-GQDs	HT (HTC prepared from microcrystalline cellulose extract of *pineapple* leaf fiber/ethylenediamine in water, pH adjusted to 14, 200°C, 10h); Filtration; Dialysis	3–8/~5.1	—	FL, Turn-off	0–30	0.00025	[57][i]
N,S-GQDs	HT (CA/thiourea in water, 160°C, 4h); Centrifugation	2–6/3.5	41.9	FL, Turn-off	0.001–0.05, 0.05–15	0.00014	[58][i, j]
N,S-GQDs	Pyrolysis (CA/D-penicillamine, 160°C, 9min); Mixed in 1 mg/mL NaOH solution; Centrifugation; Filtration	1–6.5/3.15	56.4	FL, Turn-off	0.0009–0.03	0.00069	[59][i, k]
N,S-GQDs/Ce^{4+}/I^-	Pyrolysis (CA/L-cysteine, 200°C,); Diluted with water	2–4/—	85.6	FI-CL, Turn-on	0.3–7	0.0247	[60][i]
B,N-GQDs	HT (CA/ethylenediamine/phenylboronic acid in water, 200°C, 5h); Filtration	1.04–4.81/2.73	75	FL, Turn-off	0.2–2.6	0.16	[61][i]
B,N-GQDs	HT (GO/NH_3/boric acid in water, 180°C, 20h); Filtration; Dialysis	2.2–7.6/3.8	5.13[d]	FL, Turn-off	0.2–1	0.0064	[62][i]
N,P-GQDs	Pyrolysis (*Lemon* salt/glycine/diammonium phosphate/ phosphoric acid, 225°C, 10min); Dissolved in water & pH adjusted to 7.0; Centrifugation; Filtration	10–20/—	30[e]/ 17[f]	FL, Turn-off	1.59–16.3	0.13	[63][i]
Mn^{2+}–N-GQDs	HT (Sodium citrate/glycine/$MnCl_2$ in water, 180°C, 10h); Centrifugation; Dialysis	1–5.5/4.5	42.16	FL, Turn-off	0.2–3.5	0.034	[64]
Functionalized GQDs							
Thymine-rich DNA–GQDs	Acid oxidation of rGO with HNO_3:H_2SO_4 (3:1) under stirring (24h) & ultrasonication (24h); Dilution, filtration & pH adjusted to 8.0; HT (200°C, 24h); Filtration; Dialysis; Covalent modification with thymine-rich DNA	—/~20	—	FL, Turn-off	0.001–10	0.00025	[65][k]
SR–GQDs	Chemical oxidation of GO with H_2O_2/O_3 (0°C, 1h); Acid oxidation with H_2SO_4 under MW (800W, 5min); Diluted with water; Filtration; Dialysis; Covalently modified with SR	3.2–6.4/4.38	—	FL, Ratiometric	0.6–12	0.23	[66][i, k]
Cysteine–GQDs	HT (CA in water, pH adjusted to 10, 160°C, 4h); Covalently modified with L-cysteine under reflux (80°C, 24h); Dialysis	1–8/3.8	28	FL, Turn-off	0–10	0.02	[67][i]
MEA–GQDs	Pyrolysis (CA, 190°C, 25min); Pyrolysis (Obtained paste/ MEA, 120°C, 1h); Dissolved in water & pH adjusted to 7.4	1–6/—	23.7	FL, Turn-off	0.05–5	0.01	[68][i]
RhB–GQDs	HT (CA/RhB/ethylenediamine in water, 180°C, 10h); Centrifugation; Dialysis	2.5–6.5/4.5	41.6	FL, Turn-off	0–0.01, 0.05–1	0.00016, 0.04087	[69][i]
Glycine–GQDs	Pyrolysis (CA, 200ºC, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 8.0; Covalently modified with GL	4.5–7/5.9	35.7	FL, Turn-off	0–3	0.0083	[70][i]
TUD–GQDs-	Cutting of GO under probe ultrasonication (10kHz, 2h);	5–40/18	—	EC, DPV	0.05–23	0.0235	[71][i]

