Supplementary data

Direct glucose sensing and biocompatible properties of zinc oxide - multiwalled carbon nanotube-poly(vinyl chloride) ternary composite

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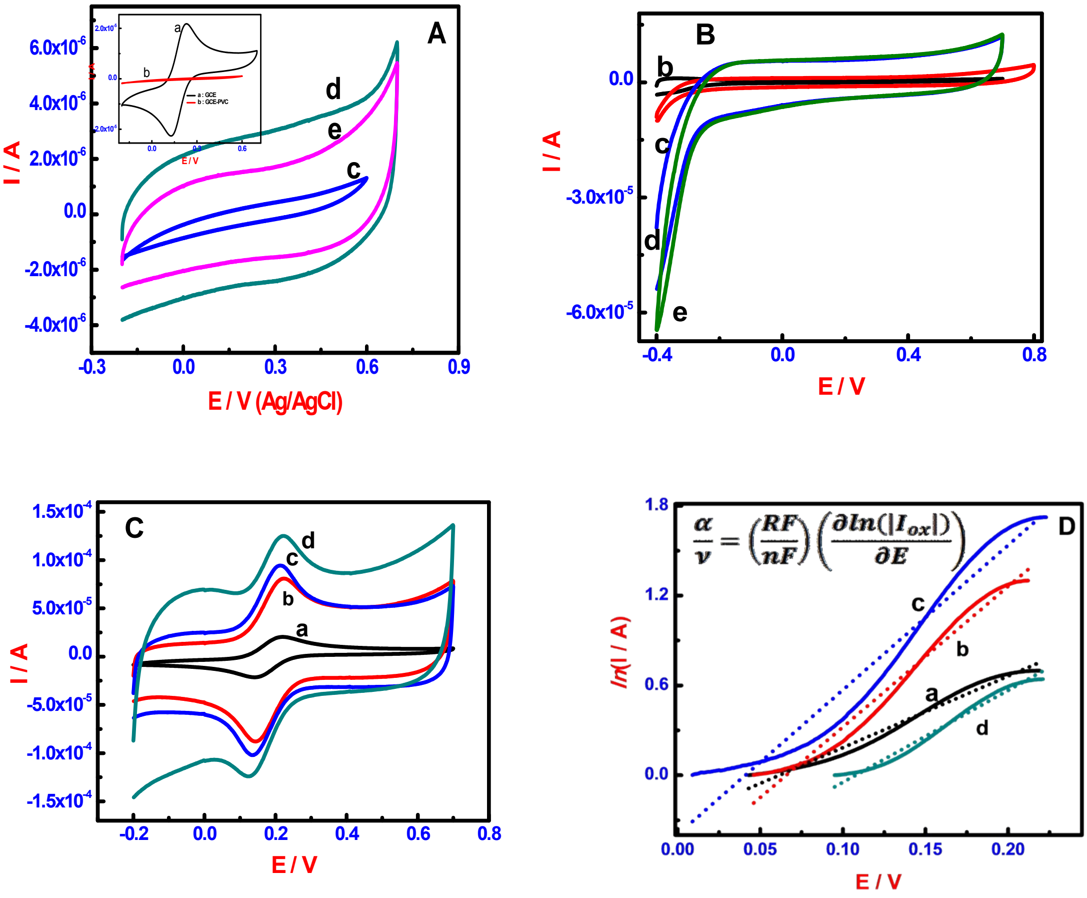


Fig. S1: (A) CV behaviors of bare-GCE (curve a), PVC (curve b), PVC- MWCNT (curve c), PVC-*p*MWCNT (curve d) and PVC-*f*MWCNT (curve e) measured in Phosphate buffer (pH 7.4) in 1mM Fe(CN)6]$^{3-/4-}$ at a scan rate 50 mVs^{-1}. (B) Effect of ZnO on the composites in Fig.S1(A). (C) Effect of absence of PVC on the CV behaviors of bare-GCE (curve a), MWCNT (curve b), *p*MWCNT (curve c) and *f*MWCNT (curve d)) measured in Phosphate buffer (pH 7.4) in 1mM Fe(CN)6]$^{3-/4-}$ at a scan rate 50 mVs^{-1}. (D) Potential *versus ln*(current) plot of [Fe(CN)6]$^{3-/4-}$ oxidation peak used to calculate charge transfer co-efficient α. Bare-GCE (curve a), MWCNT (curve b), *p*MWCNT (curve c) and *f*MWCNT (curve d).

