Electronic Supplementary Material (ESI) for New Journal of Chemistry.

Supporting Information

Carbon nanotubes/S-N-C hybrid nanomaterials as a bifunctional electrocatalyst for oxygen reduction and evolution reactions

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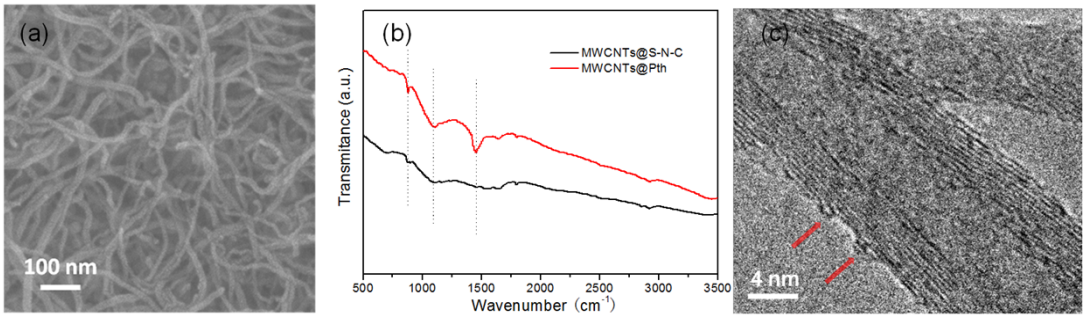

Fig. S1 (a) SEM image of MWCNTs. (b) FTIR spectra of the MWCNTs@S-N-C and MWCNTs@Pth precursor. (c) HRTEM image of MWCNTs@S-N-C.

The number of electrons transferred (n) during ORR was calculated by Koutecky-Levich equation at various electrode potentials and is given below:[1,2]

$$\frac{1}{J} = \frac{1}{J_L} + \frac{1}{J_K} = \frac{1}{B\omega^{1/2}} + \frac{1}{J_K}$$

$$B = 0.62nFC_0D_0^{2/3}\nu^{-1/6}$$

where J_k is the kinetics current density, J is the measured ORR current density, n represents the number of electrons transferred per oxygen molecule, F is the Faraday constant (F= 96485 C mol^{-1}), C_0 is the bulk concentration of O_2 (=1.2 × 10^{-6} mol cm^{-3}), D_0 is the diffusion coefficient of O_2 in the KOH electrolyte (=1.9 × 10^{-5} cm^2 s^{-1}), ν is the kinetic viscosity of the electrolyte (=0.01 cm^2 s^{-1}), and ω is the angular velocity of the disk (ω=2πN , N is the linear rotation speed).

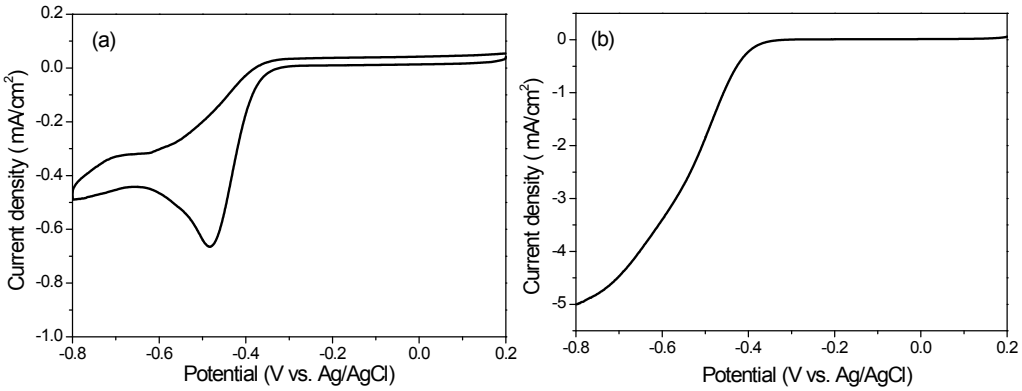

Fig. S2 (a) Cyclic voltammograms of MWCNTs@S-C catalyst and (b) RDE voltammograms of the MWCNTs@S-C catalysts at 1600 rpm in 0.1 M KOH saturated with O_2 gas.