IIP@GCE	Centrifugation; Dialysis; Covalently modified with TUD; Suspension polymerization using TUD–GQDs as a monomer with Hg^{2+}; Leaching of Hg^{2+}; Drop casted on GCE			EC, CV	0.06–0.85, 1.4–7	0.0302	
8-HQ–GQDs	Electrolysis of graphene in 0.1M NaOH ethanoic solution, 1h; Centrifugation; Drying; Covalent modification with 8-HQ	—	—	FL, Turn-off	0–0.2	0.0024	[72][i]
GQDs-involved with other counterparts							
GQDs/CdTe@SiO_2	Pyrolysis (CA, 200°C, 30min); Mixed in 0.25M NaOH solution & pH adjusted to 7.0; Non-covalently conjugated on CdTe@SiO_2	—/10[b]	—	FL, Ratiometric	0.01–22	0.0033	[73][i, l]
GQDs/ZnPc (1) GQDs/ZnPc (2) GQDs/ZnPc (3) GQDs/AlPc (4)	HT (GO dispersed in HNO_3/H_2SO_4 solution, pH adjusted to 8.0, 200°C, 12h); Filtration; Dialysis; Non-covalently conjugated with mercaptopyridine-substituted Zn-phthalocyanine or Al-phthalocyanine	—/14[c] —/21[c] —/27[c] —/22[c]	18 16 12 16	FL, Turn-off-on ″ ″ ″	0.0005–0.05 0.0005–0.05 0.0005–0.05 0.0005–0.05	0.0015 0.00052 0.00012 0.0006	[74]
GQDs/Fe_3O_4@SiO_2	Pyrolysis (CA, 200°C, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0; Covalently modified with amino-functionalized Fe_3O_4@SiO_2	—/20; 3–7/—[b]	—	FL, Turn-off	0.1–70	0.03	[75][i]
N-GQDs/PVA@ PETP	HT (CA/glycine in water, 200°C, 5h); Dialysis; Mixed with PVA & coated on PETP film	7–12/10.5	—	FL, Turn-off	0–30[g]	0.1[g]	[76][i, j]
GQDs-ssDNA-AuNPs	Pyrolysis (CA, 200°C, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0; Covalently modified with amine-containing DNA S3; Conjugated with AuNPs	—/20[b]	—	ECL	0.00001–0.1	2.48x10^{-6}	[77][i]
NH_2-Ru@SiO_2/N-GQDs/aptamer/AuNPs @GCE	Pyrolysis (CA/H_2O, 200°C, 30min); Dialysis; Non-covalently conjugated with NH_2-Ru@SiO_2; Covalently conjugated with aptamer; Casted on AuNPs electrodeposited GCE	—/49.3; —/2.3[b]	—	ECL	0.00005–1	30x10^{-6}	[78][i]

Abbreviations: SR: spirolactam rhodamine, MEA: mono-ethanolamine, RhB: rhodamine B, TUD: thiourea derivative, IIP: ion imprinted polymer, GCE: glassy carbon electrode, 8-HQ: 8-hydroxyquinoline, Pc: phthalocyanine, PVA: polyvinyl alcohol, PETP: polyethylene terephthalate, NPs: nanoparticles, CA: citric acid, ST: solvothermal, HT: hydrothermal, GO: graphene oxide, HTC: hydrothermal carbon, rGO: reduced graphene oxide, MW: microwave, GL: glycine, QY: quantum yield, FL: fluorometric, FI-CL: flow-injection chemiluminescence, EC: electrochemical, DPV: differential pulse voltammetry, CV: cyclic voltammetry, ECL: electrochemiluminescence, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: size distribution/average size of GQDs used with other counterparts, [c]: measured from dynamic light scattering, [d]: absolute QY, [e]: QY corresponding to 350 nm excitation wavelength, [f]: QY corresponding to 470 nm excitation wavelength, [g]: dynamic concentration range and corresponding LOD, [h]: LR/LOD in ppm, [i]: analytical ability in real water/biological fluid samples, [j]: paper-based sensing capability, [k]: analytical ability in living cells, [l]: visual detection capability.

Table S3. GQDs, modified-GQDs, and GQDs-involved with other counterparts for Cu^{2+} sensing application.

GQD-based sensor	Synthesis condition	Size distribution /average size (nm)[a]	QY (%)	Sensing process	LR (µM)	LOD (µM)	Ref.
Cu^{2+}							
Functionalized GQDs							
Amino–GQDs	Acid oxidation of GO dispersion in water with HNO_3:H_2SO_4 (4:1) under MW-reflux (650W, 100°C, 9h); pH adjusted to 8.0; Filtration; Dialysis; Covalent modification with amine under HT (28wt% NH_3, 200°C, 10h); Evaporation of NH_3; Dialysis	3–9/6	16.4	FL, Turn-off	0.01–0.1	0.0069	[79][d]
Undoped/doped-GQDs							
GQDs	Acid oxidation of GO with HNO_3:H_2SO_4 (1:3) under ultrasonication (5h); Centrifugation; pH adjusted to 12.0; HT (180°C, 10h); Filtration; Dialysis	10–30/19.6	—	FL, Turn-off	0–15	0.226	[80]
Oxidized GQDs	Electrolysis of graphite rod in 0.1M PBS; Filtration; Dialysis; Chemical oxidation with $K_2S_2O_8$ under ultra-violet irradiation (18W, 365nm, 72h); Dialysis	1–4/2.4	—	FL, Turn-off	0–20	2	[81]
GQDs	Chemical/acid oxidation of 3D NGFs with $KMnO_4$/HNO_3:H_2SO_4 (1:3.3) under reflux (80°C, 48h); pH adjusted to 7.0; Reduced with sodium borohydride (room temperature, 4h); Dialysis	0.7–2.3/1.4	4.5	FL, Turn-off	0.1–1	0.067	[82][d]
GQDs	Ultrasonication (*Anthracite coal* in DMF, 21kHz, 650W, 2h); Filtration; Dialysis	1.5–6/3.2	5.98	FL, Ratiometric	0–8	0.29	[83]
GQDs	HT (Humic acid in 0.15M NH_4OH aqueous solution, pH adjusted to 10, 200°C, 12h); Centrifugation; Dialysis	3–10/—	20	FL, Turn-off	1–40	0.44	[84][e]
GQDs	Ar/DC microplasma treatment of *starch* in 0.6M NaOH aqueous solution, 1h; Purification	2–6.3/4.1	27.5	FL, Turn-off	1–50	0.1109	[85]
Eu-GQDs	Acid oxidation of Eu-doped graphene with HNO_3:H_2SO_4 (1:3) under reflux (75°C, 7.5h); Mixed with 1M NaOH solution & pH adjusted to 7.0; Dialysis	2.3–5.4/—	2.4	FL, Turn-off	0.1–10	0.056	[86]
N-GQDs	ST (*p*-phenylenediamine/*p*-coumaric acid in ethanol, 180°C, 24h); Diluted in water & ethanol removed; Filtration; Dialysis	1.5–8.5/3.8	34.4	FL, Turn-off	0–10	0.057	[87]
N-GQDs	Electrolysis of graphite rod in NaOH/ethanol, 24h; Dialysis; pH	—/71.65[b]	18.4	FL, Turn-off	0.3–16.1	0.153	[88]

