Supplementary Information

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

Dongbo Yu,[a,b] Jianfeng Yao,[a] Ling Qiu,[c] Yuzhou Wu,[a] Lunxi Li,[a] Yi Feng,[*b] Qi Liu,[a] Dan Li,[c] and Huanting Wang [*a]

[a] Department of Chemical Engineering, Monash University, Clayton, Victoria 3800, Australia

[b] School of Materials Science and Engineering, Hefei University of Technology, Hefei, Anhui 230009, People's Republic of China

[c] Department of Materials Engineering, Monash University, Clayton, Victoria 3800, Australia

E-mail addresses: huanting.wang@ monash.edu (H. Wang); fy123@mail.hf.ah.cn (Y. Feng)

Tel: +61 3 9905 3449; Fax: +61 3 9905 5686

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 (NH$_4$OH, 25-28 wt%) and 1.9 ml of deionized water. The mixture was finally transferred to a 40 ml autoclave at 150 ^{o}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_4OH, respectively, and the reduced graphene (r-G) was followed the synthesis of NG without the addition of NH_4OH. 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 Kα 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_o) range of 0.002-0.3.

Reference:

1   M.J. Hu, J.F. Gao, Y.C. Dong, K. Li, G.C. Shan, S.L. Yang and R.K.Y. Li, *Langmuir*, 2012, **28**, 7101.

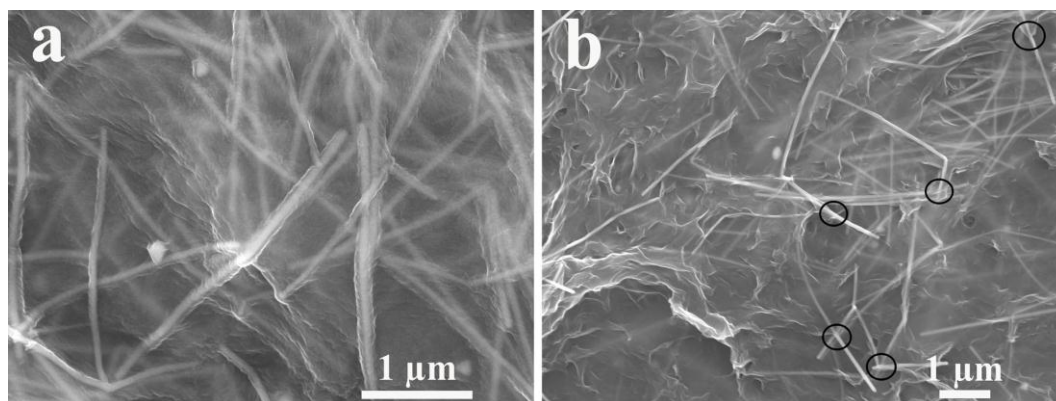2   D. Li, M.B. Muller, S. Gilje, R.B. Kaner and G.G. Wallace, *Nat. Nanotechnol.*, 2008, **3**, 101.

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.
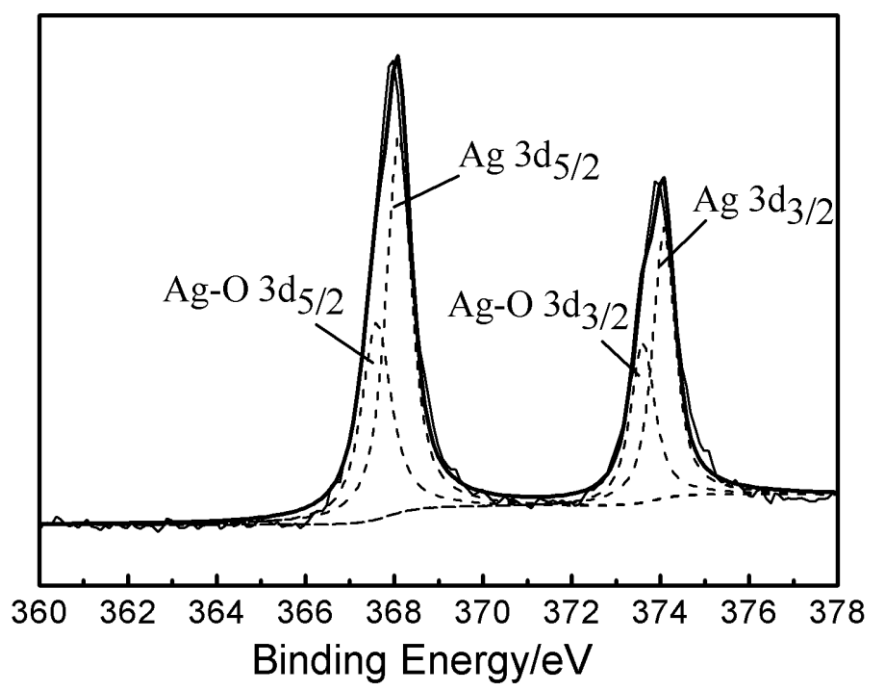

