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

Polypyrrole with functionalized multi wall carbon nanotubes hybrid nanocomposite: A new and efficient nitrite sensor

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Dispersibility of f-MWCNTs in water

Moreover, we found that the f-MWCNTs could be dispersed in the polar solvent like water more easily than as prepared raw MWCNTs. The dispersion of f-MWCNTs 0.1 mg/ml in water using probe type sonicator (SONICS® VCX750, supplied by Sonics & Materials, Inc.) are given in Fig. S1.

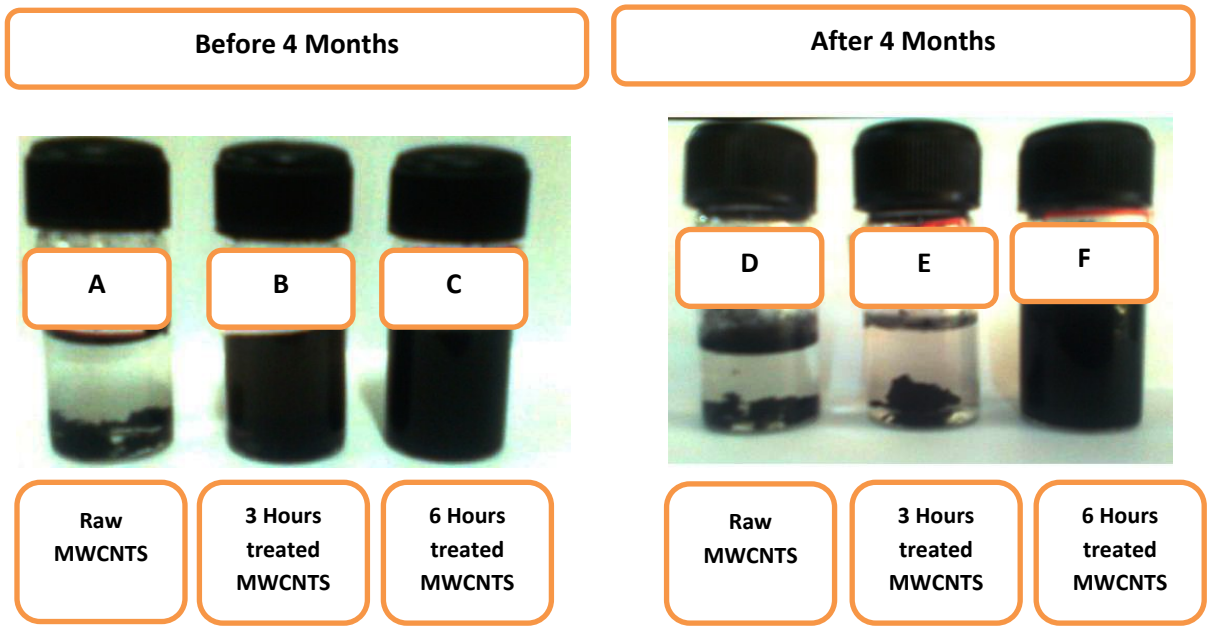

Fig. S1. Photographical images of raw MWCNTs and f-MWCNTs dispersed in water were taken immediately after dispersion (A, B, C)**.** Photographical images of raw MWCNTs and f-MWCNTs dispersed in water taken after 4 months of dispersion (D, E, F).