	adjusted to 7.0 & re-disperse in water; Gamma irradiation (200 kGy, Ar) with 4v% EDA/3v% IPA; Dialysis						
N-GQDs	Pyrolysis (Glutamic acid/tyrosine, 320°C, 1min); Dilution & centrifugation; Dialysis	—/5.0	12	FL, Turn-off	0.1–10	0.06	[89][d, e]
GQDs-involved with other counterparts							
GSH–GQDs/ CdTeQDs	Pyrolysis (Citric acid/GSH, 240°C, 10min); Diluted with water; Chromatography; Mixed with pre-synthesized CdTeQDs	—	—	FL, Ratiometric	0.1–1	0.053	[90][d, e]
N-GQDs/TryIL	HT (Citric acid/NH_3 in water, 180°C, 8h); Filtration; Dialysis; Assembly on TryIL micelles	50–350/ 139.8	37	FL, Turn-off	51–1600[c]	17[c]	[91][e]

Abbreviations: GSH: glutathione, TryIL: 1-hexyl-3-methylimidazolium tryptophan ionic liquid, GO: graphene oxide, MW: microwave, PBS: phosphate buffer saline, 3D NGFs: three-dimensional nanomesh graphene frameworks, DMF: dimethylforamide, HT: hydrothermal, Ar: argon, DC: direct current, ST: solvothermal, EDA: ethylenediamine, IPA: isopropyl alcohol, QY: quantum yield, FL: fluorometric, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: measured from dynamic light scattering, [c]: LR/LOD in µg/L, [d]: analytical ability in living cells/rat brain, [e]: analytical ability in real water/vegetable/serum samples.

Table S4. GQDs, modified-GQDs, and GQDs-involved with other counterparts for Pb^{2+} sensing application.

GQD-based sensor	Synthesis condition	Size distribution /average size (nm)[a]	QY (%)	Sensing process	LR (µM)	LOD (µM)	Ref.
Pb^{2+}							
sl-GQDs/L-Cysteine	Acid oxidation of carbon black with 6M HNO_3 under reflux (130°C, 24h); Centrifugation; Drying	—/10	—	ECL, Turn-off	0.1–10	0.07	[92][e]
GQDs@GCE	Acid oxidation of GO with periodic acid under heating (60°C, 24h); Centrifugation & washing; Dispersed in water with SPSS as a dispersant under ultrasonication (2h); Reduced by AA under stirring & heating (50°C, 24h); Filtration; Dialysis; Drop casted on GCE	5–15/—	—	EC, DPV	0.8–10	0.007	[93]
DNA aptamer–rGQDs /GO	Acid oxidation of graphite powder with HNO_3:H_2SO_4 (1:3) under ultrasonication (2h) & reflux (80°C, 24h); pH adjusted to 7.0; Dialysis; Reduced with sodium borohydride under heating (70°C, 8h); Dialysis; Covalently modified with a DNA aptamer; Mixed with GO	3–5/—[b]	10[c]	FL, Turn-off-on	0.0099–0.435	0.0006	[94]

S-GQDs	HT (TNP/Na_2S in 0.2M aqueous NaOH solution, 200°C, 10h); Dialysis	—/3	11.6	FL, Turn-off	0.1–1, 1–140	0.03	[95]
GQDs–DNA–AuNPs	GQDs purchased from XFNANO; Covalently modified with amine-containing DNA strand; Covalently conjugated with AuNPs containing thiol-modified DNA strand	—/5[b]	—	FL, Turn-on	0.05–4	0.0167	[96]
N,P,S-GQDs	Acid oxidation of *Anthracite coal* with HNO_3:H_2SO_4 (1:3) under ultrasonication (2h) & reflux (100°C, 24h); Mixed with 3M NaOH solution & pH adjusted to 7.0; Filtration; Dialysis	1–7/—	—	FL, Turn-off	1–20	0.75	[97]
DDTC–GQDs	Pyrolysis (CA/DDTC, 250°C, 5min); Mixed in 0.25M NaOH solution	—	—	RLS, Turn-on	1–10[d]	0.8[d]	[98][e]
DAP–GQDs	Acid oxidation of graphite flake with HNO_3:H_2SO_4 (1:3) under ultrasonication (2h) & reflux (120°C, 24h); pH adjusted to 7.0; Filtration; Dialysis; Covalently modified with DAP	1–5/2.9	13.4	FL, Turn-on	0–300	1.2	[99][e]