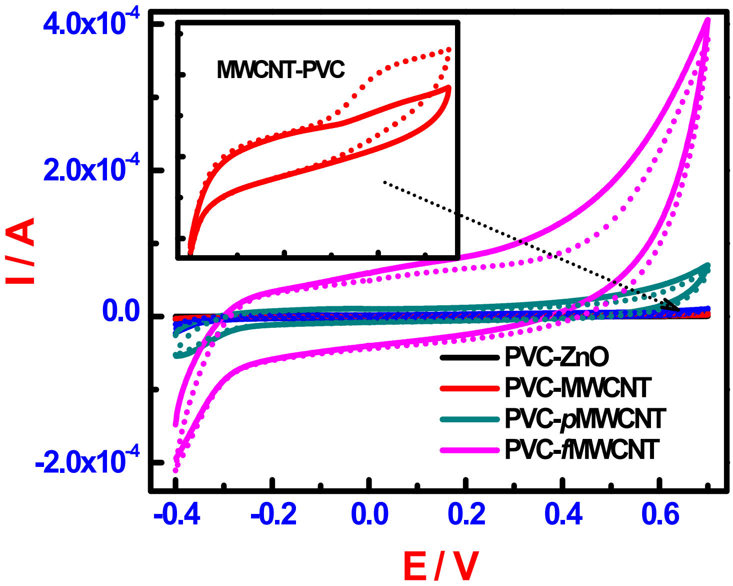


Fig. S2. CV behaviors of PVC-ZnO (black), PVC-MWCNT (red), PVC-*p*MWCNT (green), PVC-*f*MWCNT (pink) 0.1M NaOH in the absence (solid line) and presence (dotted line) of 1 mM glucose measured at a scan rate 50 mVs^{-1}.

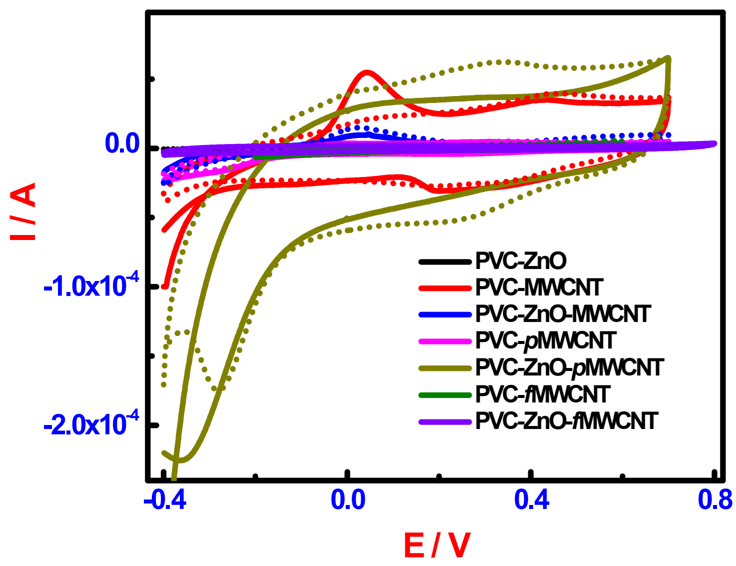


Fig. S3. CV behaviors of PVC-ZnO (black), PVC-MWCNT (red), PVC-ZnO-MWCNT (blue), PVC-*p*MWCNT (Magneta), PVC-ZnO-*p*MWCNT (Dark yellow), PVC-*f*MWCNT (olive) and PVC-ZnO-*f*MWCNT (violet) measured in 0.1M H_2SO_4 in the absence (solid line) and presence (dotted line) of 1 mM glucose at a scan rate 50 mVs^{-1}.

