Supporting information

Fabrication of noble metal nanoparticles decorated on one dimensional hierarchical Polypyrrole@MoS_2 microtubes

Yang Ling[a, d‡], Tiantian Cao[a‡], Libin Liu[b], Jingli Xu[a], Jing Zheng[a], Jiaxing Li[c], Min Zhang*[a]

[a] College of Chemistry and Chemical Enginerring, Shanghai University of Engineering Science, Shanghai 201620, PR China. E-mail: zhangmin@sues.edu.cn.

[b] School of Chemistry and Pharmaceutical Engineering, Qilu University of Technology (Shandong Academy of Sciences), Jinan 250353, China.

[c] Institute of Plasma Physics, Chinese Academy of Sciences, P.O. Box 1126, 230031 Hefei, PR China.

[d] Institute for Sustainable Energy/College of Sciences, Shanghai University, No. 99, Shangda Road, Shanghai 200444, PR China

Synthesis of PPy@MoS_2@Pd

10 mg PPy@MoS_2 was dissolved in 20 mL deionized water. Then 10 mg of $PdCl_2$ (dissolved in 10 mL of deionized water) was slowly dropped into the above solution, and the obtained mixture was sonicated for 1h. the products were harvested by centrifugation, washed with deionized water as well as ethanol and dried at 50 °C overnight to attain PPy@MoS_2@Pd.

Synthesis of PPy@MoS_2@Ag

10 mg PPy@MoS_2 was dissolved in 20 mL deionized water. Then 10 mg of $AgNO_3$(dissolved in 10 mL of deionized water) was slowly dropped into the above solution, and the obtained mixture was sonicated for 1h. the products were harvested by centrifugation, washed with deionized water as well as ethanol and dried at 50 °C

overnight to attain PPy@MoS_2@Ag.

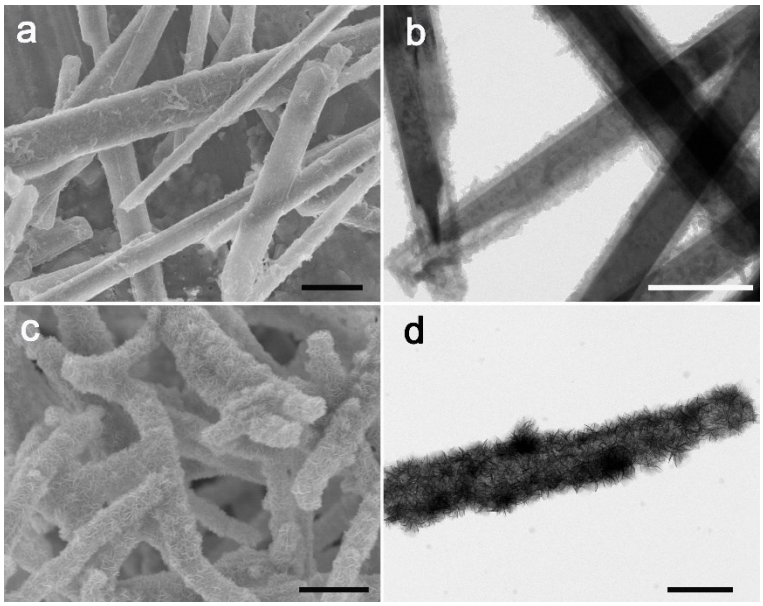

Fig. S1 SEM and TEM images of MoO_3@PANI (a, b) and PANI@MoS_2 (c, d). Scale bars: 1 μm in (a, c) and 500 nm in (b, d).