Abbreviations: sl: single-layered, GCE: glassy carbon electrode, rGQDs: reduced graphene quantum dots, GO: graphene oxide, NPs: nanoparticles, DDTC: diethyl dithiocarbamate, DAP: 2,6-diaminopyridine, SPSS: sodium polystyrene sulfonate, AA: L-ascorbic acid, HT: hydrothermal, TNP: 1,3,6-trinitropyrene, CA: citric acid, QY: quantum yield, ECL: electrochemiluminescence, EC: electrochemical, DPV: differential pulse voltammetry, FL: fluorometric, RLS: resonance light scattering, LR: linear range, LOD: limit of detection.
Note: [a]: measured from transmission electron microscopy, [b]: size distribution/average size of rGQDs/GQDs used with other counterparts, [c]: QY of rGQDs, [d]: LR/LOD in μg/L, [e]: analytical ability in real water samples.

Table S5. GQDs and modified-GQDs for Cr^{6+}/ Cr^{3+} sensing application.

GQD-based sensor	Synthesis condition	Size distribution /average size (nm)[a]	QY (%)	Sensing process	LR (μM)	LOD (μM)	Ref.
Cr^{6+}/Cr^{3+}							
GQDs/$S_2O_8^{2-}$	Acid oxidation of carbon black with HNO_3 under reflux (100°C, 24h); Centrifugation	—/10	—	ECL, Turn-off	0.05–60	0.02	[100][e]
N-GQDs	HT (1,3,6-trinitropyrene/NH_3/hydrazine hydrate in water, 200°C, 8h); Filtration; Dialysis	2–3.6/2.7	—	FL, Turn-off	1–500	0.02	[101]
N-GQDs/Nylon membrane	Immobilized on nylon membrane			″ ″	1–500[b] 1–500[c]	0.19[b] 0.17[c]	
PVP-passivated N-GQDs	HT (Citric acid/glutamic acid/PVP-K90 in water, 180°C, 12h); Centrifugation; Filtration; Dialysis	1.5–4/1.9	64.2	FL, Turn-off	0.1–100	0.091	[102][e]

GQDs cluster	MW (Citric acid/urea/Zn precursor in water); Dialysis	—/20	19	FL, Turn-off	0–10	0.04354	[25]
DA–N-GQDs	HT (Citric acid/urea in water, 160°C, 4h); Dialysis; Covalently modified with DA	—/3	—	FL, Ratiometric	166–2380[d]	4.56[d]	[103][e]

Abbreviations: PVP: polyvinyl pyrrolidone, DA: dopamine, HT: hydrothermal, MW: microwave, QY: quantum yield, ECL: electrochemiluminescence, FL: fluorometric, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: LR/LOD in single-piece test, [c]: LR/LOD in multiple-piece test, [d]: LR/LOD for Cr^{3+}, [e]: analytical ability in real water samples.

Table S6. GQDs, modified-GQDs, and GQDs-involved with other counterparts for Co^{2+}, Ni^{2+}, Al^{3+}, and As^{3+} sensing application.

GQD-based sensor	Synthesis condition	Size distribution /average size (nm)[a]	QY (%)	Sensing process	LR (µM)	LOD (µM)	Ref.
			Co^{2+}				
N-GQDs	HT (NGO/hydrazine in water, 180°C, 6h); Filtration	4–6/—	—	ECL, Ratiometric	1–70	0.2	[104][e]
			Ni^{2+}				
GQDs	Acid oxidation of carbon fiber with HNO_3:H_2SO_4 (3:1) under ultrasonication (2h) & reflux (150°C, 24h); pH adjusted to 8.0; Filtration; Dialysis	2.5–5/3.9	—	FL, Turn-on	0–90	4.1	[105][e]
			Al^{3+}				
B-GQDs	Electrolysis of graphite rod in 0.1M borax aqueous solution, 2h; Filtration, Dialysis	2–8/—	13	FL, Turn-on	0–100	3.64	[106]
N-GQDs	ST (Graphene oxide in dimethylforamide, 200°C, 5h); Filtration	20–30[b]	23.1	FL, Turn-on	2.5–75	1.3	[107][e, f]
			As^{3+}				
Fe_3O_4NPs–GQDs	HT (Functionalized graphene oxide/3wt% H_2O_2 in water, 180°C, 2h); Centrifugation; pH adjusted to 6.0; Covalently modified with amine-functionalized Fe_3O_4NPs	1–7/~3.1[c]	—	FL, Turn-on	5–100[d]	5.1[d]	[108][e]

Abbreviations: NPs: nanoparticles, HT: hydrothermal, NGO: nitrogen-doped graphene oxide, ST: solvothermal, QY: quantum yield, ECL: electrochemiluminescence, FL: fluorometric, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: measured from atomic force microscopy, [c]: size distribution/average size of GQDs, [d]: LR/LOD in ppb, [e]: analytical ability in real water samples, [f]: analytical ability in living cells.

Table S7. GQDs and modified-GQDs for Ag^{+} and Au^{3+} sensing application.