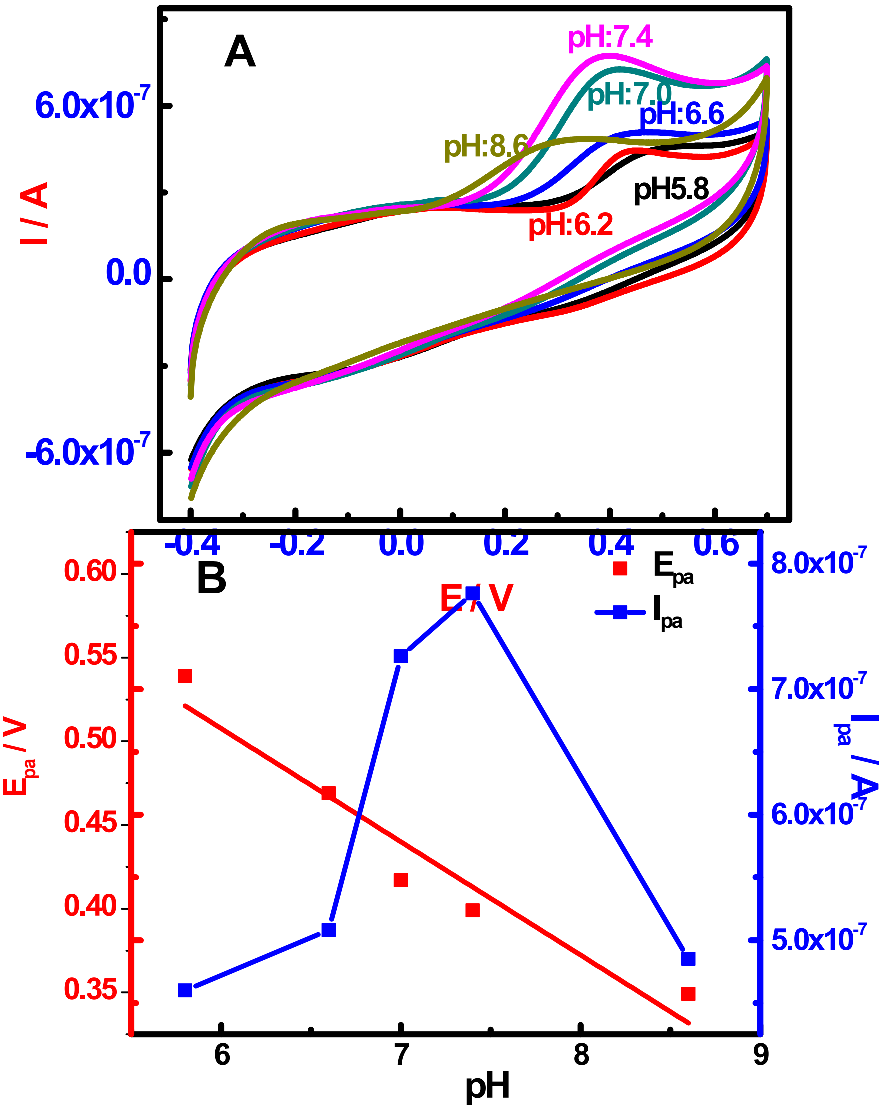


Fig. S4. (A) Effect of phosphate buffer saline pH varied from 6 to 9 on the glucose sensing response of PVC-ZnO-*p*MWCNT. CV measured at a scan rate 50 mVs^{-1}. (B) pH *versus* anodic peak potential (E_{pa}) and current (I_{pa})

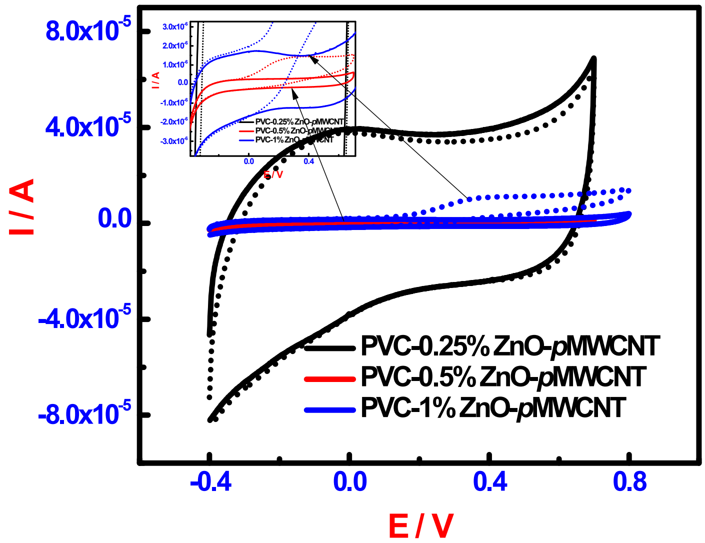


Fig. S5. Effect of ZnO loading density on glucose sensing ability of PVC-ZnO-*p*MWCNT in PBS pH 7.4. Solid line: absence of glucose. Dotted line: presence of glucose.