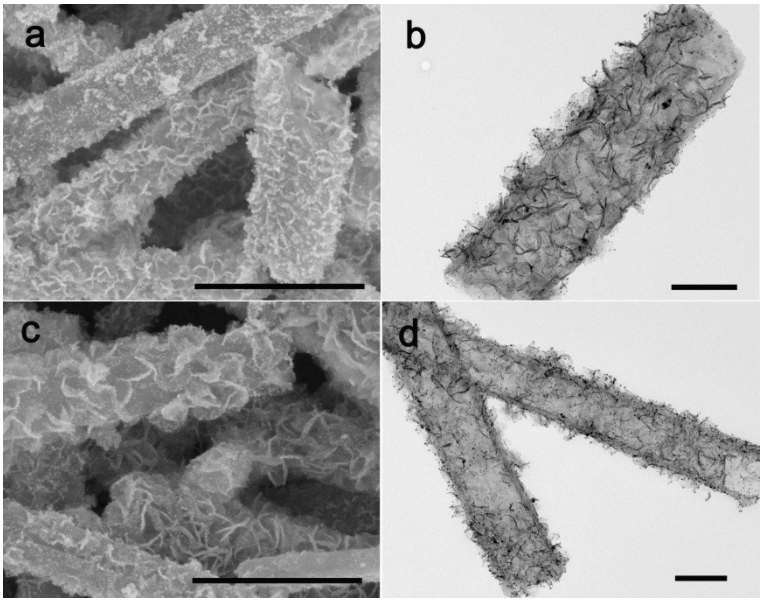

Fig. S2 SEM and TEM images of PPy@MoS_2@Au, 2 mg (a, b) and 4 mg (c, d). Scale bars: 1 μm in (a, c), and 200 nm in (b, d).

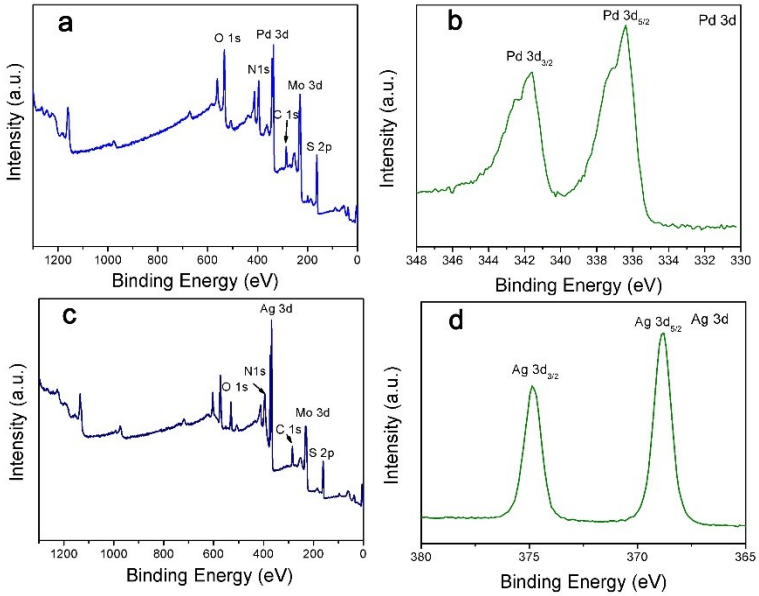

Fig. S3 XPS full spectrum of PPy@MoS_2@Pd (a) and PPy@MoS_2@Ag(c), (b) XPS spectra of Pd 3d of PPy@MoS_2@Pd and (d) XPS spectra of Ag 3d of PPy@MoS_2@Ag.