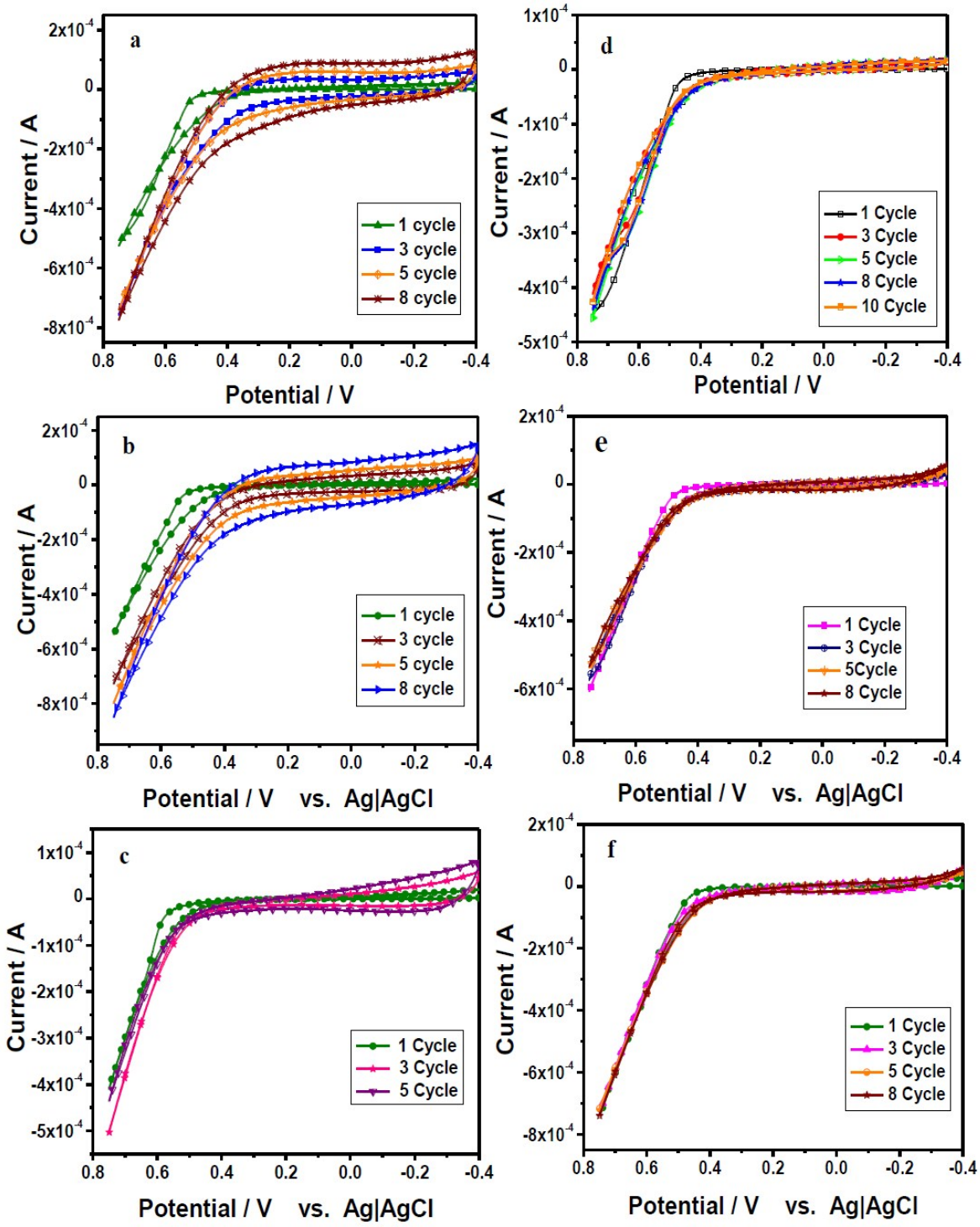

Fig. S2. Cyclic voltammograms recorded during the electrochemical polymerization of Pyrrole in the solution containing 0.1 M pyrrole and 0.05 M $LiClO_4$ for 1, 3, 5 and 8 cycles with different concentrations of SDS such as 0.01 M **(a),** 0.02 M **(b)** and 0.03 M **(c)** in the presence of 0.1 % f-

MWCNTs and different concentrations of SDS 0.01 M **(d)**, 0.02 M **(e)** and 0.03 M **(f)** in the absence of f-MWCNTs with: Scan rate 50 mV/s) [final polymerisation cycle only given].

