Electronic Supplementary Material (ESI) for Nanoscale.

Non-metal Single/Dual Doped Carbon Quantum Dots: A General Flame Synthetic Method and Electro-catalytic Properties

Supporting Information

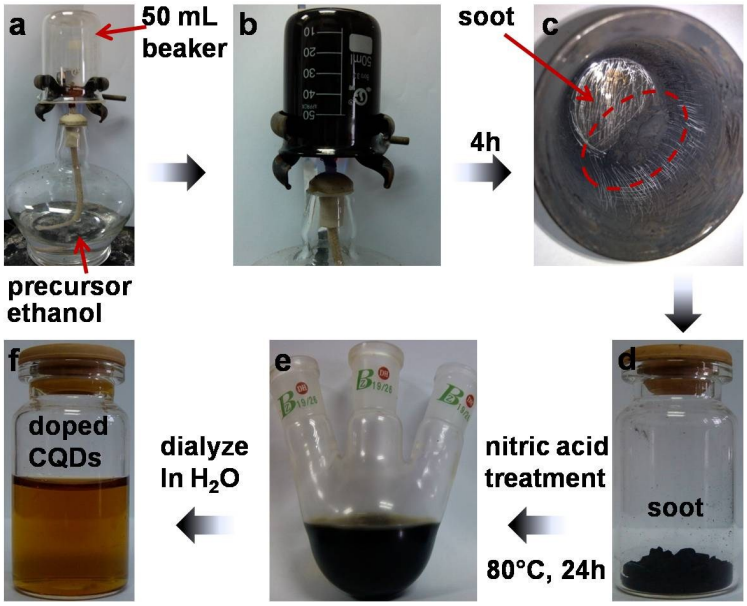

Fig. S1 The schematic set-up and process of the synthesis of various doped CQDs.