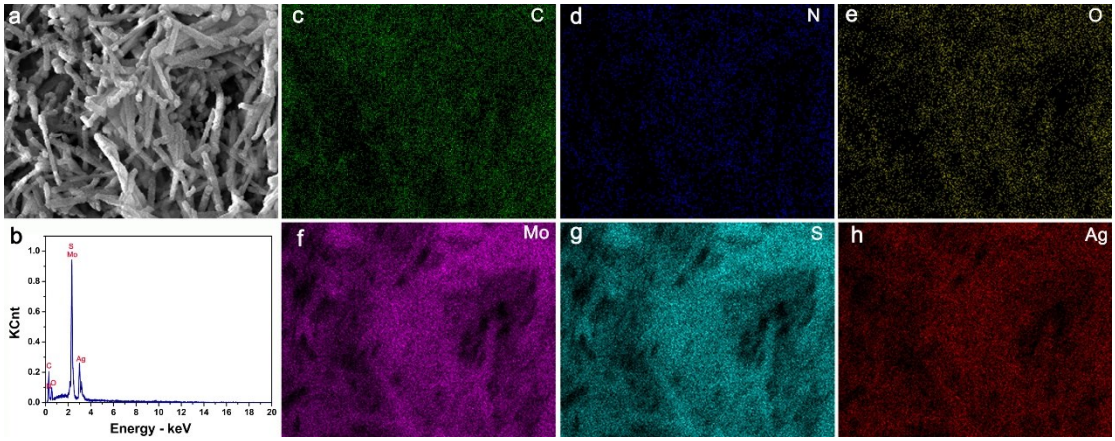

Fig. S4 SEM images and the corresponding EDS elemental mappings of C, N, O, Mo, S and Ag in PPy@MoS_2@Ag.

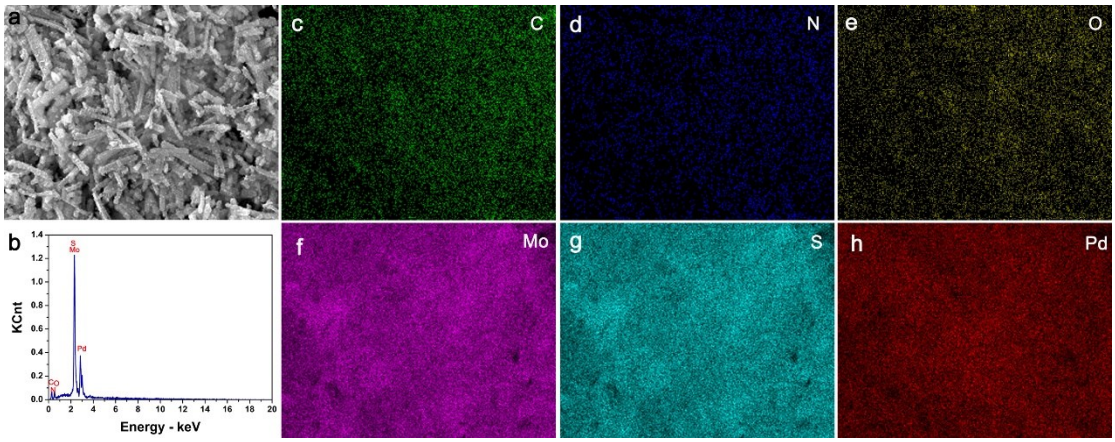

Fig. S5 SEM images and the corresponding EDS elemental mappings of C, N, O, Mo, S and Pd in PPy@MoS_2@Pd.