GQD-based sensor	**Synthesis condition**	**Size distribution/ average size (nm)[a]**	**QY (%)**	**Sensing process**	**LR (µM)**	**LOD (µM)**	**Ref.**
				Ag^{+}			
Amino–GQDs	Pyrolysis (*Neem leaves*, 1000°C, 5h, Ar); Acid oxidation with HNO_3:H_2SO_4 (1:3) under reflux (90°C , 5h); Diluted with water; Filtration; pH adjusted to 7.0; Covalently modified with amine under HT (30% NH_3, 200°C, 12h)	—/5–6	2	FL, Turn-off	—	0.033–0.1[b]	[109]
N-GQDs	MW (Glucose/NH_3 in water, 300W, 5min); Dissolved in water	—/20	—	FL, Turn-off	0.2–40	0.168	[110][c]
S-GQDs	HT (TNP/MPA in water, 200°C, 10h); Filtration; Dialysis	1.5–3.5/2.5	9.2	FL, Turn-off	0.1–130	0.03	[111][c]
GQDs	GQDs purchased from XFNANO	1–5/2.9	—	FL, Ratiometric	0–115.2	0.25	[112][c]
GQDs/Hg^{2+}/TAA	Pyrolysis (Citric acid, 200°C, 5min); Mixed in 0.25M NaOH solution & pH adjusted to 7.0	3.33–8.33/—	—	FL, Turn-on-off	0.5–10	0.18	[113][c]
				Au^{3+}			
GQDs GQDs	Pyrolysis (Glucose, 200°C, 1.5min); Diluted with water Pyrolysis (Citric acid, 200°C, 1.5min); Mixed in 10 mg/mL NaOH solution	3–33/22 2–12/8	— —	FL, Turn-off ″	1–80 5–30	0.5 1.45	[114][c]

Abbreviations: TAA: thioacetamide, MW: microwave, HT: hydrothermal, TNP: 1,3,6-trinitropyrene, MPA: 3-mercaptopropionic acid, QY: quantum yield, FL: fluorometric, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: LOD in g/L, [c]: analytical ability in real water samples.

Table S8. GQDs, modified-GQDs, and GQDs-involved with other counterparts for alkali/alkaline-earth, rare-earth, and radioactive MIs sensing application.

GQD-based sensor	Synthesis condition	Size distribution /average size (nm)[a]	QY (%)	Sensing process	LR (μM)	LOD (μM)	MIs	Ref.
Alkali/alkaline-earth MIs								
PEG-modified N-GQDs-1	ST (Graphene oxide in dimethylforamide, 200°C, 4h); Filtration; Covalently modification with organic halides of 2/3/4/5/6/7 number of ethylene glycol units	1.5–8.5/4.7	71	FL, Turn-off	0.0005–0.05	0.0002	Mg^{2+}	[115]
PEG-modified N-GQDs-2		< 5/—	73	″	0.0003–0.01	0.0001	Ca^{2+}	
PEG-modified N-GQDs-3		< 6/—	69	″	0.0008–0.02	0.0004	Sr^{2+}	
PEG-modified N-GQDs-4		< 5/—	72	″	0.001–0.02	0.0005	Li^{+}	
PEG-modified N-GQDs-5		< 6/—	71	″	0.0003–0.01	0.0001	Na^{+}	
PEG-modified N-GQDs-6		< 8/—	71	″	0.0008–0.04	0.0003	K^{+}	
PEG–GQDs/Na^{+} selective ionophore	GQDs purchased from Sigma-Aldrich; Covalently modified with propargyl group & cross-linked by azide-functionalized poly(ethylene oxide); Integrated into Na^{+}/K^{+} selective ionophores	—/10[b]	—	FL, Ratiometric	100–1x10^{6} [d]	—	Na^{+}	[116][e, f]
PEG–GQDs/K^{+} selective ionophore		—/10[b]	—	″	3–1x10^{6} [d]	—	K^{+}	[116][e]
Rare-earth MIs								
GQDs	Acid oxidation of graphene with HNO_3:H_2SO_4 (3:1) at 25°C (12h) & under ultrasonication (12h); Pyrolysis (350°C, 20min); Diluted with water; Filtration; Dialysis	3–5/—	—	FL, Turn-off	1–30	—	Eu^{3+}	[117]
N-GQDs	Reflux (Graphene oxide dispersion in *N*-methyl-2-pyrrolidone, 202°C, 24h); Filtration; Dialysis	1.2–3.2/1.8	—	FL, Turn-off	1–44	0.8352	Ce^{4+}	[118][e]
Radioactive MIs								
GQDs clusters	HT (Graphene oxide/citric acid/$NH_3.H_2O$ in water, 150°C, 48h); Obtained hydrogel soaked in NaOH aqueous solution (pH: 13), 4h; Filtration	20–1300/ 290.1[c]	—	FL, Turn-off	0–1260	2.1	U^{6+}	[119]

Abbreviations: PEG: polyethylene glycol, ST: solvothermal, HT: hydrothermal, QY: quantum yield, FL: fluorometric, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: size distribution/average size of PEG–GQDs in ionophores, [c]: measured from dynamic light scattering, [d]: dynamic concentration range, [e]: analytical ability in real samples, [f]: analytical ability in living cells.

Table S9. GQDs, modified-GQDs, and GQDs-involved with other counterparts for multiple HMIs sensing application.

