Supplementary Information

The synergetic effect of N-doped graphene and silver nanowires for high electrocatalytic performance in oxygen reduction reaction

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Experimental details

Preparation of NG/SNWs composites

SNWs were synthesized by a two-step injection method.1 Collected by centrifugation and rinsed by ethanol and deionized water for several times, then SNWs were redispersed in ethanol solution at a concentration of 50 mg/mL. Graphene oxide (GO) was prepared from natural graphite flakes by using a modified Hummers’ method.2 To the preparation of NG/SNWs composites, 60 µl of SNWs solution (50 mg/ml in ethanol) was placed into 24 ml of GO (0.33 mg/ml) ethanol solution, and then ultrasonicated for more than 3 h to achieve an uniform dispersion, followed by the addition of 0.5 ml of ammonium hydroxide solution (NH₄OH, 25-28 wt%) and 1.9 ml of deionized water. The mixture was finally transferred to a 40 ml autoclave at 150 °C for 4 h. The pure NG and reduced graphene/Ag nanowires (r-G/SNWs) composites
were prepared through the same steps only without SNWs and NH$_4$OH, respectively, and the reduced graphene (r-G) was followed the synthesis of NG without the addition of NH$_4$OH. The final product was collected by freeze-drying after washing with ethanol and deionized water.

**Apparatus and Characterization**

Electrochemistry measurements were characterized by cyclic voltammetry (CV) and linear sweep voltammetry (LSV) in 1 M KOH solution by using an Autolab 2 instrument. The KCl saturated Ag/AgCl was used as reference electrode, and graphite rod was used as counter electrode. 2 mg of catalyst, 10 mg of Nafion solution (5%) and 1 ml of 25% ethanol aqueous solution was mixed and ultrasonicated for 1 h. The resulting mixture was dispersed and yielded 0.2 mg/cm$^2$ of catalyst onto 1 cm$^2$ of carbon paper (TGPH-030, Toray). The scan rate was set at 20 mV/s. 1 M KOH solution was saturated with O$_2$ or N$_2$ by bubbling O$_2$ or N$_2$ gas, and the gas bubbling was kept through the test in order to ensure O$_2$ or N$_2$ saturation in electrolyte solution. The microstructure of catalysts was investigated by using a scanning electron microscope (SEM, JEOL JSM-7100F) and a transmission electron microscope (TEM, JEM-2100) operated at 200 KV. X-ray photoelectron spectroscopy (XPS) analyses were carried out on a Thermo Fisher X-ray photoelectron spectrometer system (ESCALAB250). The phase structure was examined by X-ray diffraction (XRD) using a BRUKER D8 Advance X-ray diffractometer with Cu K$\alpha$ radiation. Raman spectra were obtained with an excitation line at 512 nm from an Ar laser (Renishaw Invia). The samples were analyzed by the nitrogen sorption technique using a Micromeritics ASAP 2020 instrument at 77 K, and their surface area was calculated by using the Brunauer-Emmett-Teller (BET) method in the relative pressure ($P/P_\circ$) range of 0.002-0.3.

**Reference:**

Figure S1 The high-magnification SEM images of N-doped graphene/silver nanowires composite (a) silver nanowires embedded in N-doped graphene (b) silver nanowires stretched out from the edges of N-doped graphene sheets indicated by the circles.

Figure S2 High resolution XPS spectra of Ag 3d peak of N-doped graphene/silver nanowires composite.
Figure S3 Raman spectra for reduced graphene (r-G), N-doped graphene (NG) and N-doped graphene/silver nanowires (NG/SNWs) composite.

Figure S4 CVs of silver nanowires (SNWs), N-doped graphene (NG) and N-doped graphene/silver nanowires (NG/SNWs) in 1 M KOH solution by O₂ bubbling (black line) or N₂ bubbling (violet line).