

Supporting Information

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Materials Characterization

The morphology of newly prepared materials was studied by field-emission scanning electron microscopy (SEM) on a Carl Zeiss Ultra Plus system. The detailed morphologies of the samples were evaluated by transmission electron microscopy (TEM) on a JEOL JEM-2000 FX instrument operating at 200 kV. Brunauer-Emmett-Teller (BET) method was employed to determine the specific surface areas for obtained carbon materials, and the pore size distribution was calculated by a density functional theory (DFT) method using a slit pore NLDFT equilibrium model on a Quantachrome Autosorb-1 volumetric analyzer. The crystallinity of the samples was characterized by X-ray diffraction (XRD) on a Shimadzu XDe3A spectrometer using filtered Cu-K α radiation ($\lambda = 0.15418\text{nm}$) generated at 40 kV and 30 mA. X-ray photoelectron spectra (XPS) were acquired with a VG Escalab210 spectrometer fitted with a Mg 300 W X-ray source.

Electrochemical measurements

ORR electrochemical performance tests were carried out in a conventional three-electrode cell on a CHI660D electrochemical analyzer (CH Instruments). The working electrode comprised

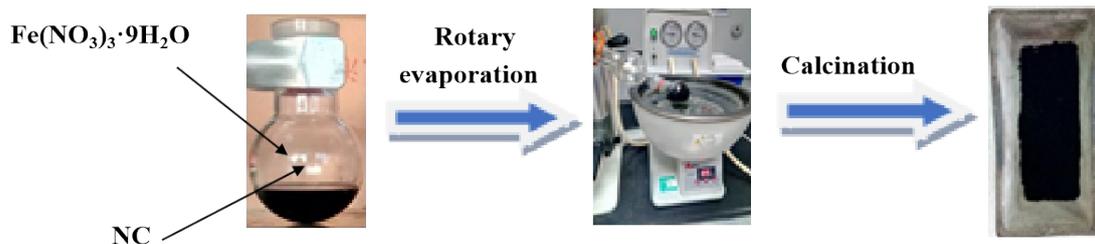
a 5 mm diameter glassy carbon disk onto which a thin-film of active material was prepared as follows: 2 mg of catalyst were dispersed into 0.4 mL Nafion ethanol solution (0.25 wt%) by ultrasonic mixing for 5 min. 8 μ L of ink containing 40 μ g catalyst were dropped onto the surface of a polished glass-carbon rotating disc electrode (catalyst loading: 0.204 mg cm⁻²) and air dried. For performance comparison, commercial Pt/C (20wt% Johnson Matthey) catalysts were used for the preparation of working electrodes according to the same procedure. Ag/AgCl in saturated KCl was chosen as a reference electrode and Pt wire (ORR) as a counter electrode. 0.1 M KOH purged with N₂ for 30 min was used as an electrolyte for all electrochemical tests in this study. All potential values recorded in the study were converted to potentials vs. reversible hydrogen electrode (RHE) using the following equation: $E_{RHE} = E_{Ag/AgCl} + 0.059 pH + 0.197 V$.

For the ORR at a RDE, the electron transfer number (n) and kinetic current density (J_k) were calculated from the Koutecky-Levich equation:

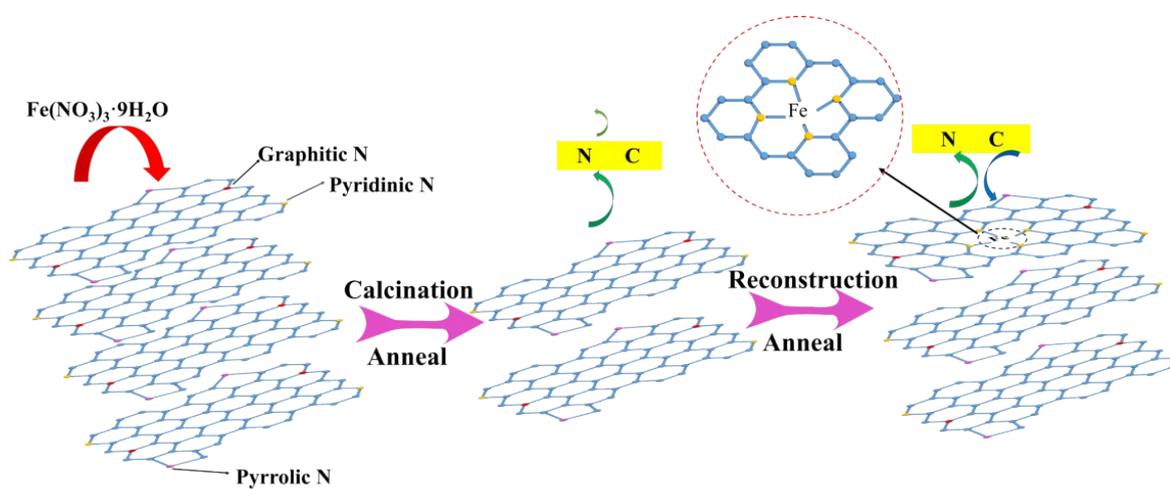
$$j^{-1} = j_k^{-1} + (0.62nFC D^{2/3} \gamma^{1/6} \omega^{1/2})^{-1} \quad (1)$$

$$j_k = nF\kappa C_0 \quad (2)$$

where j is the measured current density, j_k is the kinetic current density, n is the number of electron transfer, F is the Faraday constant ($F = 96485 C mol^{-1}$), C is the bulk concentration of O₂ ($C = 1.2 \times 10^{-3} mol L^{-1}$), D is the diffusion coefficient of O₂ in the 0.1 M KOH solution ($D = 1.9 \times 10^{-5} cm^2 s^{-1}$), γ is the kinetic viscosity of the electrolyte ($\gamma = 0.01 cm^2 s^{-1}$), and ω is the angular velocity of the disk ($\omega = 2\pi N$, N is the linear rotation rate).[1]



Scheme S1. The experimental procedure for preparing FCG-5, FCG-2 and FCF-1.25.



Scheme S2. Schematic illustration of FCG-x formation mechanism.

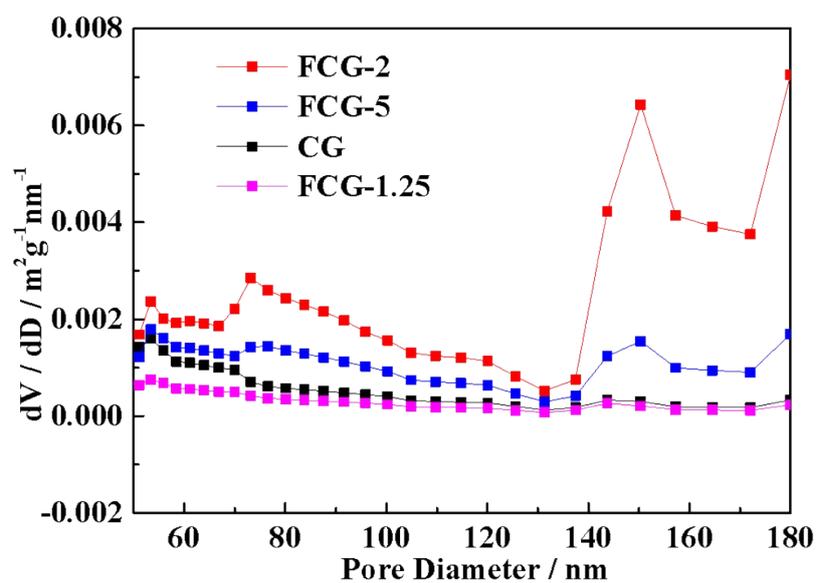


Figure S1. macropore size distributions of FCG-x and CG samples.