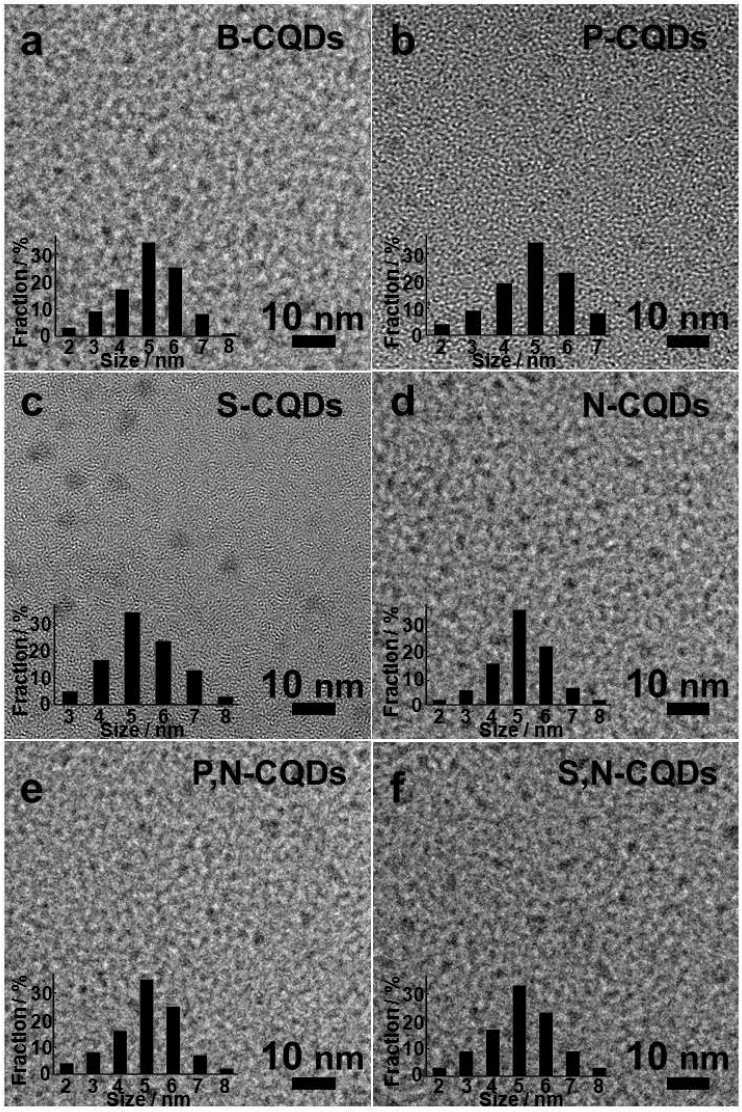

Fig. S2 TEM images of (a) B-CQDs; (b) P-CQDs; (c) S-CQDs; (d) N-CQDs; (e) P,N-CQDs and (f) S,N-CQDs (the insets are corresponding Particle size distribution).

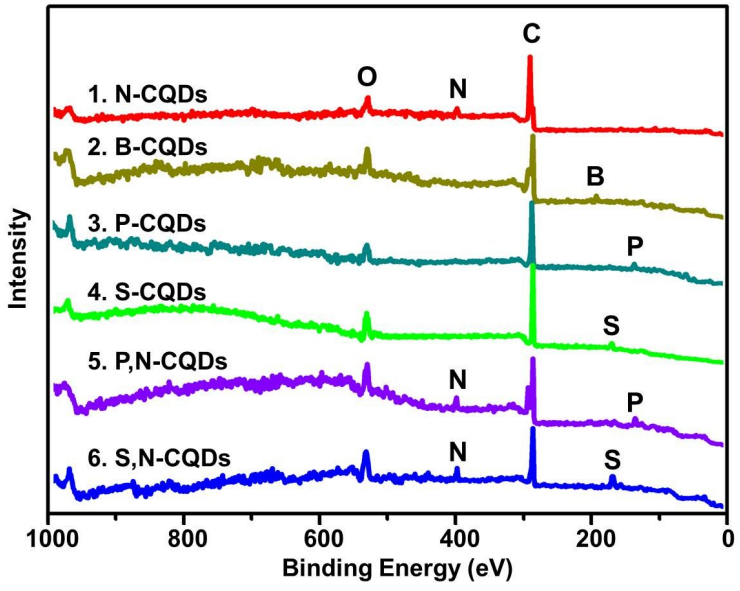

Fig. S3 The full XPS spectra of various single/dual-doped CQDs.