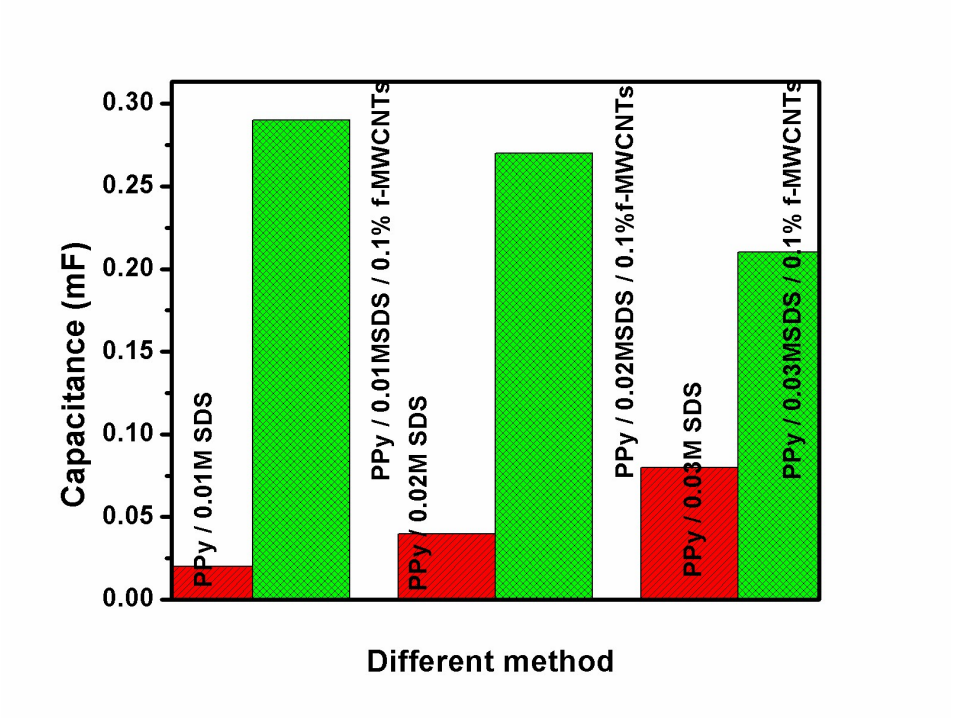

Fig. S3. Bar diagram of capacitance values calculated for PPy/SDS/f-MWCNTs and PPy/SDS composites obtained electrochemical polymerisation in solution containing 0.1 M Pyrrole + 0.05 M $LiClO_4$ + 0.1 % f-MWCNTs in the presence of different concentrations of SDS at 3 cycles of polymerization: 0.01 M SDS, 0.02 M SDS and 0.03 M SDS.

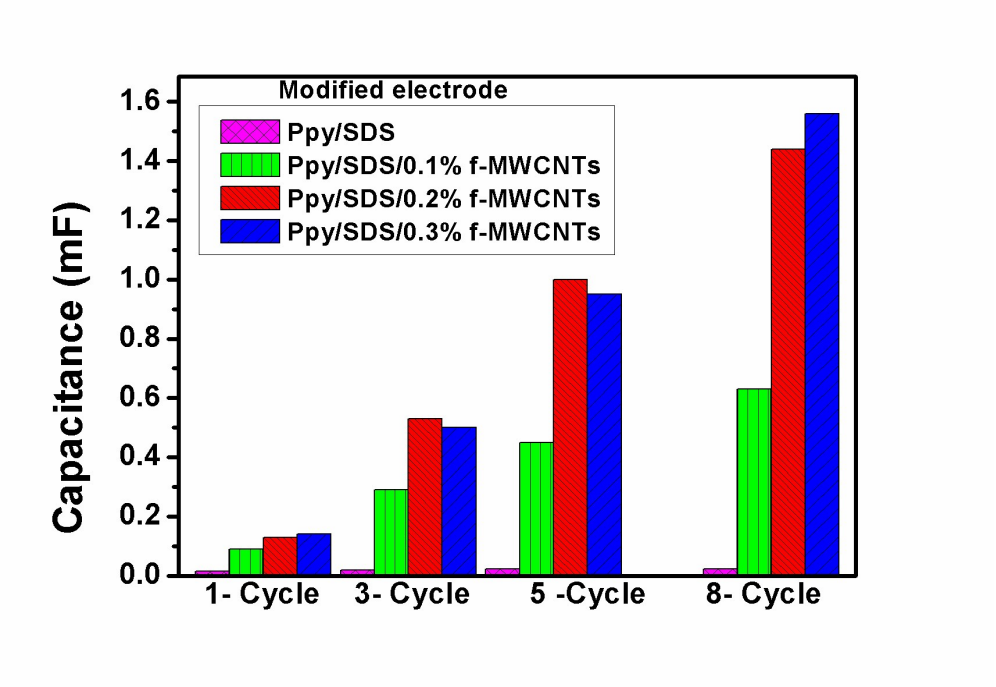

Fig. S4. Bar diagram of capacitance values calculated for PPy/SDS, PPy/SDS/0.1% f-MWCNTs, PPy/SDS/0.2% f-MWCNTs and PPy/SDS/0.3% f-MWCNTs films.