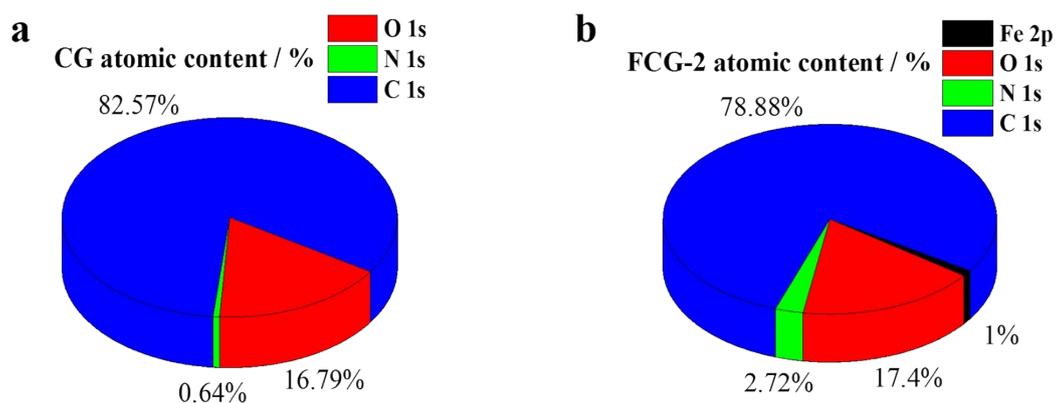


Figure S2. XPS spectra of Fe 2p , O1s , N 1s and C 1s atomic content of CG(a) and FCG-2(b).

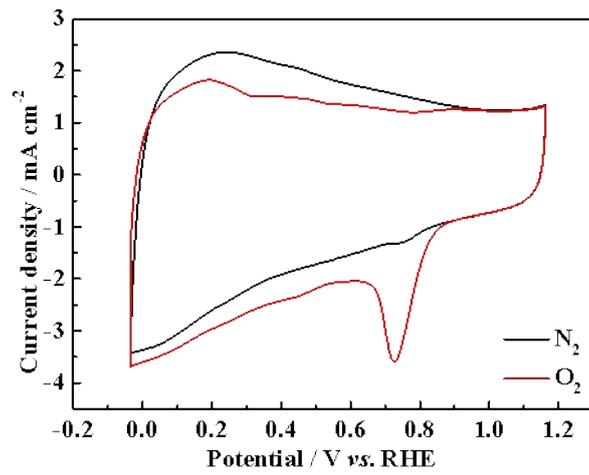


Figure S3. CV curves of FCG-2 modified GC electrodes in 0.1 M KOH solution saturated by N₂/O₂ at a scan rate of 50 mV s⁻¹.