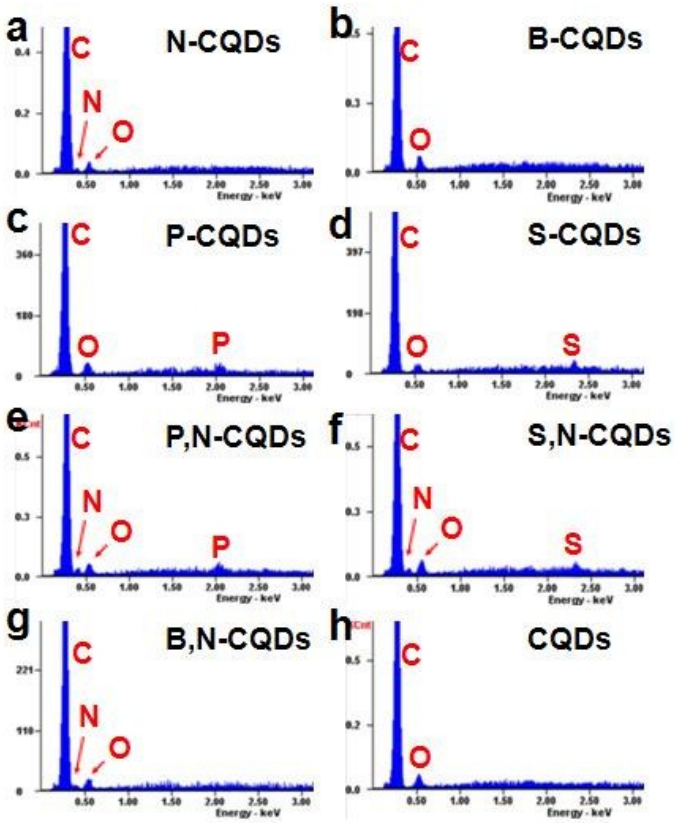

Fig. S4 The Energy Dispersive X-ray Spectroscopy (EDS) analysis of (a) N-CQDs; (b) B-CQDs; (c) P-CQDs; (d) S-CQDs; (e) P,N-CQDs; (f) S,N-CQDs; (g) B,N-CQDs and (h) CQDs.

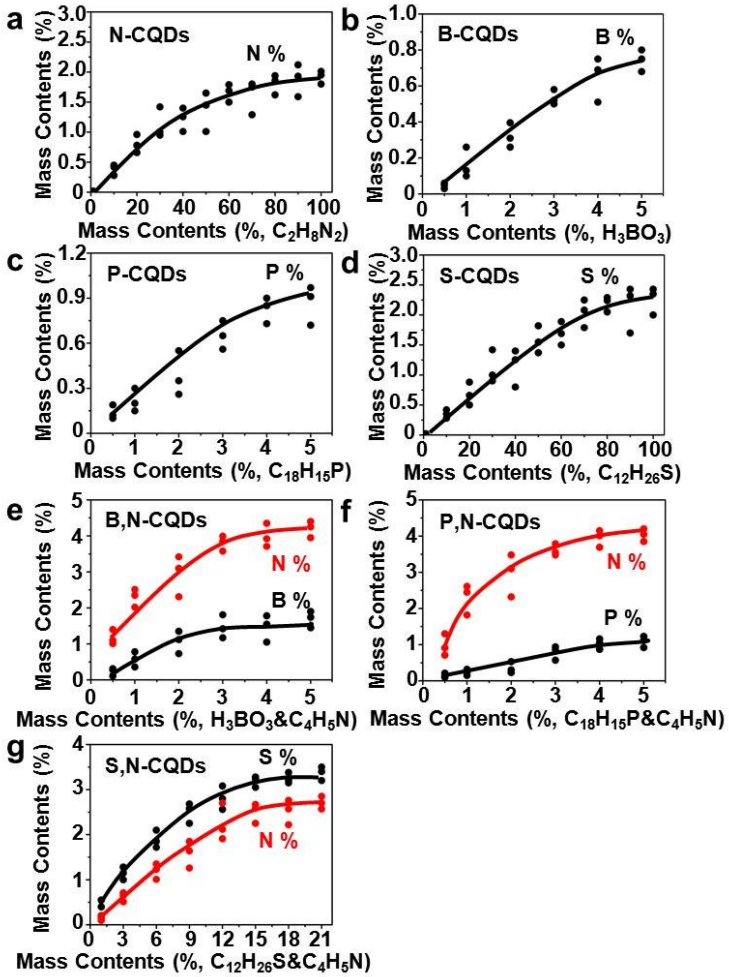

Fig. S5 The doping contents of different heteroatoms (N, B, P and S) in various single/dual-doped CQDs over the concentrations of precursors in ethanol.

