Supporting Information

Synthesis of B-doped graphene quantum dots as metal-free electrocatalyst for oxygen reduction reaction

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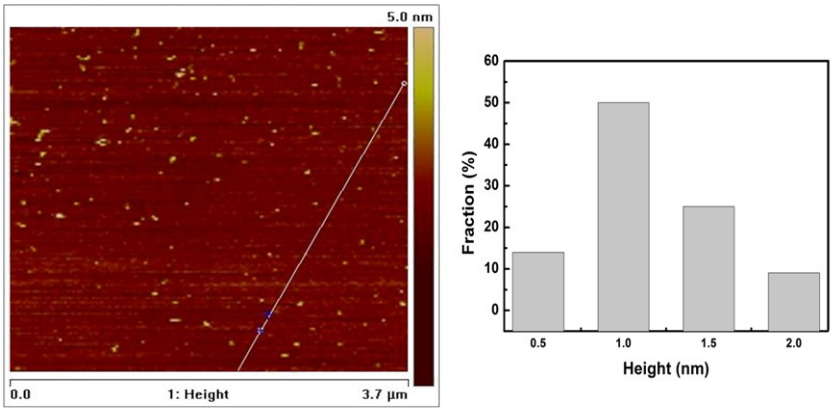


Fig. S1 AFM image of BGQD on mica substrate and its height distribution.

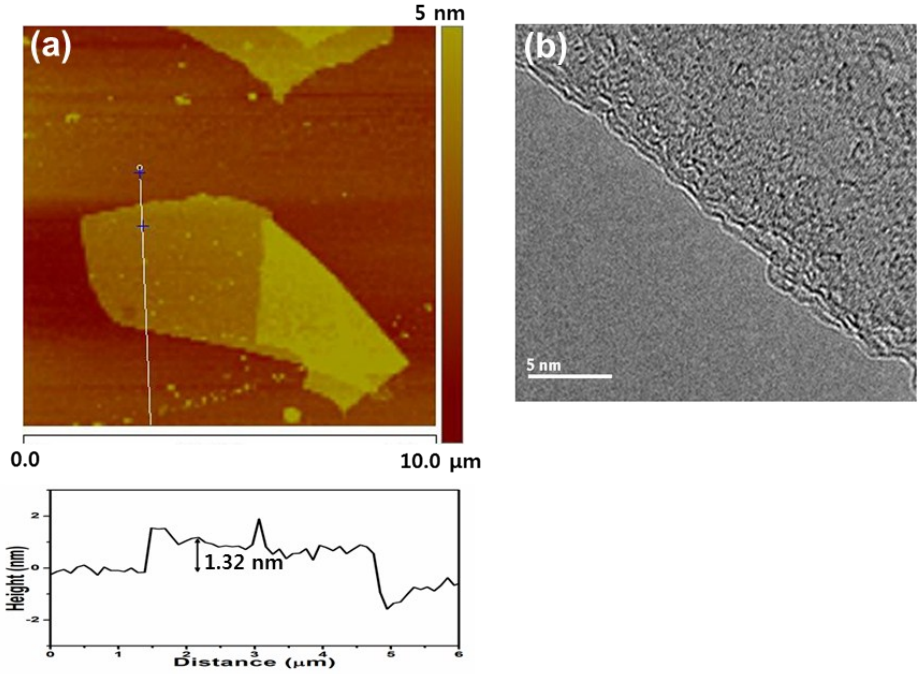


Fig. S2 AFM and TEM images of G-BGQD composite.

