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Solar exfoliated graphene-carbon nanotube hybrid nano composite as efficient catalyst support for proton exchange membrane fuel cells

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4. Steady state performance evaluation of Pt/sG-*f* MWNT catalyst recorded at a potential of 0.5 V.

1. XRD spectra

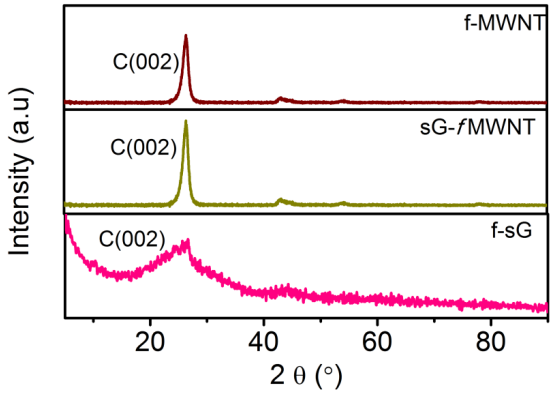

Fig.S1 X-ray diffractograms of f-sG, f-MWNT and sG-*f* MWNT hybrid nanocomposite.

The XRD of f-sG shows a weak and broad peak C (002) around 25º, confirming the formation of graphene (Figure S1). A sharper and narrower carbon C (002) diffraction peak appears for f-MWNT, which indicates a highly graphitic ordered structure of f-MWNT. The spectra of sG-*f* MWNT composite exhibit a sharp peak at 26º similar to that of f-MWNT.

2. FTIR spectra

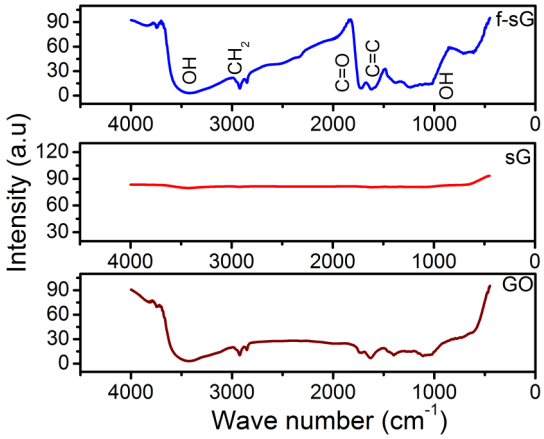

Fig. S2 FTIR spectra of GO, sG and f-sG.

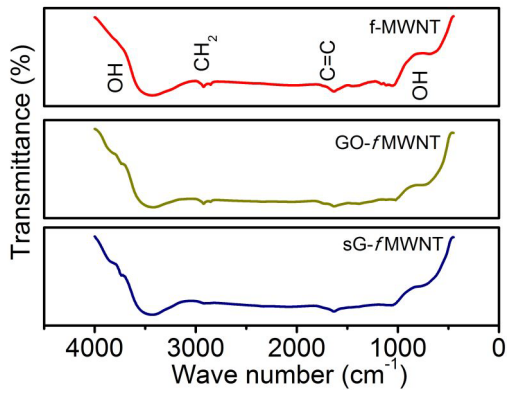

Fig.S3 FTIR spectra of f-MWNT, GO-*f* MWNT and sG-*f* MWNT.

The FTIR spectra of GO identifies the presence of –OH (3535 cm^{-1}), asymmetric and symmetric CH_2 (~2925 and 2852 cm^{-1}), C=O (~1736 cm^{-1}), C=C (~2371 cm^{-1}) and OH (~1073 cm^{-1}). FTIR spectrum of solar graphene validates the efficient exfoliation of GO, with its lack of any oxygen containing functional groups. Refluxing in conc.HNO_3 introduces functional groups over the surface of sG as is evident from its FTIR spectrum (Figure S2). The systematic analysis of the presence of functional groups over the hybrid nano composite has been demonstrated in Figure S3. It is observed that after the exfoliation of GO-*f* MWNT composite, the resultant hybrid nano composite sG-*f* MWNT still retain some of the functional groups present in *f* MWNT and in GO. The existence of these functional groups may helps in anchoring the Pt nano particles towards the nano composite during reduction.

Raman finger prints of carbon nano materials

Sample	I_D/I_G	La
f-sG	0.44	10
sG-*f*MWNT	0.50	8.8

Table S1: In plane crystallite sizes of f-sG and sG-*f* MWNT composite.

Stability analysis of Pt/sG-f MWNT fuel cell

One of the main obstacles to the commercialization of PEM fuel cells is the high cost and poor durability of electrocatalytic materials [1]. Also, deterioration of the electrocatalysts is one of the main reasons for the long-term decline in fuel cell performance [2]. Therefore long-term stability check of the fuel cell stack is a very important factor to be measured. Hence, in the present work, we have analyzed the stability of Pt/sG-*f* MWNT by recording the power density of the fuel cell stack containing Pt/f-MWNT as anode catalyst and Pt/sG-*f* MWNT as cathode catalyst, at 0.5 V for a period of nearly 24 h. The stable power density value is an indication of the excellent stability of the present low cost sG-*f* MWNT catalyst support.

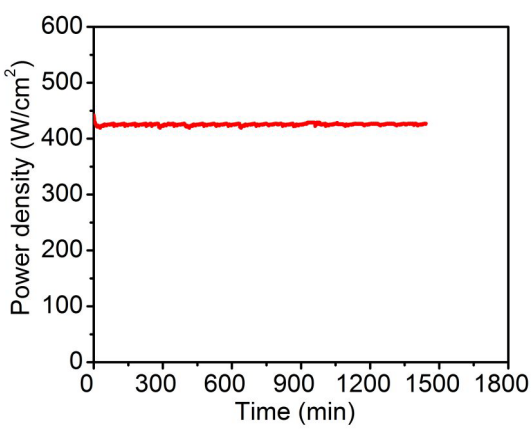

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Fig.S5 Steady state performance evaluation of Pt/sG-*f* MWNT catalyst recorded at a potential of 0.5 V.

References

1. Y. Shao, S. Zhang, C. Wang, Z. Nie, J. Liu, Y. Wang, Y. Lin, J. Power Sources 195 (2010) 4600.
2. J. Xie, D. L. Wood, K. L. More, P. Atanassov, R. L. Borup, J. Electrochem. Soc., 152, (2005) A1011.