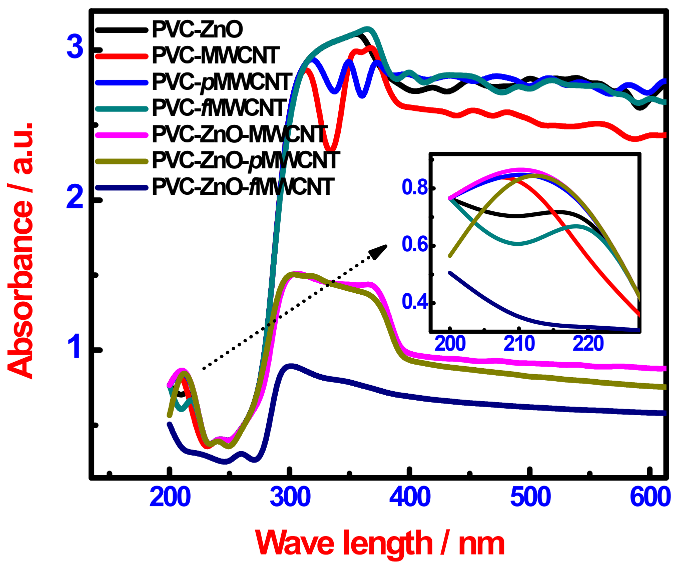


Fig. S6. UV-Vis spectra of PVC-ZnO, PVC-MWCNT, PVC-*p*MWCNT, PVC-*f*MWCNT, PVC-ZnO-MWCNT, PVC-ZnO-*p*MWCNT and PVC-ZnO-*f*MWCNT

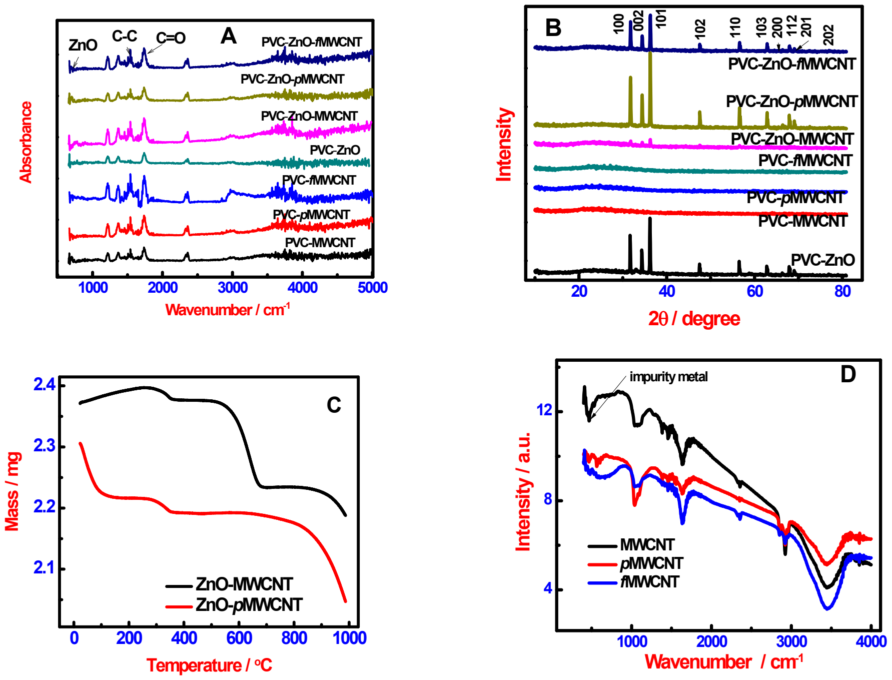


Fig. S7. (A) ATR-FTIR, (B) XRD pattern of the PVC-ZnO, PVC-MWCNT, PVC-*p*MWCNT, PVC-*f*MWCNT, PVC-ZnO-MWCNT, PVC-ZnO-*p*MWCNT, PVC-ZnO-*f*MWCNT. (C) Thermo gravimetry behaviours of ZnO-MWCNT and ZnO-*p*MWCNT. (D). FTIR spectra of MWCNT (black), *p*MWCNT (red) and *f*MWCNT (blue).