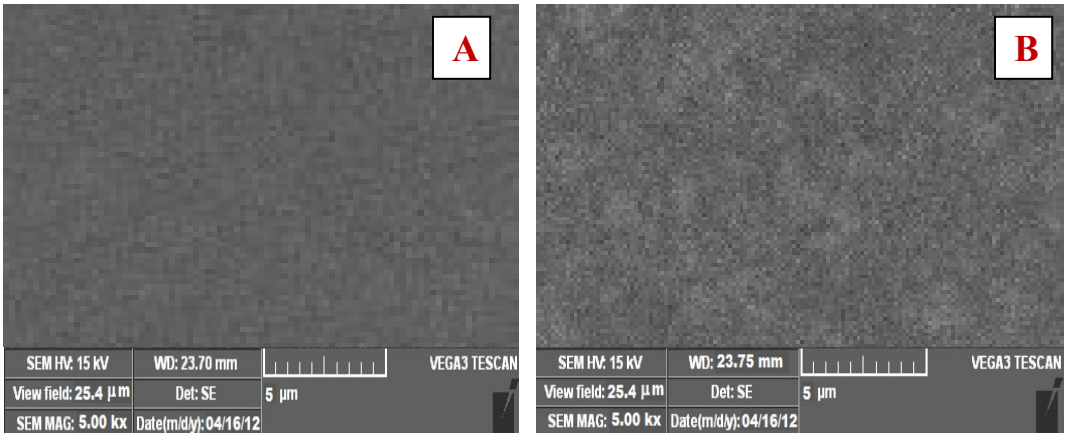

Fig. S5. SEM images of electrochemically deposited PPy (A) ITO electrode. (B) PPy at 1 cycle.