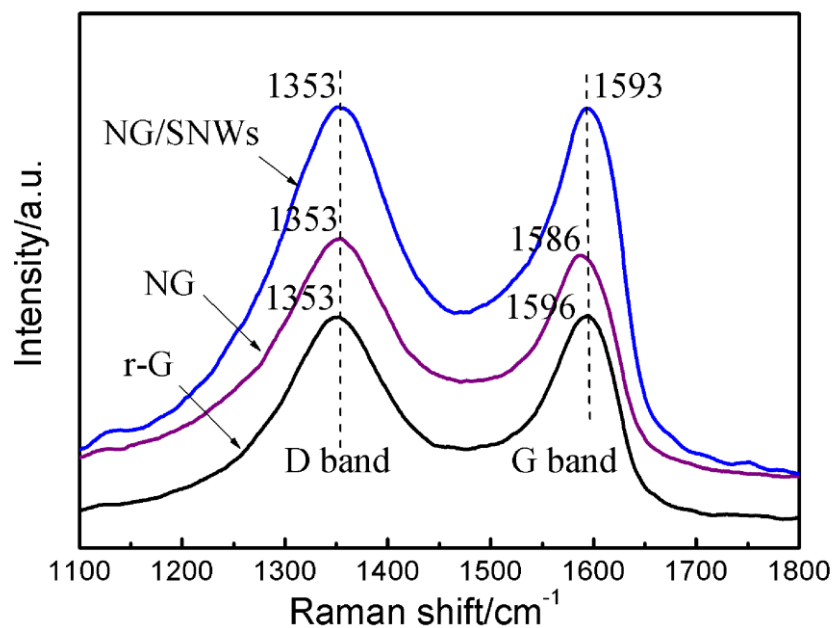**Figure S2** High resolution XPS spectra of Ag 3d peak of N-doped graphene/silver nanowires composite.

Figure S3 Raman spectra for reduced graphene (r-G), N-doped graphene (NG) and N-doped graphene/silver nanowires (NG/SNWs) composite.
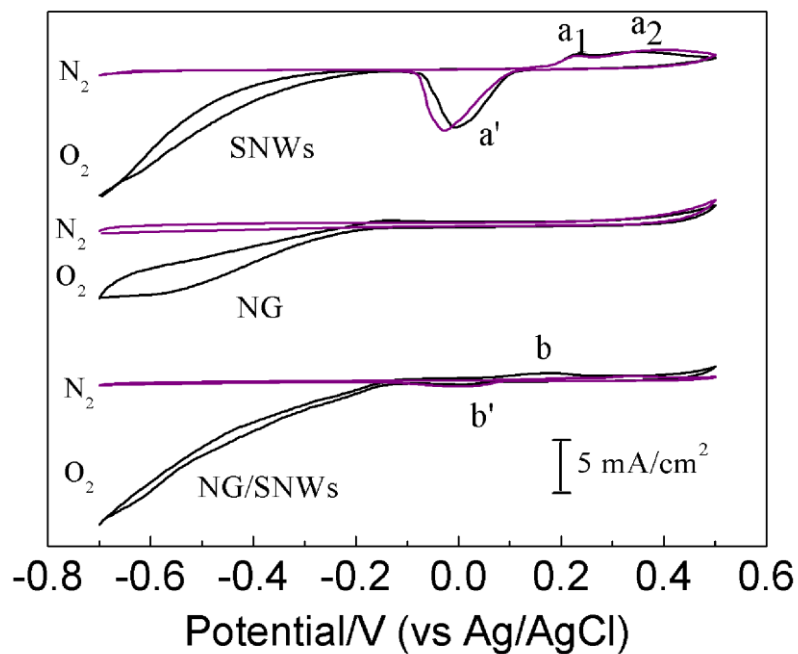

Figure S4 CVs of silver nanowires (SNWs), N-doped graphene (NG) and N-doped graphene/silver nanowires (NG/SNWs) in 1 M KOH solution by O_2 bubbling (black line) or N_2 bubbling (violet line).