GQD-based sensor	Synthesis condition	Size distribution/ average size (nm)[a]	QY (%)	Sensing process	LR (µM)	LOD (µM)	HMIs	Ref.
Multiple HMIs (EC sensor)								
GQDs–AuNPs @GCE	Acid oxidation of carbon black with HNO_3 under reflux (100°C, 24h); Centrifugation; Covalently conjugated with cysteamine-capped AuNPs; Drop casted on GCE	—/2[b]	—	EC, ASV ″	0.00002–0.1 0.00005–0.5	0.00002 0.00005	Hg^{2+} Cu^{2+}	[120][g]
GQDs/Chitosan @Bi-GCE	Pyrolysis (Citric acid, 200°C, 30min); Dissolved in 10 mg/mL NaOH solution & pH adjusted to 7.0; Non-covalently modified with Chitosan; Drop casted on Bi-plated GCE	1.7–3/2.5[b]	—	EC, SWASV ″ ″	50–450[d] 50–450[d] 50–450[d]	8.84[d] 1.99[d] 3.10[d]	Zn^{2+} Cd^{2+} Pb^{2+}	[121]
GQDs/Nafion @GCE	Pyrolysis (Citric acid, 200°C, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0; Mixed with Nafion & drop coated on GCE	—/3[b]	—	EC, SWASV ″	20–200[d] 20–200[d]	11.3[d] 8.49[d]	Cd^{2+} Pb^{2+}	[122][g]
Multiple HMIs (FL sensor)								
Undoped/doped-GQDs								
GQDs	Pyrolysis (Citric acid, 200°C, 25min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0	—/20	—	FL, Turn-off	10–200 10–200	10 10	Fe^{3+} Hg^{2+}	[123][g, h]
GQDs	Chemical oxidation of graphene oxide with sodium hypochlorite under UV irradiation (365nm, 6-7h); HT (180°C, 2h); Centrifugation; Dialysis	2–10/—	—	FL, Turn-off ″	0–50000[e] 0–100000[e]	1 4	Fe^{3+} Cr^{3+}	[124]
GQDs	Acid oxidation of graphene oxide with HNO_3:H_2SO_4 (4:1) under reflux (120°C, 24h); pH adjusted to 8.0; Centrifugation; Filtration; Dialysis	2–10/—	—	FL, Turn-off ″ ″	0.01–0.1, 0.1–0.5 0.01–0.05, 0.1–0.5 0.01–0.05, 0.1–1	0.047 0.098 0.098	Fe^{3+} Cr^{3+} Pb^{2+}	[125]
GQDs	HT (*Starch* powder in water, 180°C, 2h); Centrifugation	1–25/—	—	FL, Turn-off ″ ″ FL, Turn-off-on ″ ″	— ″ ″ ″ ″ ″	— ″ ″ ″ ″ ″	Fe^{3+} Cu^{2+} Cr^{3+} Al^{3+} Ga^{2+} In^{3+}	[126]
GQDs	Acid oxidation of reduced graphene oxide with	35–75/50	—	FL, Turn-off	0–5[f]	1.171	Hg^{2+}	[127]

	HNO_3:H_2SO_4 (3:1) under ultrasonication (8h); Filtration, washing, dispersion in water & pH adjusted to 8.0; HT (200°C, 10h); Filtration			〃 〃	0–5[f] 0–5[f]	2.011 2.455	Pb^{2+} Cd^{2+}	
N,S-GQDs	HT (Citric acid/thioacetamide in water, 180°C, 10h); Centrifugation; Dialysis	1.5–4/2.5	—	FL, Turn-off 〃	0.001–0.09, 0.1–30 0.001–0.03, 0.1–1	0.00288, 0.05549 0.00027, 0.03685	Fe^{3+} Hg^{2+}	[128][g]
N,S-GQDs	Pyrolysis (Citric acid/thiourea, 300°C, 20min); Diluted in water	2.3–8.3/4–5	—	FL, Turn-off 〃	30–140 12–125	9.14 12.9	Hg^{2+} Ag^{+}	[129]
N-GQDs	Pyrolysis (Citric acid/3%w/v HNO_3, 250°C, 5min); Mixed in 0.25M NaOH solution	—	83.42	FL, Turn-off 〃	20–100 100–500	0.42 13.19	Hg^{2+} Cu^{2+}	[130][g, h]
Functionalized GQDs								
PEI–GQDs	HT (*Coffee ground*/hydrazine hydrate in water, 180°C, 8h); Filtration; Dialysis; Covalently modified with PEI under HT (120°C, 10h); Filtration	1–5/2.67	24	FL, Turn-off 〃	0–1 0–1	— —	Fe^{3+} Cu^{2+}	[131]
DPA–GQDs	HT (Citric acid/DPA in water, 200°C, 2.5h); Diluted with water	—/1.11[c]	—	FL, Turn-off 〃 〃 〃 〃 FL, Turn-on	10–150[f] 1–9[f] 1–150[f] 1–70[f] 1–70[f] 1–45[f]	10[f] 1[f] 1[f] 1[f] 1[f] 1[f]	Hg^{2+} Au^{3+} Pb^{2+} Co^{2+} Cu^{2+} Ag^{+}	[132][g]
ARS–GQDs	Pyrolysis (Citric acid, 180°C, 15min); Mixed in acetone & 0.1N NaOH solution to separate oily part; Covalently modified with ARS	15–20/—	—	COL, Turn-on 〃	1–30 〃	0.31 0.35	Co^{2+} Fe^{3+}	[133]
EBT–GQDs	Pyrolysis (Citric acid, 180°C, 15min); Mixed in acetone & 0.1N NaOH solution to separate oily part; Covalently modified with EBT	4–8/—[b]	—	COL, Turn-on 〃	$2x10^4$–$8x10^4$ $1.5x10^4$–$20x10^4$	14000 18000	Co^{2+} Cu^{2+}	[134]

