# Design of Bimetallic PtFe-Based Reduced Graphene Oxide as Efficient Catalyst for Oxidation Reduction Reaction

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**Supporting information:**

**Experimental Section**

***Synthesis of Materials***

***Synthesis of graphene oxide (GO).*** For the synthesis of GO we used modified Hummers method [11]. Previous reports were used to adjust the detailed technique for GO production [12]. Pomegranate peel aqueous extract (PPAE) was employed in the GO production procedure for neutralization [12,13]. After centrifugation, the brown GO solid was dried at 50 °C overnight and used for further study.

***Synthesis of PtFe/RGO and Pt/RGO***

The polyol technique was used to make PtFe/RGO nanoparticles by reducing Pt4+, Fe3+, and the GO mixture at the same time. For ORR activity comparison, chemically reduced graphene oxide-supported platinum nanoparticles (Pt/RGO) were also made. In a round bottomed flask, 80 mg of GO was suspended in ethylene glycol for 30 minutes before being ultrasonicated. Later, under continuous ultrasonication, 40 mg $H_2PtCl_6.6H_2O$ and 64 mg $Fe(NO_3)_3.9H_2O$ were added to this suspension, and the pH was adjusted to 11. On reduced graphene oxide, the weight of metal precursor was determined to yield 10% Pt + 10% Fe (RGO). 2 mg sodium borohydride was added to this mixture, and the complete reaction mixture was refluxed at 150 °C for 3 hours to allow simultaneous reduction of Pt4+ and Fe3+ ions, as well as GO, to create Pt nanoparticles on reduced graphene oxide (PtFe/RGO). The reaction mixture was allowed to cool to room temperature before being rinsed with distilled water numerous times until it reached a pH of neutral. Water/methanol combination (50:50 v/v) was used to wash the PtFe/RGO product produced. The obtained product was dried hot air oven at 60ºC overnight. Similar procedure was utilized for the fabrication of Pt/RGO and Fe/RGO as described for PtFe/RGO nanoparticles.