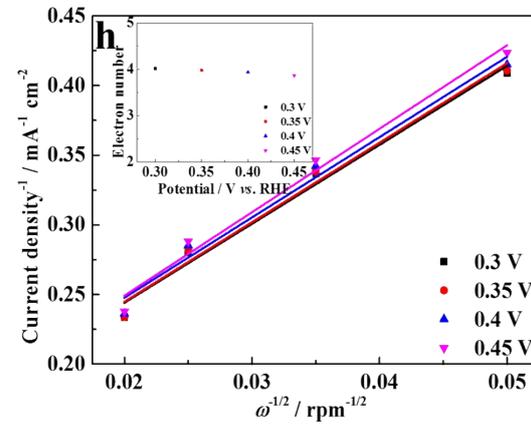
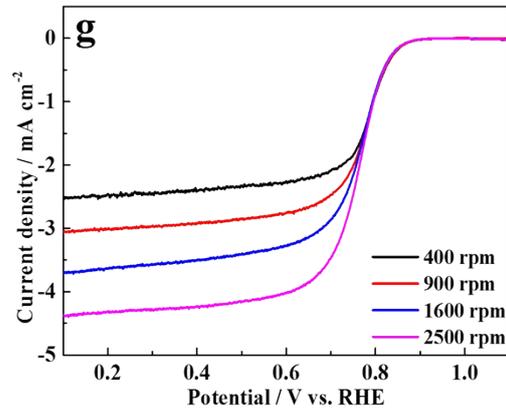
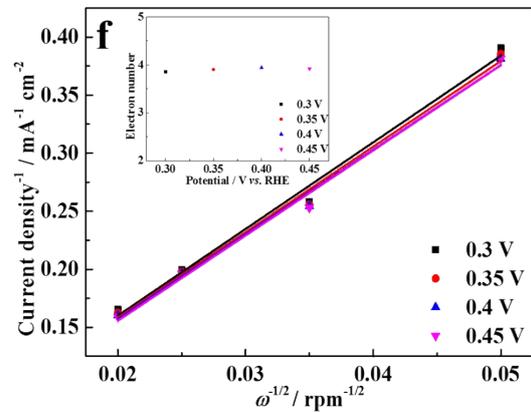
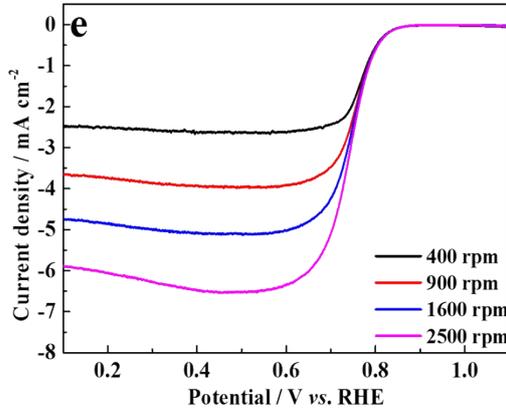
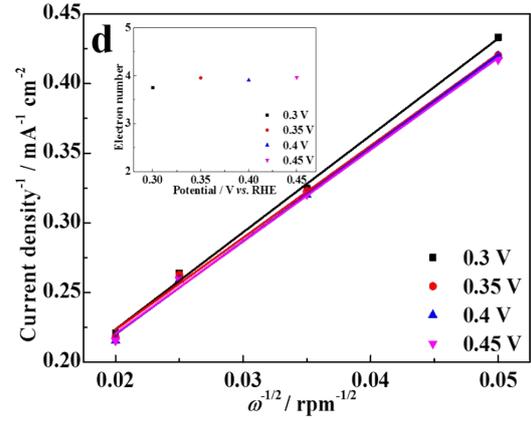
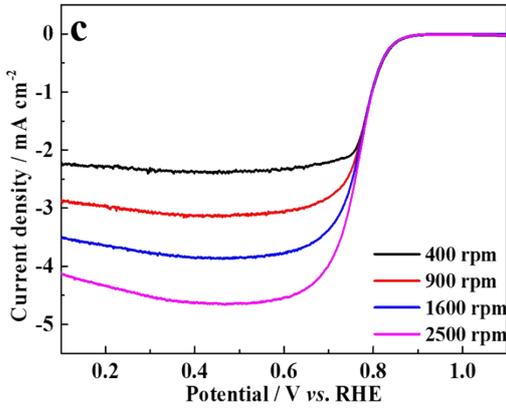
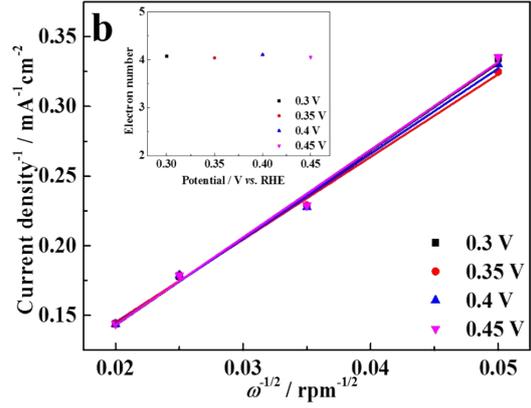
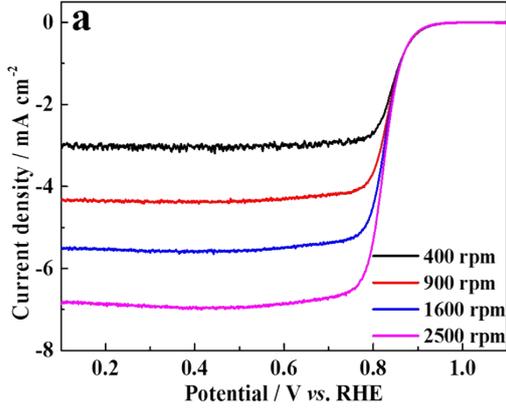