Abbreviations: NPs: nanoparticles, GCE: glassy carbon electrode, PEI: polyethylene imine, DPA: D-penicillamine, ARS: alizarine red S, EBT: eriochrome black T, UV: ultra-violet, HT: hydrothermal, QY: quantum yield, EC: electrochemical, ASV: anodic stripping voltammetry, SWASV: square wave anodic stripping voltammetry, FL: fluorometric, COL: colorimetric, LR: linear range, LOD: limit of detection.

Note: [a]: measured from transmission electron microscopy, [b]: size distribution/average size of GQDs used with other counterparts or before functionalization, [c]: measured from dynamic light scattering, [d]: LR/LOD in μg/L during simultaneous detection, [e]: dynamic concentration range, [f]: LR/LOD in ppm, [g]: analytical ability in real water/other real samples, [h]: simultaneous detection capability of multiple HMIs.

Table S10. GQDs, modified-GQDs, and GQDs-involved with other counterparts for anion sensing application.

GQD-based sensor	Synthesis condition	Size distribution / average size (nm)[a]	QY (%)	Sensing process	LR (μM)	LOD (μM)	Ref.
Anions							
Phosphate (PO_4^{3-})							
GQDs/Eu^{3+}	Acid oxidation of graphene sheets with HNO_3:H_2SO_4 (3:1) under ultrasonication (17h); HT (Oxidized graphene sheets in water & pH adjusted to 8.0, 200°C, 12h); Filtration; Dialysis	10–20/—	—	FL, Turn-off-on	0.5–190	0.1	[135][i]
GQDs/Eu^{3+}	Acid oxidation of graphene with HNO_3:H_2SO_4 (3:1) at 25°C (12h) & under ultrasonication (12h); Pyrolysis (350°C, 20min); Diluted with water; Filtration; Dialysis	3–5/—	—	FL, Turn-off-on	1–12	0.1	[117][i]
sl-GQDs/Al^{3+}	Hydroquinone in water treated with 20%H_2O_2 followed by triethylenetetramine (25°C, 5min); Dialysis	2.5–6/4.5	—	FL, Turn-on-off	0.25–7.5	0.1	[136][i]
sl-GQDs/Dy^{3+}	HT (PTCDA/triethylamine in water, 220°C, 48h); Filtration; Dialysis; Exfoliated in methanol; Drying	1.3–3.4/2.1	—	FL, Turn-off-on	0.2–30	0.1	[137][i]
B-GQDs/Fe^{3+}	HT (1,3,6-trinitropyrene/borax in 0.125M NaOH aqueous solution, 200°C, 6h); Dialysis	< 5/2	16.8[d]	FL, Turn-off-on	3–40	0.34	[16][i]
N-GQDs/ $Mo_7O_{24}^{6-}$	ST (Julolidine/acetic acid in ethanol, 200°C, 12h); Filtration; Dialysis	—/4.8	53	FL, Turn-off-on	7–30	0.05	[138][i, j]
Pyrophosphate ($P_2O_7^{4-}$)							
N-GQDs/Eu^{3+}	Chemical oxidation of graphene oxide/lysine with 30% H_2O_2 under reflux (130°C, 4h); Removal of excess H_2O_2; Filtration; Dialysis	1.5–3.5/—	13.2	FL, Turn-off-on	0.3–5	0.074	[139][i]
Hypochlorite (ClO^-)							
GQDs	Pyrolysis (Glucose, 180°C, 1.5min); Diluted with water	—/20	—	CL, Turn-on	0.5–1000	0.3	[140][i]
o-PD–GQDs	HT (GO/KO_2 in water, 200°C, 24h); pH adjusted to 7.0; Filtration; Dialysis; Covalently modified with *o*-PD	2–8/~5.2	6.2	FL, Turn-off	0.1–1	0.069	[141][i, j]
GQDs	Pyrolysis (Citric acid, 200°C, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0	10–25/15	—	COL, Turn-on	5–240	2.1	[142][i]
GQDs	Pyrolysis (Citric acid, 200°C, 30min); Mixed in 10	15–25/—	4.54	FL, Turn-off	0.25–5	0.0221	[48]