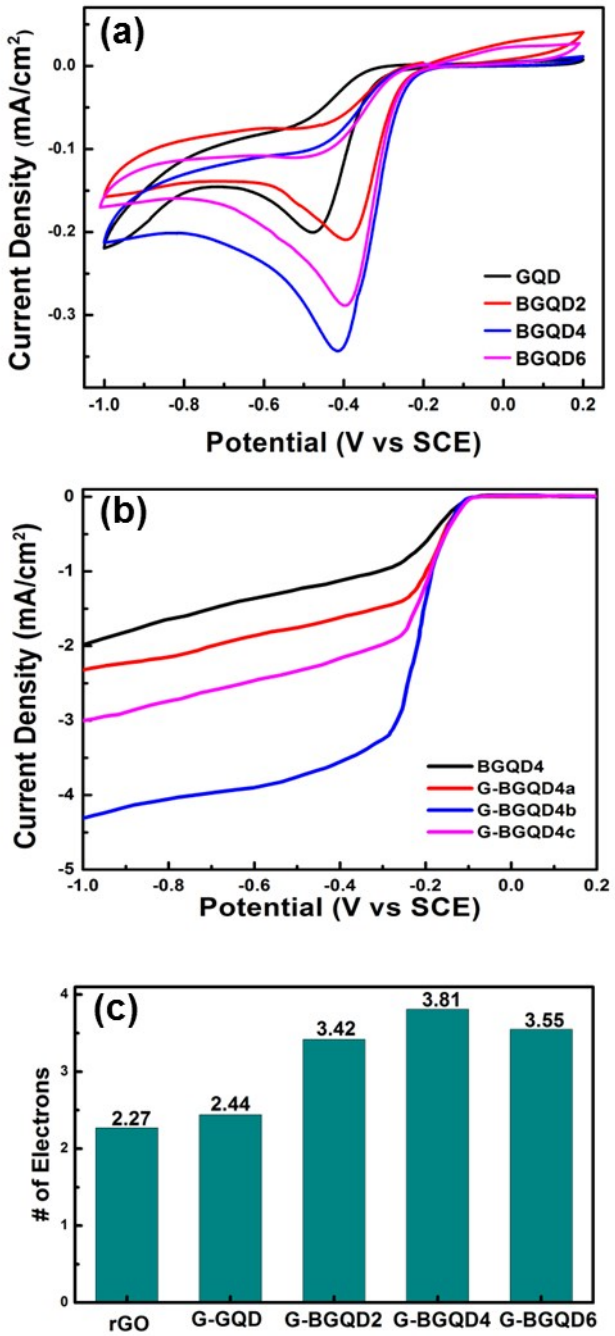


Fig. S3 (a) Cyclic voltammogram of different BGQD at a scan rate of 10 mV s^{-1}. (b) LSV curves of various concentrations of graphene in G-BGQD composites. The 40 mL GO solution of 0.2, 0.5 and 1.0 mg/mL was mixed with the 20 mL BGQD4 solution (0.03 mg/mL) for G-BGQD4a, G-BGQD4b and G-BGQD4c, respectively. (c) The electron transfer number (n) for different G-BGQD composites at -0.8 V.

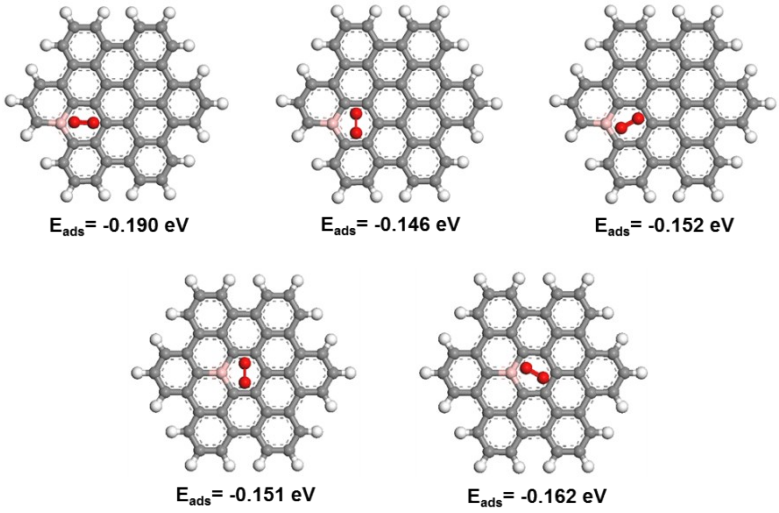


Fig. S4 Different optimized structures of O_2 adsorption on BC_3 bond structure in BGQD.

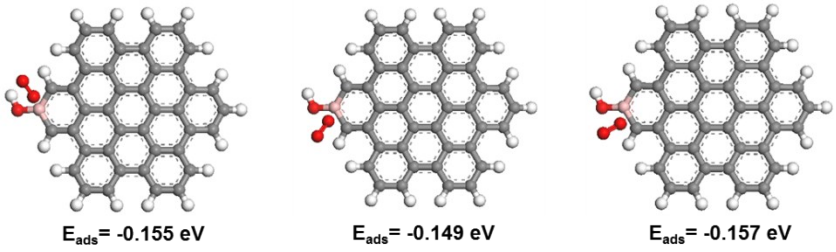


Fig. S5 Different optimized structures of O_2 adsorption on BC_2O bond structure in BGQD.