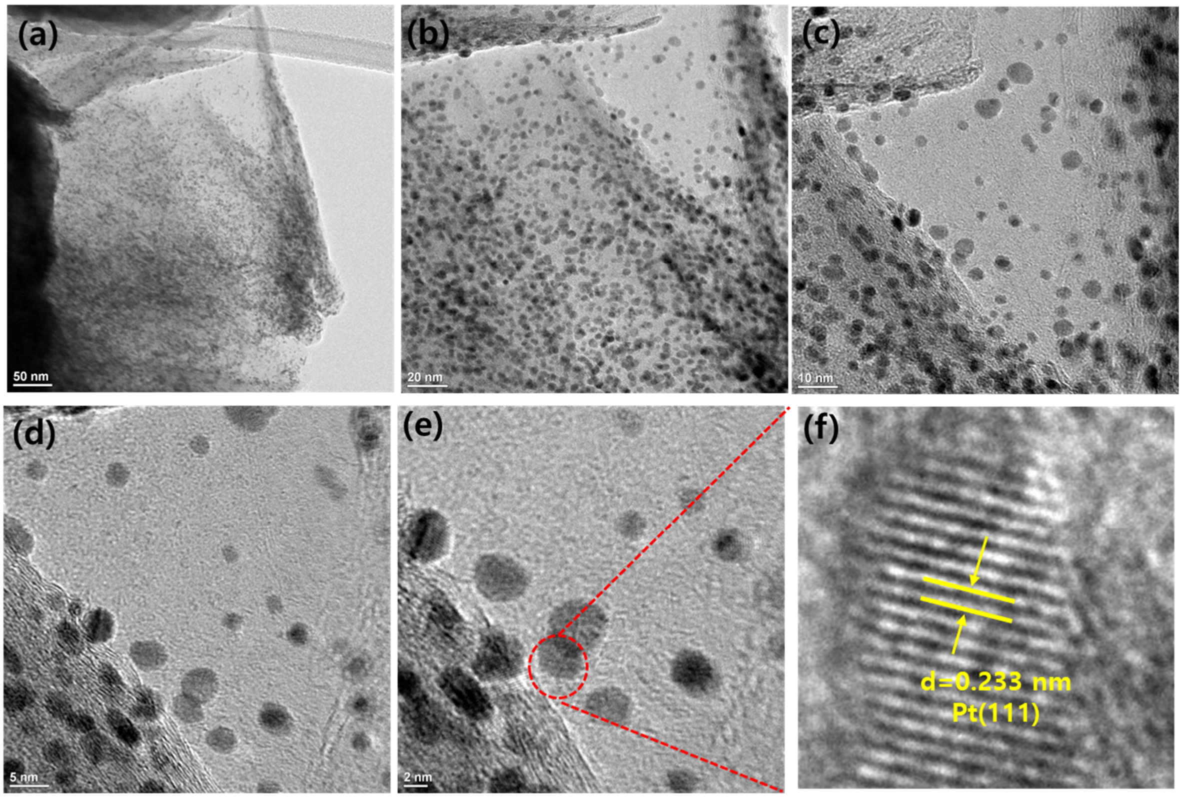


**Figure S1.** Transmiossion electron microscopy TEM and high-resolution transmission electron microscopy (HRTEM) images of Pt/RGO metal nanoparticles.