	mg/mL NaOH solution & pH adjusted to 7.0						
BSA–GQDs	HT (Citric acid/BSA in water, 180°C, 3h)	2–11/5.4	—	FL, Turn-off	500–1000	35.39	[143]
Sulfide (S^{2-})							
GQDs/Cu^{2+}	Acid oxidation of graphene oxide with HNO_3:H_2SO_4 (1:3) under ultrasonication (5h); Centrifugation; Dispersed in water and pH adjusted to 12.0; HT (180°C, 10h); Filtration; Dialysis	10–30/20.22	—	FL, Turn-off-on	0.2–20	0.1	[144][i]
SA,GSH–GQDs/ Cu^{2+}	Chemical oxidation of GO with H_2SO_4/$KMnO_4$/H_2O_2; Dialysis; Covalently modified with SA and GSH	—/10.3	3.37	FL, Turn-off-on	0.05–3.75	0.0126	[145][i]
Cyanide (CN^-)							
AuNPs–Peptides@ GQDs	ST (Graphene oxide in dimethylforamide, 200°C, 4.5h); Filtration; Dialysis; Non-covalent modification with AuNPs–Peptides; Centrifugation	—/3.8[b]	28	FL, Turn-on	1–200	0.52	[146][j]
N,S-GQDs/AgNPs	Pyrolysis (Citric acid/L-cysteine, 240°C, 10min); Dissolved in water	1.2–3.2/2.2	67	FL, Turn-off-on COL, Turn-off	10–500 10–400	0.52 0.78	[147][i]
GQDs/Hg^{2+}	Pyrolysis (Citric acid, 220°C, 5min); Mixed in 0.25M NaOH solution	—/7.12	28.7	FL, Turn-off-on	5–15	3.1	[148][i]
Nitrite (NO_2^-)							
N-GQDs/NCNFs @GCE	HT (Citric acid/dicyandiamide/NCNFs in water, 180°C, 12h); Filtration; Washing; Drop-casted on GCE	—	—	EC, DPV	5–300, 400–3000	3	[149][i]
S,P-GQDs	HT (Citric acid/anhydrous sodium sulfate/sodium phytate in water, 180°C, 7h); Centrifugation; Dialysis	2.5–4.25/3.5	15.69	FL, Turn-off	0.7–9	0.3	[150][i]
Iodide (I^-)							
N-GQDs/Ag^+	HT (Citric acid/urea in water, 160°C, 4h); Centrifugation	2–8/4.6	15.3	FL, Turn-off-on	0.0125–0.35, 0.35–4	0.0056	[151][i]
Fluoride (F^-)							
B,N-GQDs/Hg^{2+}	HT (Citric acid/ethylenediamine/phenylboronic acid in water, 200°C, 5h); Filtration	1.04–4.81/ 2.73	75	FL, Turn-off-on	0.25–7	0.18	[61][i]
Thiocyanate (SCN^-)							
GQDs/Hg^{2+}	Pyrolysis (Citric acid, 200°C, 14min); pH adjusted to 7.0; Dialysis	—/1.8[c]	—	FL, Turn-off-on	—	—	[152]
Other anions							
GQDs/RF@GCE	Pyrolysis (Citric acid, 200°C, 30min); Mixed in 10 mg/mL NaOH solution & pH adjusted to 7.0; Drop-	—	—	EC, Amperometry	1–1000[e]	0.2[e]	[153]

	casted on GCE; Electrochemical deposition of RF						
N-GQDs/Fe^{3+}	Pyrolysis (Citric acid/NH_3, 210°C, 1h); Diluted with water	—	15.5	FL, Turn-off-on	4–200^{f}	1.43^{f}	[154]^{i}
IL@GQDs	HT (1,3,6-trinitropyrene in 5 mg/mL aqueous NaOH solution, 200°C, 4h); Filtration; Dialysis; Non-covalently modified with IL ($BMIMBF_4$); Dialysis	1.6–2.4/2	11.8	FL, Turn-off	0.1–50^{g}, 50–2500^{g}	0.04^{g}	[155]^{i}
GQDs/Hg^{2+}/CN^{-}	Pyrolysis (Citric acid, 220°C, 5min); Mixed in 0.25M NaOH solution	—/7.12	28.7	FL, Turn-off	10–50^{g}	9.48^{g}	[148]^{i}
MEA-GQDs/ Hg^{2+}	Pyrolysis (Citric acid, 190°C, 25min); Pyrolysis (Obtained paste/MEA, 120°C, 1h); Dissolved in water & pH adjusted to 7.4	1–6/—	23.7	FL, Turn-off-on	0.05–3^{h}	0.03^{h}	[68]^{i}

Abbreviations: sl: single-layered, *o*-PD: 1,2-diaminobenzene/*o*-phenylenediamine, BSA: bovine serum albumin, SA: sulfanilic acid, GSH: glutathione, NPs: nanoparticles, NCNFs: nitrogen-doped carbon nanofibers, GCE: glassy carbon electrode, RF: riboflavin, IL: ionic liquid, MEA: mono-ethanolamine, HT: hydrothermal, PTCDA: perylene-3,4,9,10-tetracarboxylic dianhydride, ST: solvothermal, GO: graphene oxide, $BMIMBF_4$: 1-butyl-3-methylimidazolium tetrafluoroborate, QY: quantum yield, FL: fluorometric, CL: chemiluminescence, COL: colorimetric, EC: electrochemical, DPV: differential pulse voltammetry, LR: linear range, LOD: limit of detection.

Note: ^{a}: measured from transmission electron microscopy, ^{b}: size distribution/average size of GQDs used with other counterparts, ^{c}: measured from AFM, ^{d}: absolute QY, ^{e}: LR/LOD in the detection of persulfate ($S_2O_8^{2-}$), ^{f}: LR/LOD in the detection of sulfite (SO_3^{2-}), ^{g}: LR/LOD in the detection of ferricyanide ($Fe(CN)_6^{3-}$), ^{h}: LR/LOD in the detection of ethyl xanthate (EtX^{-}), ^{i}: analytical ability in real samples, ^{j}: analytical ability in living cells.

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