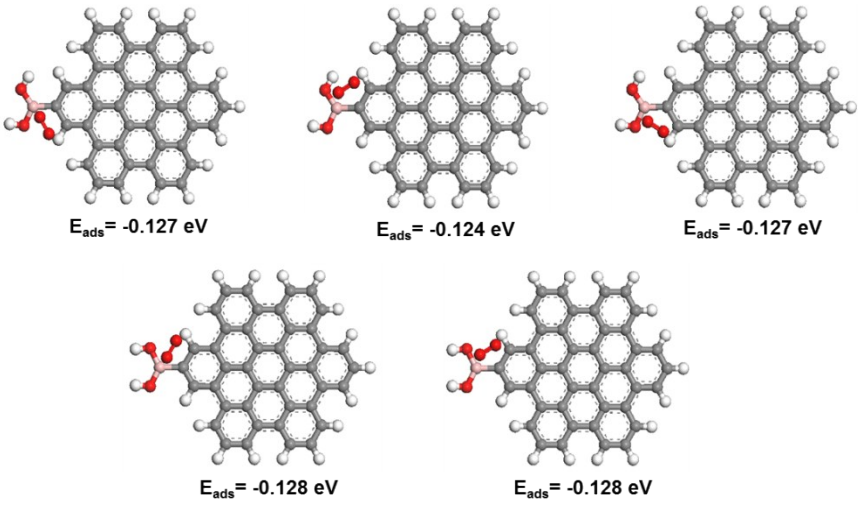


Fig. S6 Different optimized structures of O_2 adsorption on BCO_2 bond structure in BGQD.

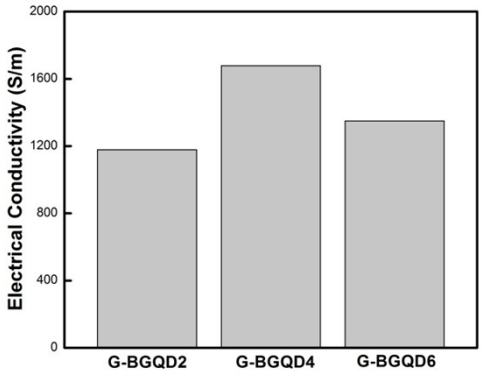
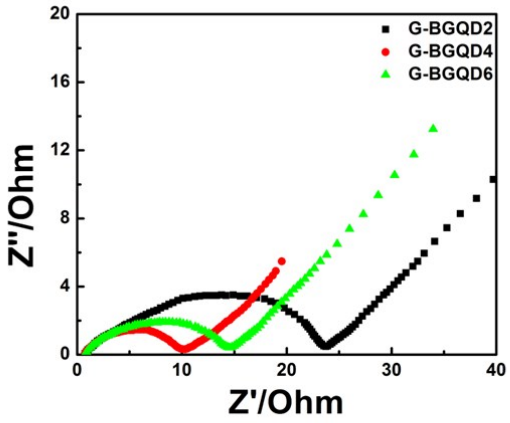


Fig. S7 The electric conductivity of different G-BGQD composites.



Sample	R_s (Ω)	R_{ct} (Ω)	CPE (μF)	Z_w ($Ω^{-1}$)
G-BGQD2	0.996	23.62	13.5	0.135
G-BGQD4	0.758	9.236	15.38	0.0675
G-BGQD6	0.876	14.342	15.08	0.09

Fig. S8 Nyquist plots of different G-BGQD composites and the fitted parameters from the Nyquist plots. The inset (top) is the equivalent circuit used to fit the EIS spectra. In the circuit, the R_s represents the resistance of electrolyte solution, R_{ct} is charge-transfer resistance of catalyst, CPE is a constant phase element and Z_w is the Warburg diffusion impedance.

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Table S1 Summary of the reported ORR performance of doped carbon materials

Catalyst	Synthesis method (precursors)	Doped carbon		Pt/C		Ref
		E_{onset} (V *vs.* Ag/AgCl)	# of electron	E_{onset} (V *vs.* Ag/AgCl)	# of electron	
G-BGQD	Hydrothermal reaction (glucose, boric acid)	-0.005	3.81	-0.035	3.91	***This work***
B-doped carbon	Thermal treatment (tetraphenylboron sodium)	-0.20	3.73	-0.05	-	s1
B-doped graphene	Thermal treatment (graphene oxide, boron oxide)	-0.05	3.7	> -0.05	-	s2
B-doped mesoporous carbon	Thermal treatment (sucrose, 4-hydroxyphenylboronic acid)	-0.16	3.86	-0.07	4	s3
B-N-doped GQDs	Thermal treatment (graphene oxide, boric acid, ammonia)	~0	3.93	~0	4	s4
B-N-doped graphene ribbon	Thermal treatment (graphene oxide, boric acid, ammonia)	0.1	3.89	~-0.5	3.91	s5
B-doped hollow carbon spheres	Hydrothermal, thermal treatment (resorcinol, 4-hydroxyphenylboronic acid)	-0.101	3.7	-0.09	3.9	s6
N-doped GQDs/graphene	Electrochemical reaction (graphene oxide, tetrabutylammonium perchlorate)	-0.16	3.6~4.4	-	-	s7
N-doped carbon nanoparticles/carbon nanofiber	Plasma, thermal treatment (2-cyanopyridine)	-0.14	3.2~3.5	-0.08	3.74~3.95	s8
N-doped carbon nanocages	Thermal treatment (Magnesium carbonate, pyridine)	-0.13	3.27	-0.03	3.92	s9
N-doped graphene	Oxidation, chemical treatment (graphite mesh, 4-aminobenzoic acid)	-0.13	3.2~3.5	-	-	s10

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