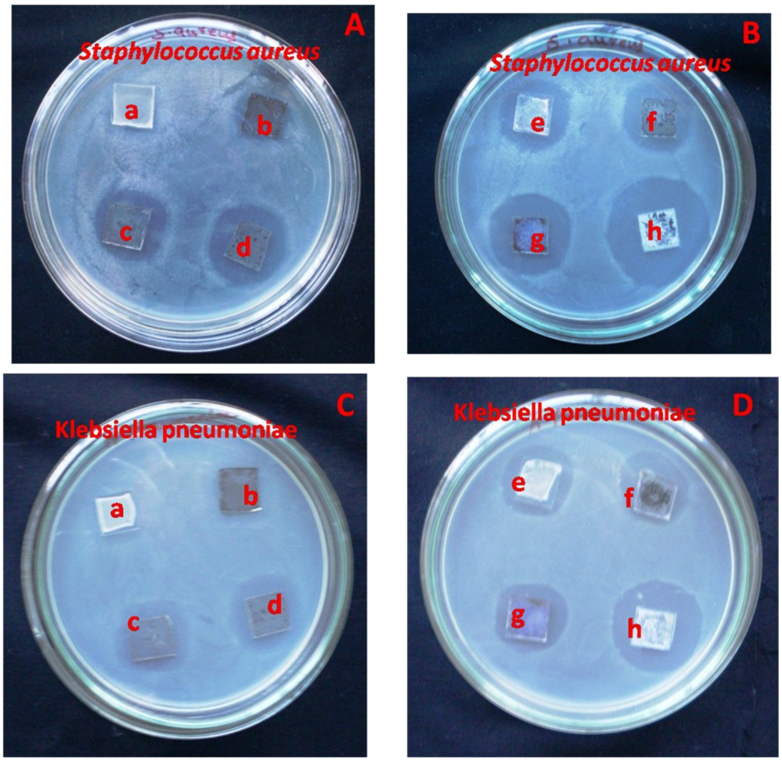
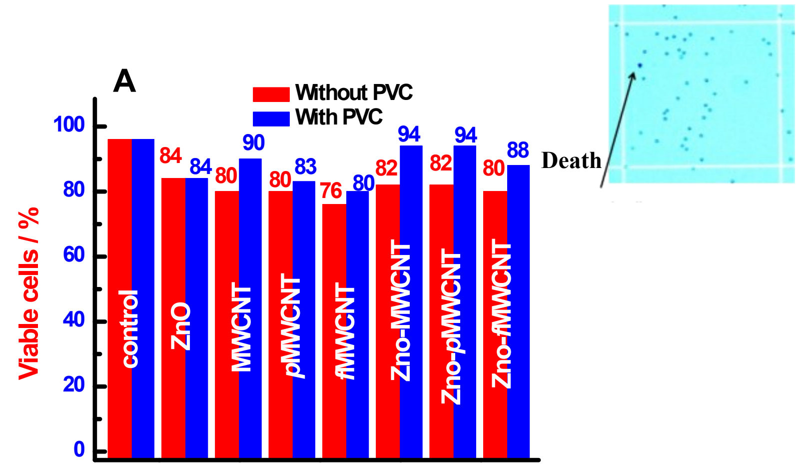


Fig. S8. Effect *Staphylococcus aureus* (A and B) *Klebsiella pneumoniae* (C an D) cidal on PVC (a), PVC-MWCNT (b), PVC-*p*MWCNT (c), PVC-*f*MWCNT (d) in absence of ZnO (A and C) and presence of ZnO (B and D)



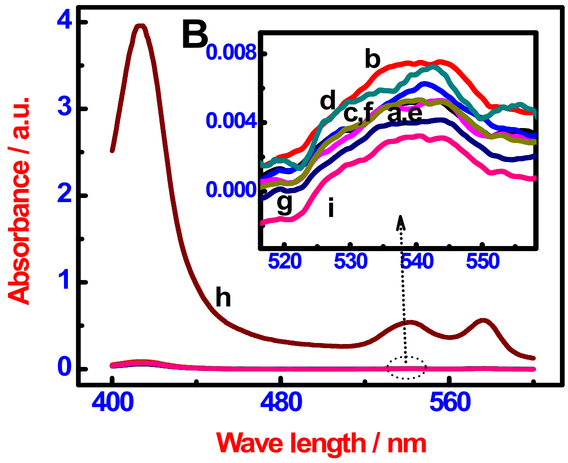


Fig. S9. (A) Blood cells viability counting by hemocytometer for ZnO, ZnO, MWCNT, *p*MWCNT, *f*MWCNT, ZnO-MWCNT, ZnO-*p*MWCNT, ZnO-*f*MWCNT (red bars) compared with the effect of PVC (blue bars). Microscopic (Nikon Eclipse 80i) image for human blood cells in hemocytometer stained with trypan blue. (B) UV-Vis analysis of supernatant (800 rpm for 10 min) of human blood incubated (37 °C for 60 min) in ACD buffer along with ZnO (a), MWCNT (b), *p*MWCNT (c), *f*MWCNT (d), ZnO-MWCNT (e), ZnO-*p*MWCNT (f), ZnO-*f*MWCNT (g), reference negative (h) and blank negative (i).