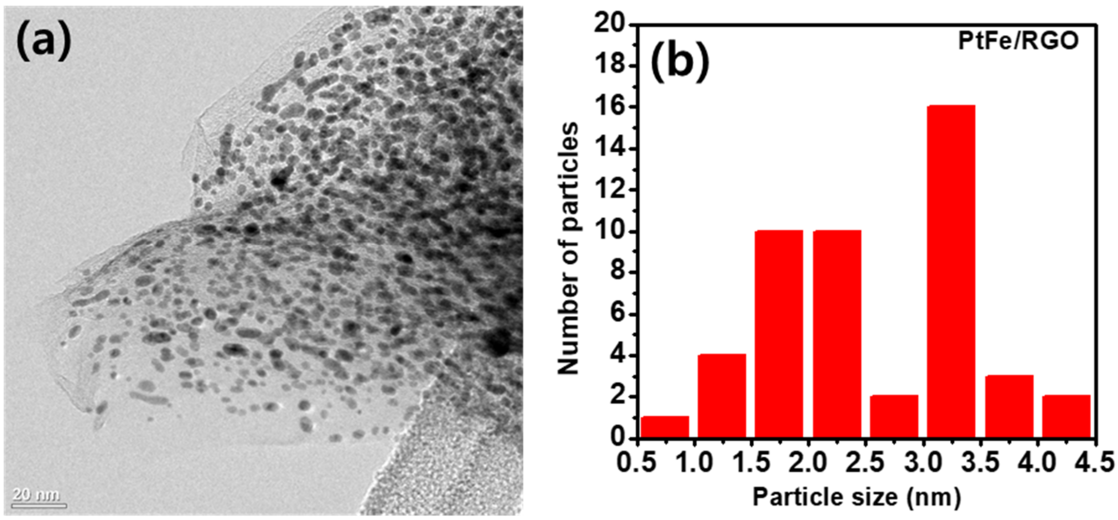


**Figure S2.** TEM images of PtFe/RGO and size distribution of PtFe/RGO catalyst.

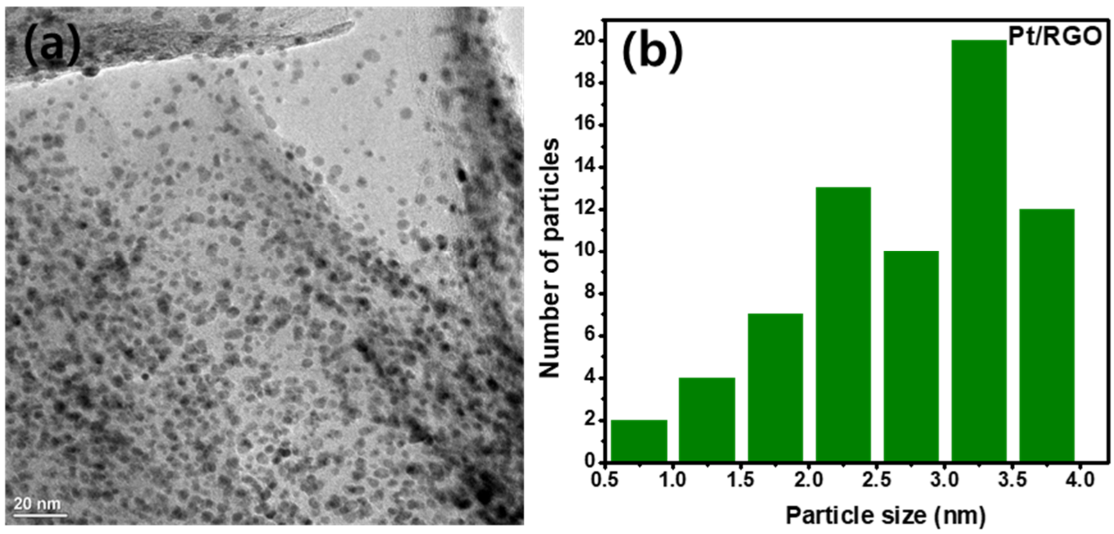


**Figure S3.** TEM images of Pt/RGO and size distribution of Pt/RGO catalyst.

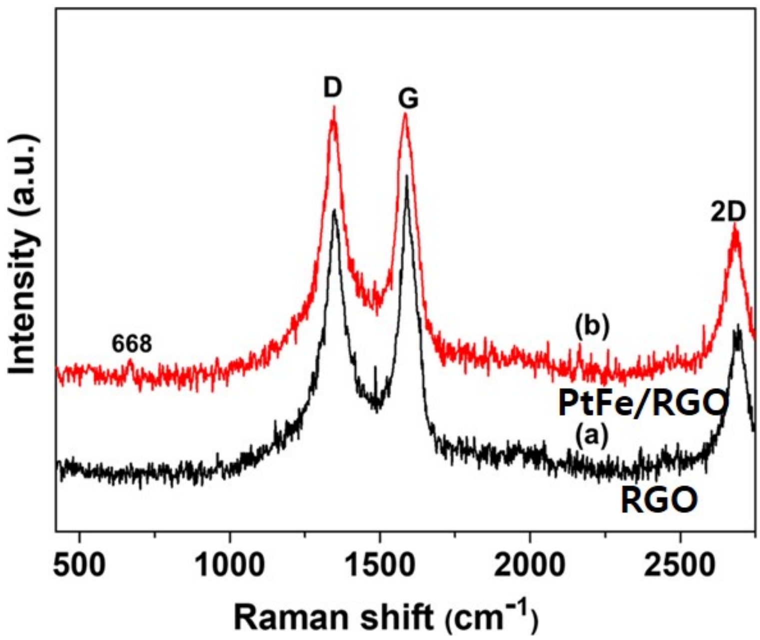


**Figure S4.** (a, b) Raman spectra of RGO, and PtFe/RGO composite.

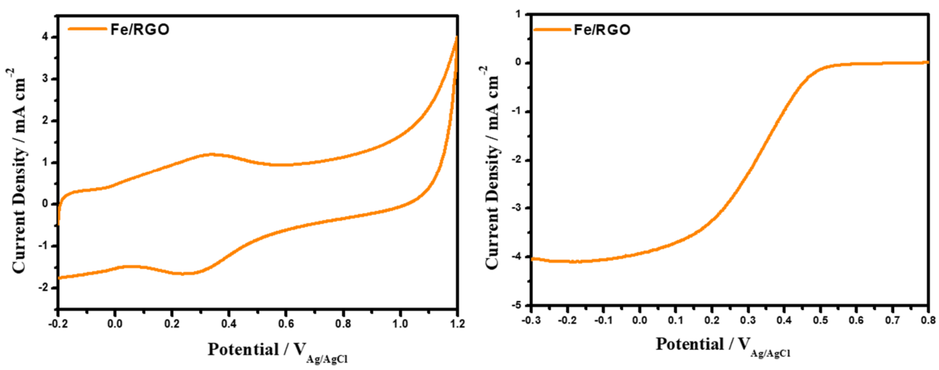


**Figure S5.** Cyclic voltammetry (CV) and oxygen reduction reaction (ORR) polarization curves of Fe/RGO.

| **Catalyst** | **Electrolyte** | **ECSA ($m^2/g$)** | **$E_{1/2}$ (V vs Ag/AgCl)** | **Mass activity J ($mA/cm^2$)** | **Reference** |
|---|---|---|---|---|---|
| PtFe/RGO | 0.5M $H_2SO_4$ | 39.89 | 0.503 | 4.85 | This work |
| Pt/RGO | 0.5M $H_2SO_4$ | 33.52 | 0.336 | 4.76 | This work |
| Fe/RGO | 0.5M $H_2SO_4$ | 15.1 | 0.352 | 4.08 | This work |
| $Pt_{30}Fe_{70}$/OMC | 0.5M $H_2SO_4$ | -- | 0.42 | 3.7 | 42 |
| Pt-Ni/graphene | 0.5M $H_2SO_4$ | 32.0 | 0.5 | -- | 43 |

Table S1. ORR activity comparison table of Pt and Fe based ORR catalysts.