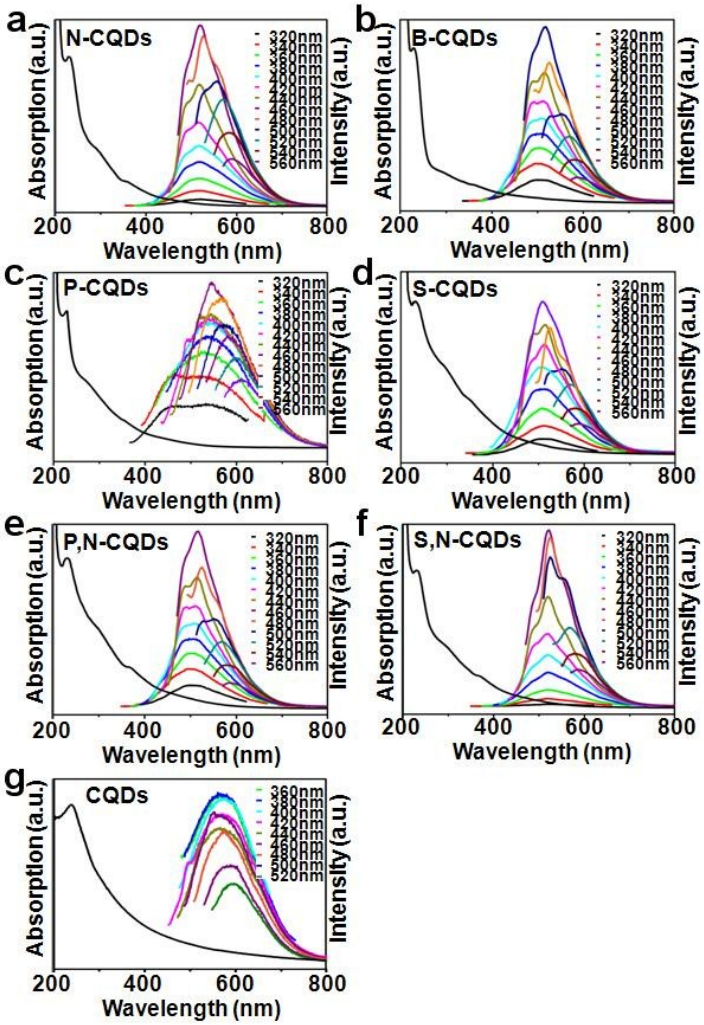

Fig. S6 UV-Vis absorption and PL spectra (recorded from 320 to 560 nm with 20 nm increment) of the obtained (a) N-CQDs; (b) B-CQDs; (c) P-CQDs; (d) S-CQDs; (e) P,N-CQDs; (f) S,N-CQDs; (g) CQDs (360 to 520 nm with 20 nm increment).

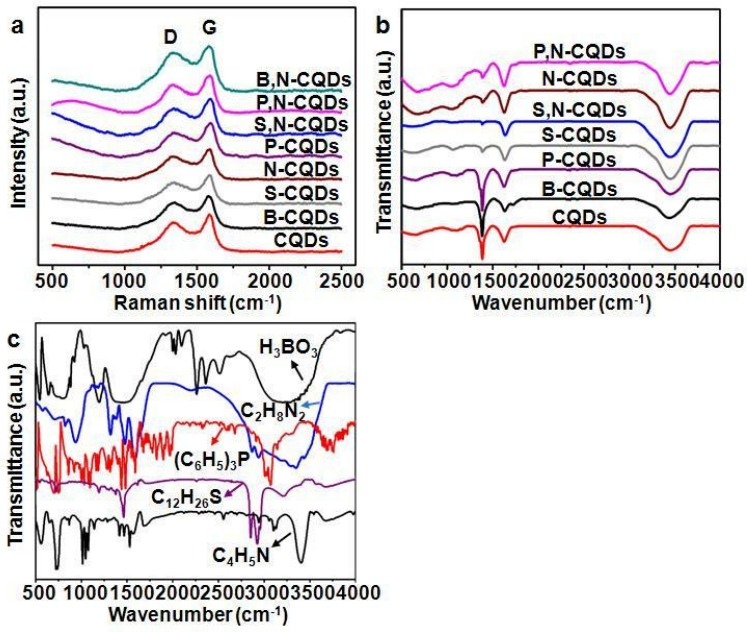

Fig. S7 (a) Raman and (b) FTIR spectra of various single/dual-doped CQDs; (c) the FTIR spectra of precursors used in the experiments (boric acid, ethylenediamine, dodecanethiol, triphenylphosphine, and pyrrole).