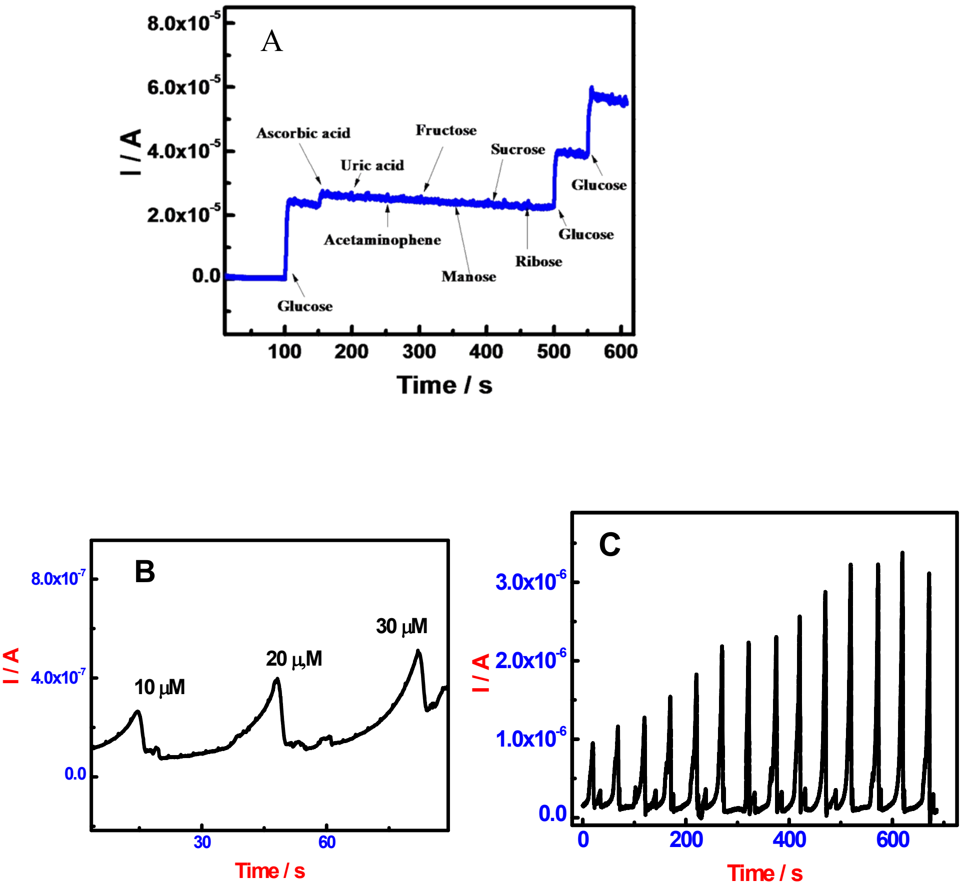


Fig. S10. (A) Glucose sensing selectively at the PVC- ZnO-*p*MWCNT (B) Low concentration detection (C) Effect of injection of increasing concentration of glucose (2 - 28mM)

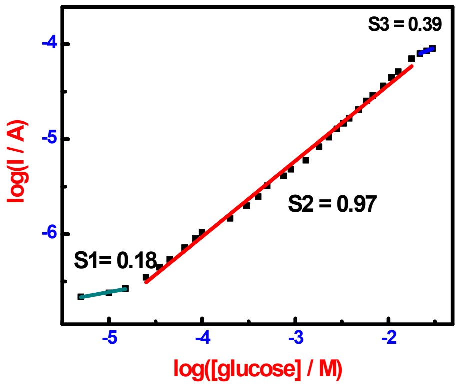


Fig. S11. Plot of log concentration *versus* log current for evaluating the order of glucose reaction of PVC-ZnO-*p*MWCNT

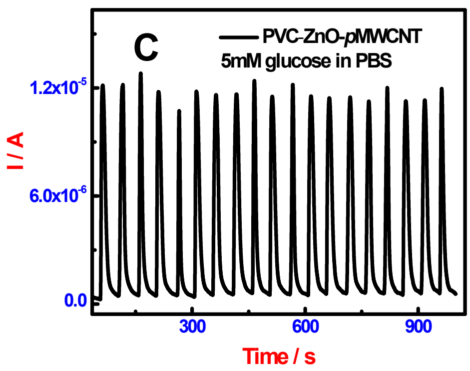


Fig. S12. (A) CV behavior of the PVC-ZnO-*p*MWCNT measured for 4 days in phosphate buffer containing 1 mM glucose. (B) Plot of current versus hours of storage. (C) FIA measurement of 5 mM glucose in PBS showing the data stability under flow conditions.