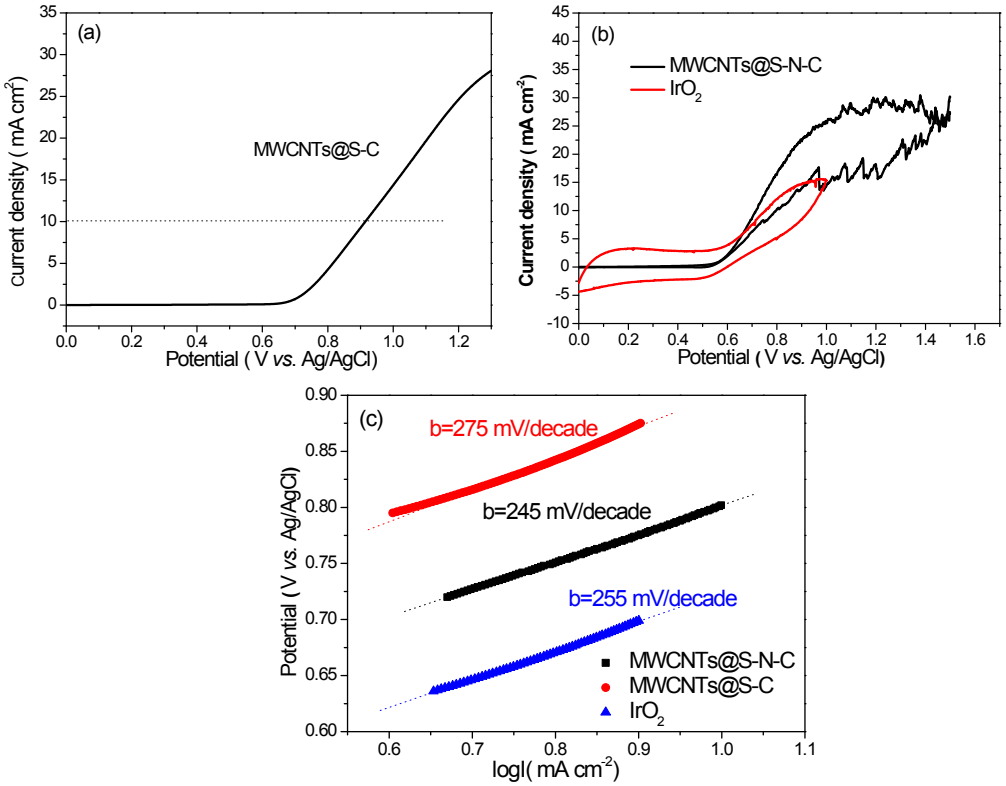

Fig. S3 (a) linear sweep voltammograms of MWCNTs@S-C catalyst; (b) Oxygen evolution CV curves of MWCNTs@S-N-C and IrO_2 measured in a 0.1 M KOH with a sweep rate of 10 mV s^{-1} and (c) Tafel plots of the IrO_2, MWCNTs@S-C and MWCNTs@S-N-C hybrids derived by the mass-transport correction of corresponding RDE data.