Table S1 The doping contents of different elements in various single/dual-doped CQDs.

Sample	C%	O%	B%	N%	P%	S%
N-CQDs	91.3	6.5	-	2.2	-	-
B-CQDs	89.9	9.25	0.85	-	-	-
P-CQDs	88.8	10.2	-	-	1.0	-
S-CQDs	88.9	8.7	-	-	-	2.4
B,N-CQDs	84.5	9.1	1.9	4.5	-	-
P,N-CQDs	83.7	10.8	-	4.3	1.2	-
S,N-CQDs	84.9	8.7	-	2.9	-	3.5
CQDs	82.6	17.4	-	-	-	-

Table S2 The summary of ORR performance on various catalysts in O_2-saturated 0.1 M KOH solution.

Catalysts	Onset potential (V)	Peak potential (V)	Reaction current (mA/cm^2)
N-CQDs	-0.14	-0.36	-1.6
B-CQDs	-0.19	-0.38	-1.1
P-CQDs	-0.13	-0.31	-1.6
S-CQDs	-0.17	-0.37	-1.4
B,N-CQDs	-0.08	-0.25	-2.3
P,N-CQDs	-0.09	-0.26	-2.0
S,N-CQDs	-0.11	-0.28	-1.2
CQDs	-0.23	-0.44	-1.0