Table S1 Glucose sensing at carbon nanotube based sensor devices

Sl.No	Composites used and parameter	K_M	Reference
1	'Glucose Biosensors Based on Carbon Nanotube Nanoelectrode Ensembles' Glucose oxidase was covalently immobilized on CNT NEEs via carbodiimide chemistry	0.08 mM, to 30 mM	Yuehe Lin, Fang Lu,Yi Tu, and Zhifeng Ren Nano Lett., Vol. 4, No. 2, 2004
2	Glucose sensors made of novel carbon nanotube-gold nanoparticle composites The enhancement of sensitivity can be attributed to an accelerated electron transfer rate from glucose oxidase Gox to the electrode	0.1 mM, to 5 mM	Cai D, Yu Y, Lan Y, Dufort FJ, Xiong G, Paudel T, Ren Z, Wagner DJ, Chiles TC BioFactors 30 (2007) 271–277
3	Electrodeposition of polypyrrole–multiwalled carbon nanotube–glucose oxidase nanobiocomposite film for the detection of glucose A nanobiocomposite film consisted of polypyrrole (PPy), functionalized multiwalled carbon nanotubes (cMWNTs), and glucose oxidase (GOx) a linear range up to	4 mM	Yu-Chen Tsai , Shih-Ci Li, Shang-Wei Liao Biosensors and Bioelectronics 22 (2006) 495–500
4	Multi-walled carbon nanotubes-based glucose biosensor prepared by a layer-by-layer technique □	0.9×10^{-4} M, 10 mM	Jiadong Huang , Yu Yang , Haibin Shi , Zhao Song, Zixia Zhao, Jun-ichi Anzai, Tetsuo Osa, Qiang Chen Materials Science and Engineering C 26 (2006) 113 – 117
5	Amperometric glucose biosensor based on self-assembling glucose oxidase on carbon nanotubes	linear response range of 15 µM to 6 mM and a detection limit of 7 µM	Guodong Liu, Yuehe Lin Electrochemistry Communications 8 (2006) 251–256
6	Multilayer membranes for glucose biosensing via layer-by-layer assembly of multiwall carbon nanotubes and glucose oxidase e detection of glucose	5.0 mM with a detection limit of 58 µM.	Hongtao Zhao, Huangxian Ju Anal. Biochem. 350 (2006) 138–144
7	Amperometric Glucose Biosensing of Gold Nanoparticles and Carbon Nanotube Multilayer Membranes	10.6 mM o 9.0 mM with a detection limit of 128 mM	Ying Liu, Shuo Wu, Huangxian Ju, Li Xu Electroanalysis 19, 2007, No. 9, 986 – 992
8	Biosensor Based on Self-Assembling Glucose Oxidase and Dendrimer-Encapsulated Pt Nanoparticles on Carbon Nanotubes for Glucose Detection	2.5 mM, a wide linear range of 5 mM – 0.65 mM, a short response time (within 5 s), and high sensitivity (30.64 mA mM□1 cm□2)	Lihuan Xu, Yihua Zhu, Longhua Tang, Xiaoling Yang, Chunzhong Li Electroanalysis 19, 2007, No. 6, 717 – 722
9	Amperometric Glucose Biosensor on Layer by Layer Assembled Carbon Nanotube and Polypyrrole Multilayer Film	linear response range from 1 mM to 50 mM of glucose concentration with excellent sensitivity of 7.06 mA/mM.	Mahendra D. Shirsat, Chee O. Too, b Gordon G. Wallace Electroanalysis 20, 2008, No. 2, 150 – 156
10	Amperometric Biosensors for Glucose Based on Layer-by-Layer Assembled Functionalized Carbon Nanotube and Poly (Neutral Red) Multilayer Film Multiwalled carbon nanotubes	2 mM	Fengli Qu, Minghui Yang, Jiwei Chen, Guoli Shen & Ruqin Yu Analytical Letters, 39: 1785–1799, 2006