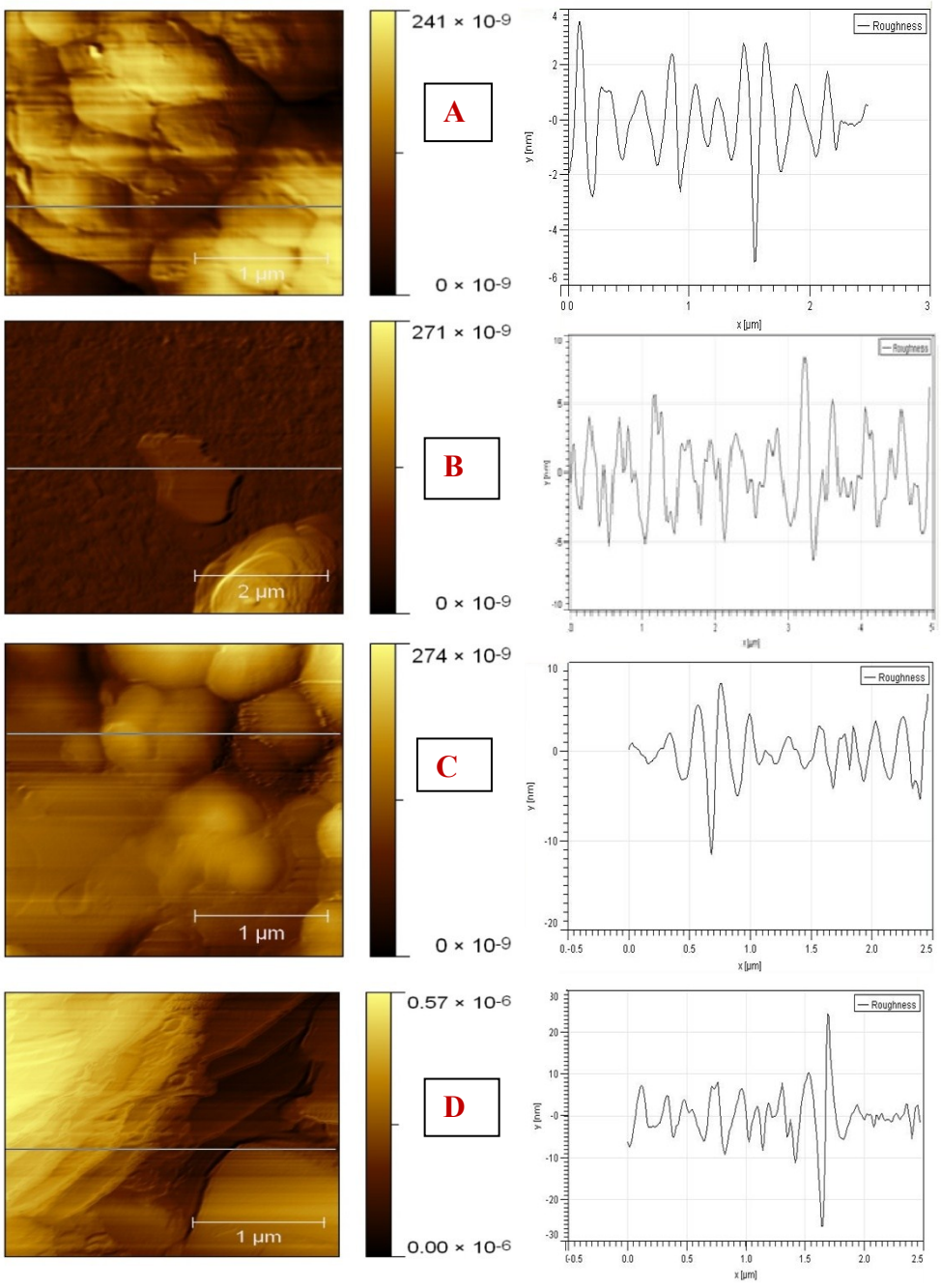

Fig. S6. AFM image and Roughness curve of PPy/SDS -3 cycle film -2.5 µm [A], PPy/SDS/0.1% f-MWCNTs- 3 cycle composite- 5µm [B], PPy/SDS/0.2% f-MWCNTs- 3 cycle composite -2.5 µm [C], PPy/SDS/0.2% f-MWCNTs- 5 cycle composite -2.5 µm [D].

AFM images of composite films and pure PPy films.

Fig. S6 shows the AFM images (A, B, C and D) of the PPy/SDS and PPy/SDS/ f-MWCNTs composite films. The average value of roughness of the composite film increases with increasing the concentration of the f-MWCNTs in the film compare to PPy/SDS surface (A). Similarly, the average thickness of the composites increases with increasing the concentration of the f-MWCNTs was greater than for the reference PPy/SDS composite film. All the data derived from AFM images of the composite films are given in Table. S2.

Table S1. FT-IR spectral data and identification of functional groups of the f-MWCNTs samples prepared at different treatment time in acid solution.

Treatment time (hour)			**Functional group/assignment**	**Reference**
3 hours	**6 hours**	**9 hours**		
cm^{-1}	**cm^{-1}**	**cm^{-1}**		
3462	3430	3422	O-H stretching	[1]
2920	2924	2924	C-H stretching in CH_2 group	[2]
2359	2382	2357	O-H stretching from strongly hydrogen bonded COOH group	[3, 4]
1640	1636	1645	C=O stretching of carboxylate group	[5, 6]
1383	1385	1383	C-OH Bending	[7, 8]
1040	1038	1036	C-O stretching	[9]
-	606	679	C-H out of plane bending	[9]
1111	1109	-	C–C–O ring stretching, C–C–C asymmetric stretching	[10]

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Table S2. AFM data from the PPy/SDS, PPy/SDS/0.1% f-MWCNTs, PPy/SDS/0.2% f-MWCNTs composite films**.**

Data	**PPy/SDS 3 cycle 2.5 µm**	**PPy/SDS/0.2% f-MWCNTs 3 cycle 2.5 µm**	**PPy/SDS/0.2% f-MWCNTs 5 cycle 2.5 µm**	**PPy/SDS/0.1% f-MWCNTs 3 cycle 5 µm**
Roughness average (nm)	1.1	2.1	3.9	2.2
Root mean square roughness (nm)	1.4	2.9	5.8	2.7
Average maximum height of profile (nm)	5.3	11.1	23.4	12.2
Average maximum height of the roughness (nm)	5.3	9.8	21.5	10.4
Maximum height of the profile (nm)	96.2	159.3	226.0	65.2
Thickness (µm)	0.24	0.27	0.57	0.27

Table S3. Comparison of performance of various nitrite sensors

Electrodes	**Linear range (μM)**	**LOD (μM)**	**Reference**
Fe(III)P/MWCNTs/GCE	1–600	0.5	[1]
CR-GO/GCE	8.9–167	1.0	[2]
Pt/Fe(III) nanoparticle	1.1–11,000	0.47	[3]
Thionine modified aligned carbon nanotubes electrode	3–500	1.12	[4]
Au/Fe(III) nanoparticle modified GCE	0.3–150	0.20	[5]
CME/GC–Ru(III)–BSAP–PLA	0–159	1.81	[6]
poly(oanisidine)/ IL-CPE	2–50	1.05	[7]
EPPGE–SWCNT–Co	0–189	5.61	[8]
p-duroquinone / CPE	6–400	4.3	[9]
GCE	2.5–10	0.40	[10]
Au-penicillamine SAM	20–800	4.0	[11]
MgO2/CCE	0–200	0.60	[12]
Pd-nanostructures/CNTs	2–238	0.25	[13]
PPy/SDS/f-MWCNTs	3-1120	0.11	Present study

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