Figure S4. LSV curves of Pt / C (a) CG (c) FCG-5(e) and FCG-1.25(g) on RDE in O₂ saturated KOH solution at various rotation rates; and Kouteckye-Levich plots of Pt / C (b) CG (d) FCG-5(f) and FCG-1.25(h) for ORR.

Table S1. Comparison of the ORR performance of FCG with various catalysts reported in the recent literature.

Catalyst	Electrolyte	E _{onset} (V vs. RHE)	E _{1/2} (V vs. RHE)	Reference
FCG	0.1M KOH	0.923	0.788	This work
Fe ₂ O ₃ /NS-C-600	0.1M KOH	0.84	0.78	Hydrogen Energy, 2019, 44(10), 4707-- 4715
Fe ₂ O ₃ /Ppy/GO	0.1M KOH	0.864	0.724	Electrochimica Acta, 2015, 178, 179-189
Fe ₂ O ₃ @NC-700	0.1M KOH	0.889	0.609	Catalysis Science & Technology, 2019, 9 (17) 4581-4587
Fe/Fe ₂ O ₃ @ Fe-N-C-1000	0.1M KOH	0.92	0.812	Nano Research, 2016, 9, 2123–2137.
Fe ₂ O ₃ /N-PCs-850	0.1M KOH	0.936	0.776	Catalysts, 2018, 8(3)

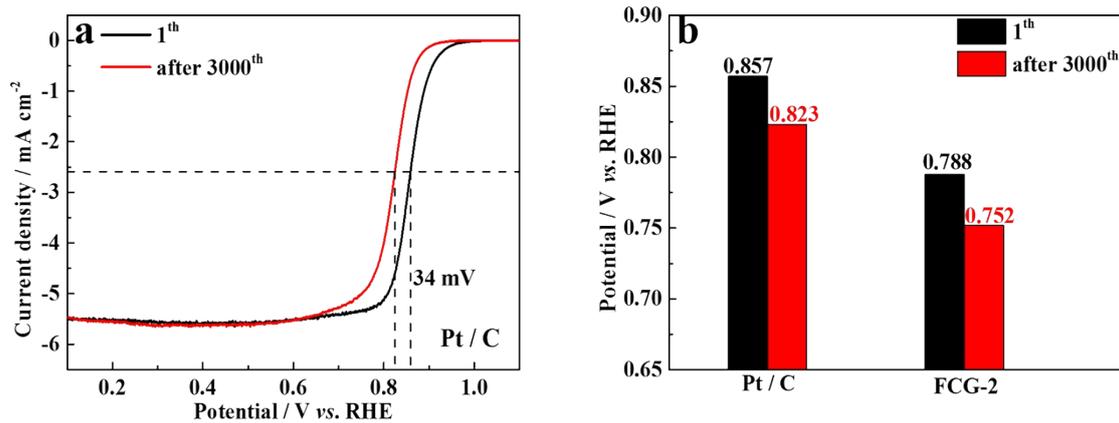


Figure S5. ORR LSV curves of the initial and after 3000th cycles on Pt/C electrode (a), and the corresponding half-wave potentials of Pt/C electrode and FCG-2 electrode (b).

[1] Z. Mo, R. Zheng, H. Peng, H. Liang, S. Liao, Nitrogen-doped graphene prepared by a transfer doping approach for the oxygen reduction reaction application, *J. Power Sources*, 245 (2014) 801-807.