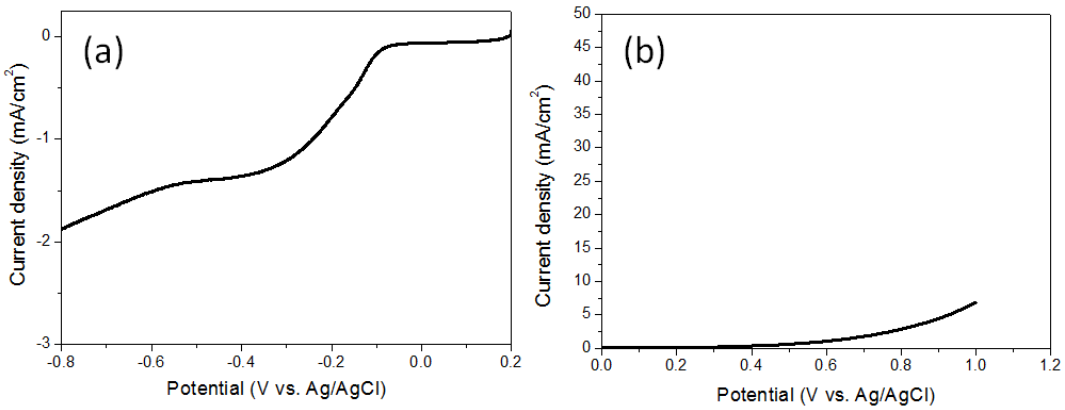

Fig. S4 (a) linear sweep voltammograms of the MWCNTs catalysts at 1600 rpm in 0.1 M KOH saturated with O_2 gas. (b) Oxygen evolution curves of MWCNTs in a 0.1 M KOH with a sweep rate of 10 mV s^{-1}.

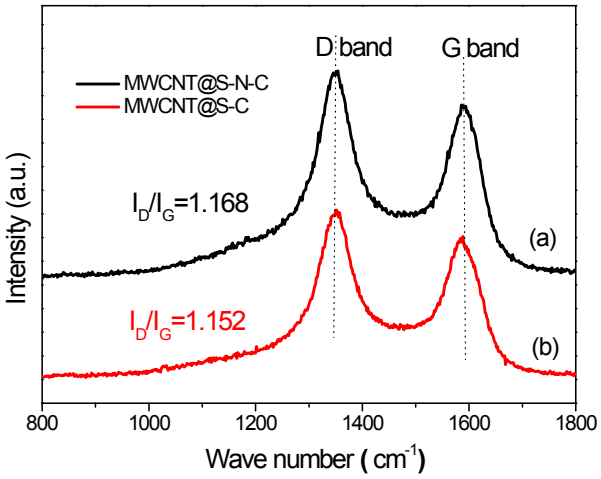

Fig. S5 Comparison of the Raman spectra: (a) MWCNTs@S-N-C and (b) MWCNTs@S- C.

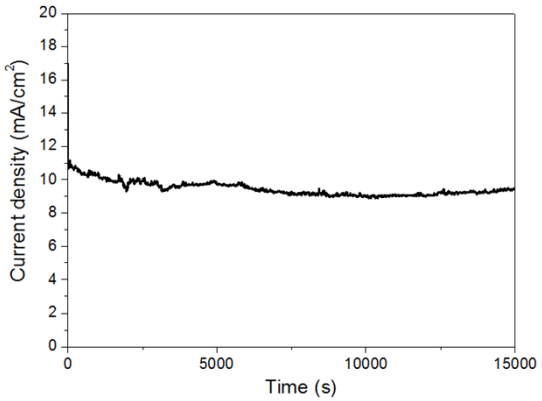

Fig. S6 Chronopotentiometric response at a constant current density of 10.0 mA cm^{-2} of MWCNTs@S-N-C at 1600 rpm in 0.1 M KOH (E = 0.7 V vs. Ag/AgCl).

References:

(1) S. Y. Wang, D. S. Yu, L. M. Dai, D. W. Chang and J. B. Baek, Polyelectrolyte-Functionalized Graphene as Metal-Free Electrocatalysts for Oxygen Reduction. *ACS Nano*, 2011, **5**, 6202−6209.

(2) S. B. Yang, X. L. Feng, X. C. Wang and K. Mullen, Graphene-Based Carbon Nitride Nanosheets as Efficient Metal-Free Electrocatalysts for Oxygen Reduction Reactions. *Angew. Chem. Int. Ed.*, 2011, **50**, 5339−5343.