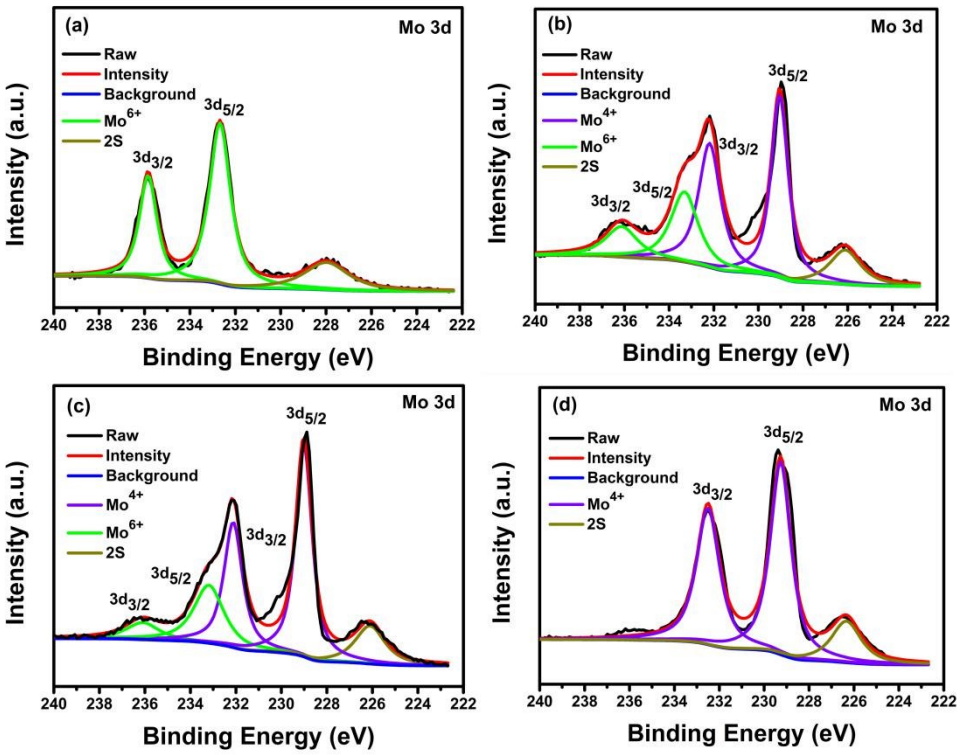

Fig. S6 XPS spectra of the Mo 3d for PPy@MoS_2 composites at different reaction time: (a) 3 h, (b) 6 h, (c) 12 h, and (d) 24h.

Table S1 Summary of XPS analysis of valence states, peak position and relative contents in PPy@MoS_2 composites reacted at different time

Time		Mo^{4+}		Mo^{6+}	
(h)		$3d_{5/2}$	$3d_{3/2}$	$3d_{5/2}$	$3d_{3/2}$
3	Position(eV)	-	-	232.6	235.8
	Relative Content	-		100%	
6	Position(eV)	229.0	232.2	233.3	236.1
	Relative Content	67.01%		32.99%	
12	Position(eV)	229.0	232.1	233.2	236.0
	Relative Content	72.98%		27.02%	
24	Position(eV)	229.3	232.5	-	-
	Relative Content	100%		-	

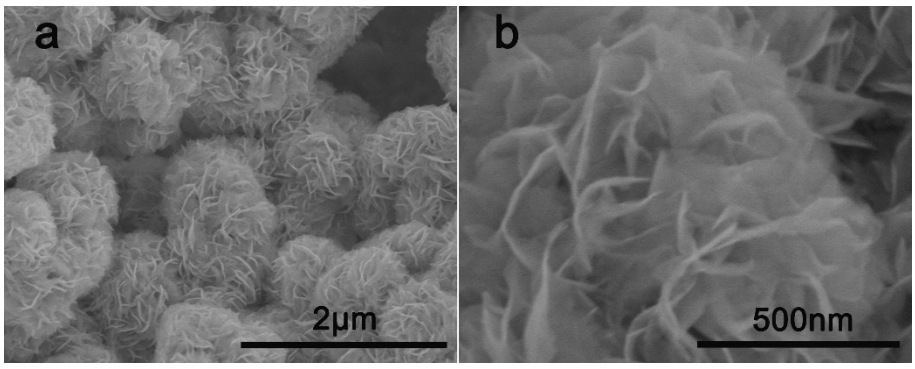

Fig. S7 SEM images of MoS_2.