	(MWNTs) were treated with a mixture of concentrated sulfuric and nitric acid to introduce carboxylic acid groups to the nanotubes. Conducting polymer film was prepared by electrochemical polymerization of neutral red (NR).		
11	Amperometric Glucose Biosensors Based on Integration of Glucose Oxidase onto Prussian Blue/Carbon Nanotubes Nanocomposite Electrodes	linear response up to 8 mM with a low detection limit of 12.7 mM Km and the maximum current imax of the biosensor were 18.0 mM and 4.68 mA	Liande Zhu, Jiangli Zhai, Yingna Guo, Chunyuan Tian, Ruilan Yang Electroanalysis 18, 2006, No. 18, 1842 – 1846
11	A simple method to fabricate a Prussian Blue nanoparticles=carbon nanotubes=poly(1,2-diaminobenzene) based glucose biosensor Prussian Blue nanoparticles=carbon nanotubes=poly(1,2-diaminobenzene)	10 mM to 2.5 mM detection limit of about 5 mM	Jinxiang Zeng, Wanzhi Wei, Xiaoyin Liu, Ying Wang, Guangming Luo Microchim Acta (2008) 160: 261–267
12	Nanofibrous glucose electrodes were fabricated by the immobilization of glucose oxidase (GOx) into an electrospun composite membrane consisting of polymethylmethacrylate (PMMA) dispersed with multiwall carbon nanotubes (MWCNTs) wrapped by a cationic polymer (poly(diallyldimethylammonium chloride) (PDDA))	2 0 M to 15 mM with a detection limit of 1 M	K.M. Manesh, Hyun Tae Kimb, P. Santhosh, A.I. Gopalan, Kwang-Pill Lee Biosensors and Bioelectronics 23 (2008) 771–779
13	Amperometric Glucose Biosensor Based on Glucose Oxidase Encapsulated in Carbon Nanotube – Titania – Nafion Composite Film on Platinized Glassy Carbon Electrode mesoporous carbon nanotube – titania – Nafion composite	3 mM	Han Nim Choi, Jee Hoon Han, Ji Ae Park, Joong Min Lee, Won-Yong Lee Electroanalysis 19, 2007, No. 17, 1757 – 1763
14	Electrochemical biosensors based on colloidal gold–carbon nanotubes composite electrodes	14.9 mM,	J. Manso, M.L. Mena, P. Yanez-Seden, J. Pingarro´n Journal of Electroanalytical Chemistry 603 (2007) 1–7
15	Enzymatic Glucose Biosensor Based on Multiwalled Carbon Nanotubes-Zinc Oxide Composite	linear range of 0.2-27.2 mM with 20 µM and a sensitivity of 4.18 µA/ mM.	Selvakumar Palanisamy, Srikanth Cheemalapati, Shen-Ming Chen Int. J. Electrochem. Sci., 7 (2012) 8394 - 8407
16	A novel multi-walled carbon nanotube-based biosensor for glucose detection	12 mM	S.G. Wang, Qing Zhang, Ruili Wang, and S.F. Yoona Biochemical and Biophysical Research Communications 311 (2003) 572–576
17	'Fixure-reduce method for the synthesis of Cu2O/MWCNTs nanocomposites and its application as enzyme-free glucose sensor' Cu2O/MWCNT	6.53_A_mol L−1 and a detection limit of 0.05_mol L−1 (signal-to-noise ratio of 3).	Xiaojun Zhang, GuangfengWang, Wei Zhang, YanWei, Bin Fang Biosensors and Bioelectronics 24 (2009) 3395–3398

18	'A highly sensitive nonenzymatic glucose sensor based on CuO nanoparticles-modified carbon nanotube electrode' CuO/MWCNT	1.2mMwith a detection limit of 0.2_M(signal/noise = 3).	Liao-Chuan Jiang, Wei-De Zhang Biosensors and Bioelectronics 25 (2010) 1402–1407
19	A sensitive nonenzymatic glucose sensor in alkaline media with a copper nanocluster/multiwall carbon nanotube-modified glassy carbon electrode	$7.0 \cdot 10^{-7}$ to $3.5 \cdot 10^{-3}$ M low detection limit of $2.1 \cdot 10^{-7}$ M,	Xinhuang Kang, Zhibin Mai, Xiaoyong Zou, Peixiang Cai, Jinyuan Mo Analytical Biochemistry, 363, (2007) 143-150
20	A highly sensitive non-enzymatic glucose sensor based on a simple two-step electrodeposition of cupric oxide (CuO) nanoparticles onto multi-walled carbon nanotube arrays	detection limit is 800nM linear response up to 3mM	Jiang Yang, Liao-Chuan Jiang, Wei-De Zhang, Sundaram Gunasekaran Talanta 82 (2010) 25–33
21	PVC-ZnO-MWCNT	Lowest detection limit: 5µM Linear range: 20 µM – 17.8 mM k_M is 21.9 mM	This work