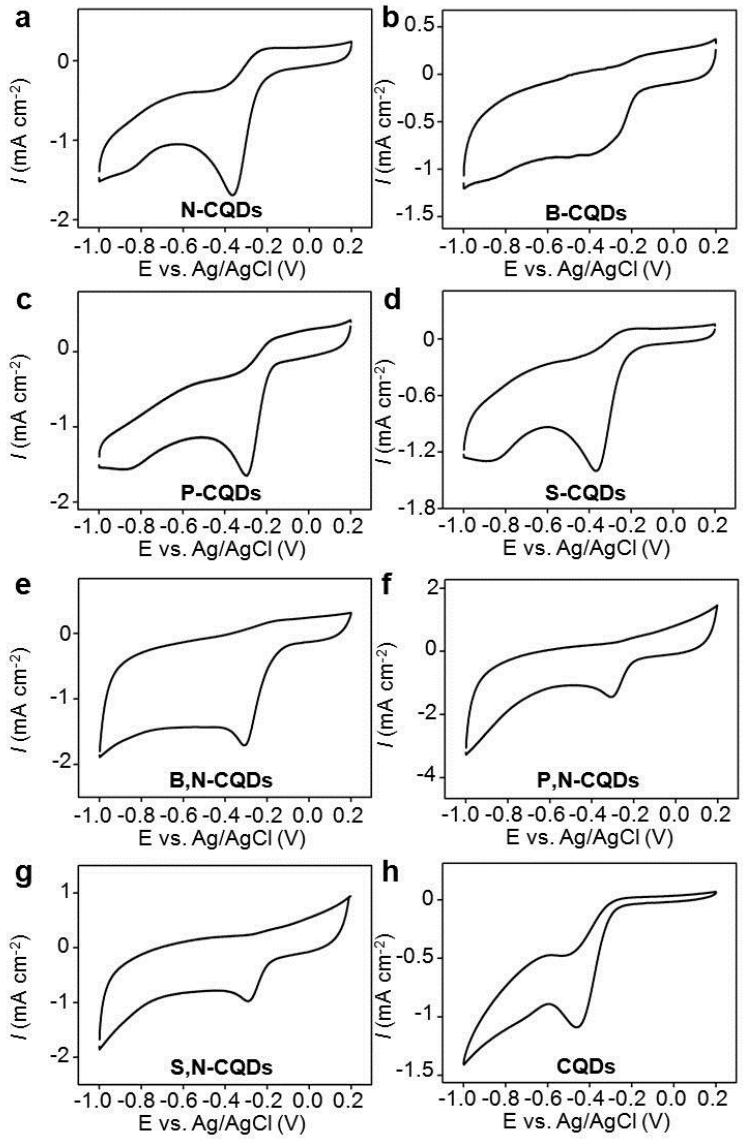

Fig. S8 CV curves of (a) N-CQDs, (b) B-CQDs, (c) P-CQDs, (d) S-CQDs, (e) B,N-CQDs, (f) P,N-CQDs, (g) S,N-CQDs and (h) CQDs from 0.2 V to -1.0 V vs Ag/AgCl in O_2 saturated 0.1 M KOH aqueous electrolyte. Scan rate is 100 mV s^{-1}.

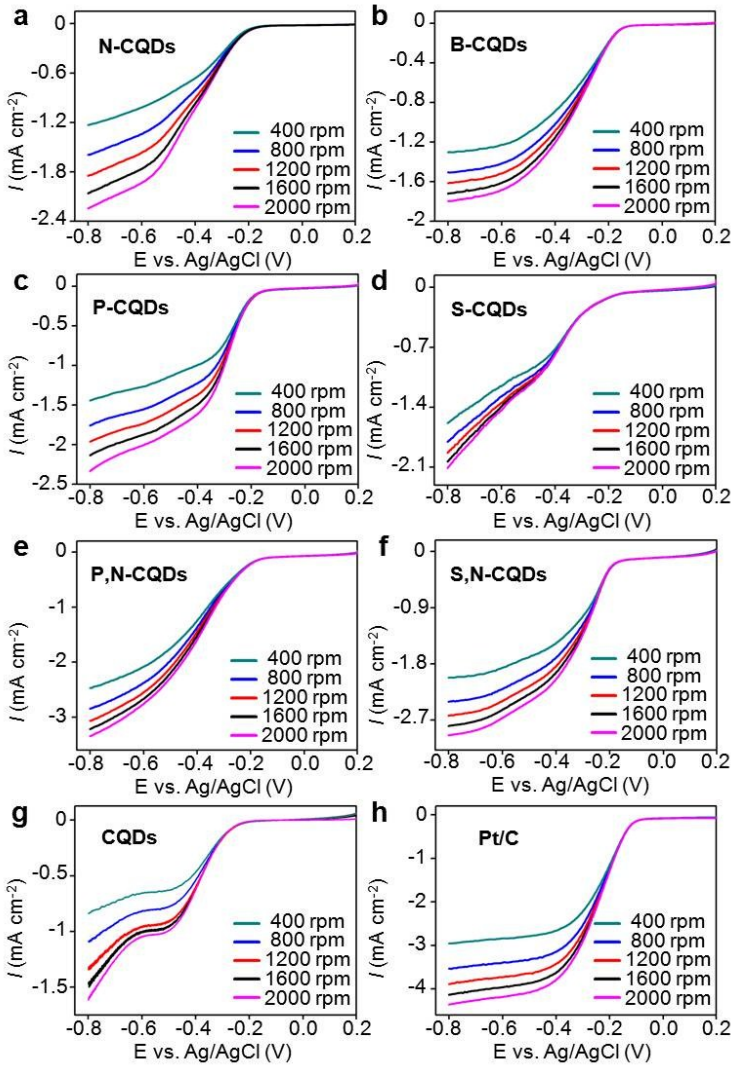

Fig. S9 LSVs of (a) N-CQDs, (b) B-CQDs, (c) P-CQDs, (d) S-CQDs, (e) P,N-CQDs, (f) S,N-CQDs, (g) CQDs and (h) Pt/C on a RDE at different rotating speeds from 400 rpm to 2000 rpm. All the tests were conducted from 0.2 V to -0.8 V vs Ag/AgCl with scan rate of 10 mV s^{-1} in an O_2 saturated 0.1 M KOH aqueous electrolyte.