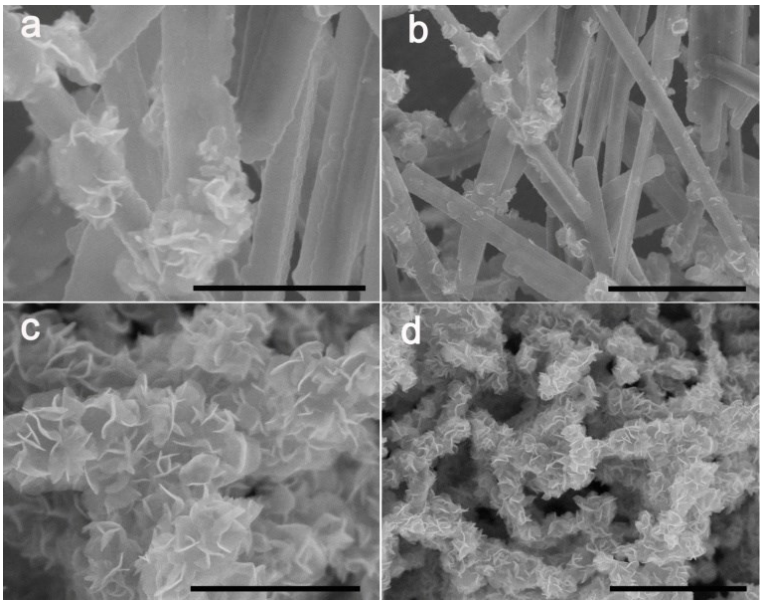

Fig. S8 SEM images of C@MoO_2@MoS_2-100 (a, b) and C@MoO_2@MoS_2-50 with the MoO_2@C as precursor (c, d) Scale bars: 1μm in (a, c) and 2 μm in (b, d).

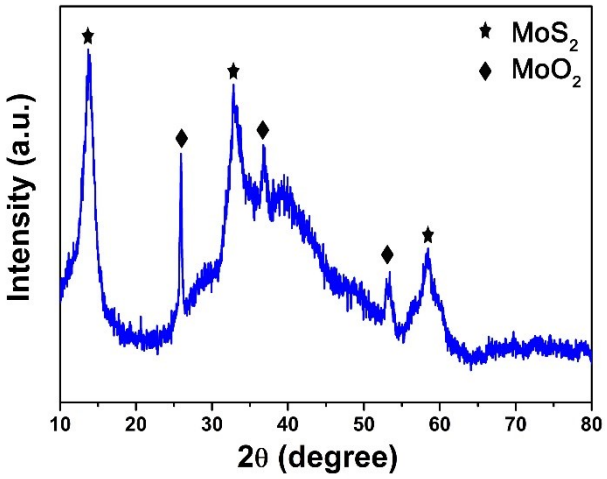

Fig. S9 XRD of diffraction patterns of C@MoO_2@MoS_2-50.

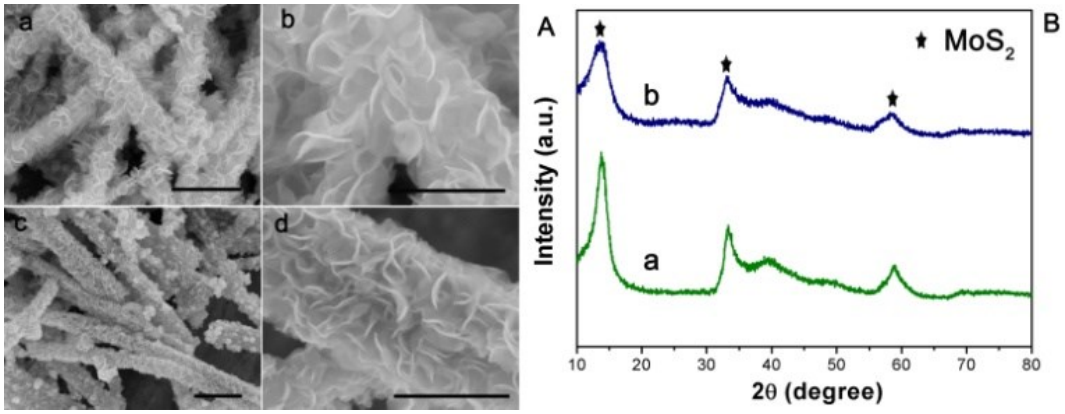

Fig. S10 (A) SEM images of PPy@MoS_2 with MoO_3@PPy-50 μL (a, b) and 150 μL (c, d). Scale bars: 1 μm in (a, c), and 500 nm in (b, d). (B) XRD of diffraction patterns PPy@MoS_2-50 μL(a); 150 μL (b).

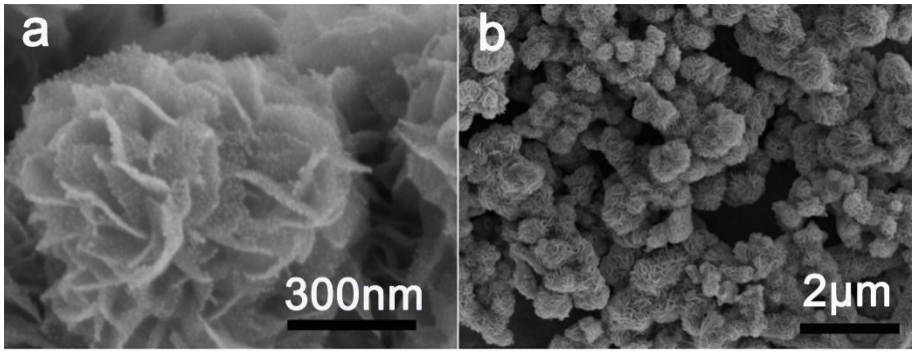

Fig. S11 SEM images of MoS_2@Au.

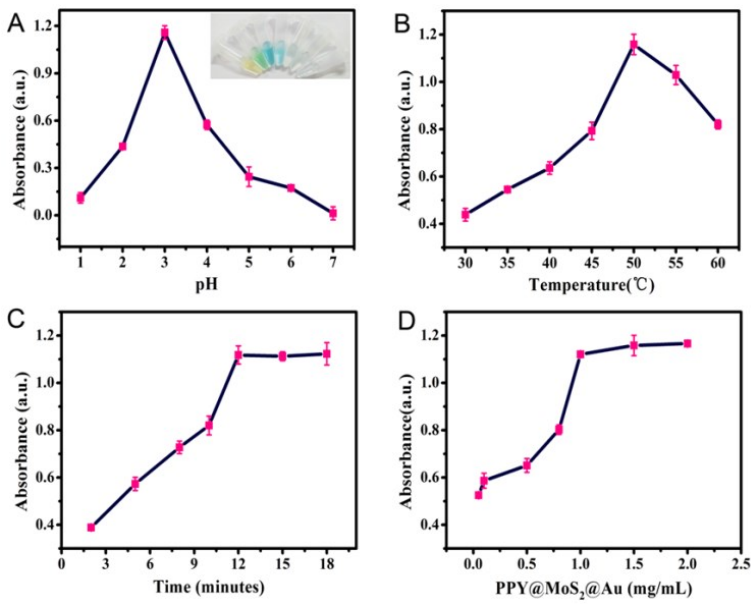

Fig. S12 Peroxidase activities under varied reactions condition. (A) A pH-dependent response curve performed at pH 1.0-7.0. (B) temperature (30℃, 35℃, 40℃, 45℃, 50℃, 55℃, 60℃). (C) Dependence of the peroxidase-like activity on time (2, 5, 8, 10, 12, 15, 18 min), and (D)effect of material concentration on catalytic efficiency (0.05, 0.1, 0.5, 0.8, 1.0, 1.5, 2.0 $mg \cdot mL^{-1}$). Experiments were measured in 0.2 M NaAc-HAc buffer solution (pH 3.0) at 50℃, using a certain amount of PPy@MoS_2@Au containing 0.25 mM TMB and 0.25 mM H_2O_2 as substrates, respectively. Error bars represent the standard error derived from three repeated measurements.

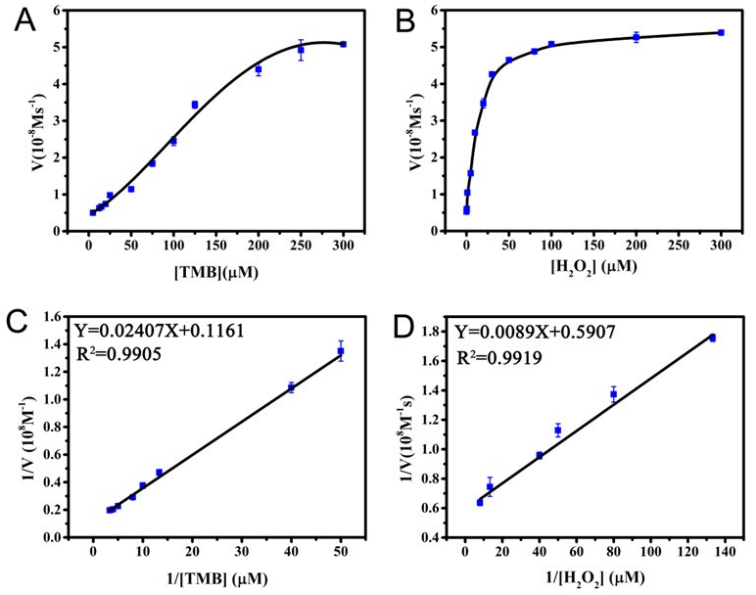

Fig. S13 Steady-state kinetic assays of PPy@MoS_2@Au. (A) The concentration of H_2O_2 was 0.25 mM and the TMB concentration was varied. (B) The concentration of TMB was 0.25 mM and the

H_2O_2 concentration was varied. (C, D) The Lineweaver-Burk plots of the double reciprocal of the Michaelis−Menten equation, with the concentration of one substrate fixed and the other varied. The velocity (v) of the reaction was performed by applying 0.025 mg·mL^{-1} PPy@MoS_2@Au in 0.2 M NaAc-HAc buffer solution (pH 3.0) at 50℃ for 12 minutes. Error bars shown represent the standard error obtained from three repeated measurements.

Table S2 Comparison of the apparent kinetic parameters (K_m and V_m) of various enzyme mimics and PPy@MoS_2@Au.

Enzyme mimics	K_m(mM)		V_m (10^{-8} s^{-1})		Reference
	TMB	H_2O_2	TMB	H_2O_2	
HRP	0.434	3.7	10	8.71	1
MoS_2	0.525	0.0116	5.16	4.29	2
MoS_2 -Pt_{74} Ag_{26}	0.386	25.71	0.322	0.729	3
SWCNT-Au NPs [a]	0.48	0.65	14.2	5.8	4
MoS_2@$MgFe_2O_4$	0.806	0.238	1.413	0.378	5
SDS-MoS_2 NPs[b]	2.04	0.013	1.60	0.193	6
MoS_2-PPy-Pd	0.93	6.4	_	_	7
PPy@MoS_2@Au	0.207	0.015	8.67	1.69	This work

[a]SWCNT-Au NPs (gold nanoparticles decorated single walled carbon nanotubes)

[b]SDS-MoS_2 NPs (sodium dodecyl sulfate modified MoS_2 nanoparticles)

1. J. Liu and Y. Lu, *Angew Chem Int Ed Engl*, 2010, **118**, 90-94.

2. L. Tianran, Z. Liangshuang, G. Liangqia, F. Fengfu and C. Guonan, *Nanoscale*, 2014, **6**, 11856-11862.

3. S. Cai, Q. Han, C. Qi, Z. Lian, X. Jia, R. Yang and C. Wang, *Nanoscale*, 2016, **8**, 3685-3693.

4. W. Haider, A. Hayat, Y. Raza, A. A. Chaudhry and J. L. Marty, *RSC Advances*, 2015, **5**, 24853-24858.

5. Y. Zhang, Z. Zhou, F. Wen, J. Tan, T. Peng, B. Luo, H. Wang and S. Yin, *Sensors Actuators B: Chem.*, 2018, **275**, 155-162.

6. K. Zhao, W. Gu, S. Zheng, C. Zhang and Y. Xian, *Talanta*, 2015, **141**, 47-52.

7. M. Chi, Y. Zhu, L. Jing, C. Wang and X. Lu, *Analytica Chimica Acta*, 2018, **1035**, 146-153.