Supporting Information

Multifunctional sandwich-like mesoporous silica-Fe_3O_4-graphene oxide nanocomposites for removal of methylene blue from water

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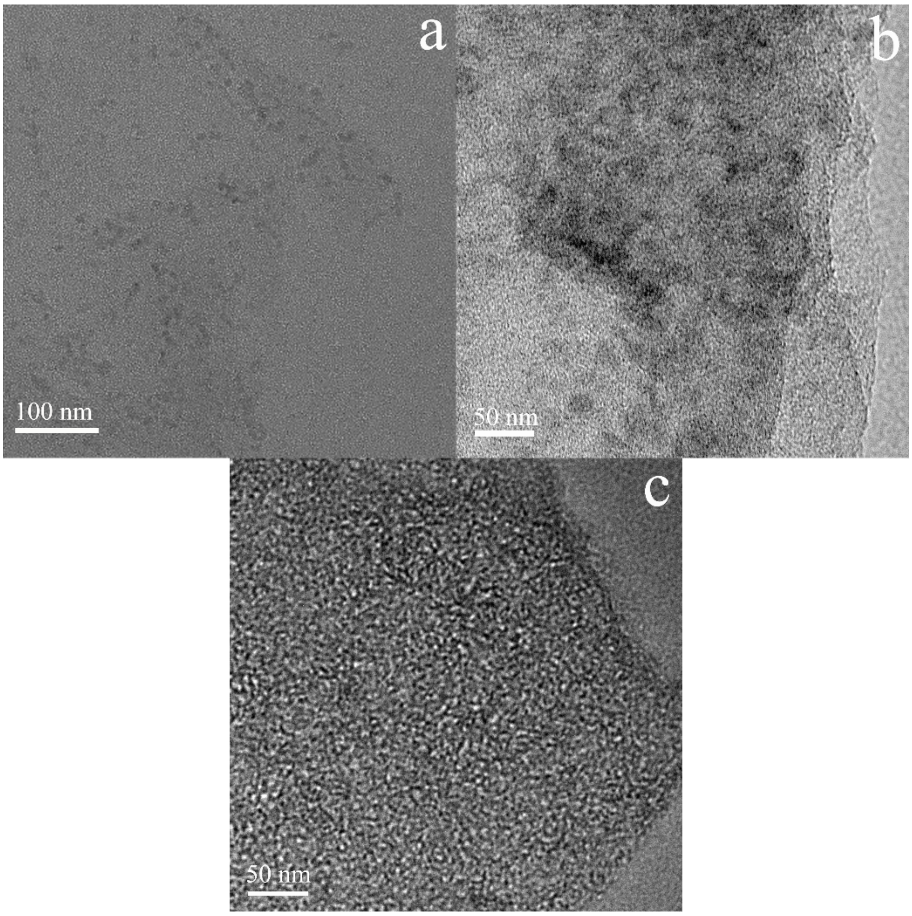

Fig.S1 TEM images of Fe_3O_4/GO (a), Fe_3O_4/GO@mSiO_2 (b), GO@mSiO_2 (c)

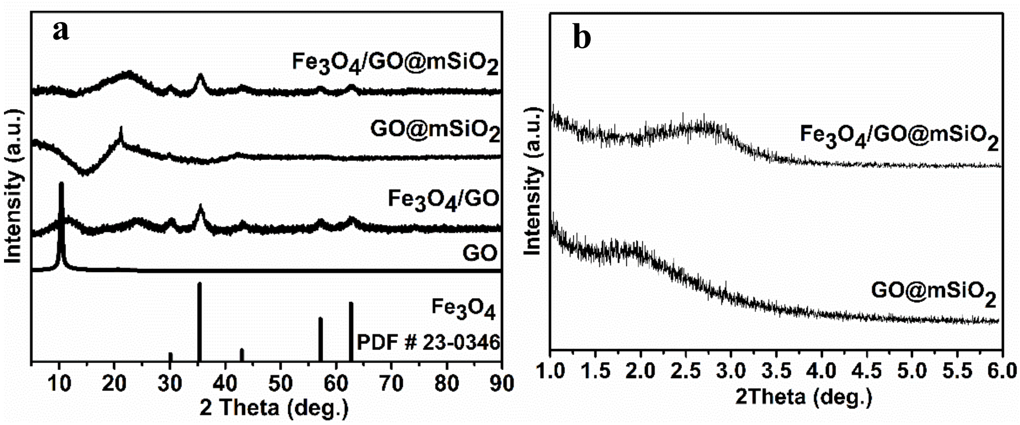

Fig.S2 XRD patterns (a) of GO, Fe_3O_4/GO, GO@mSiO_2 and Fe_3O_4/GO@mSiO_2

Low-angle XRD patterns (b) of GO@mSiO_2 and Fe_3O_4/GO@mSiO_2

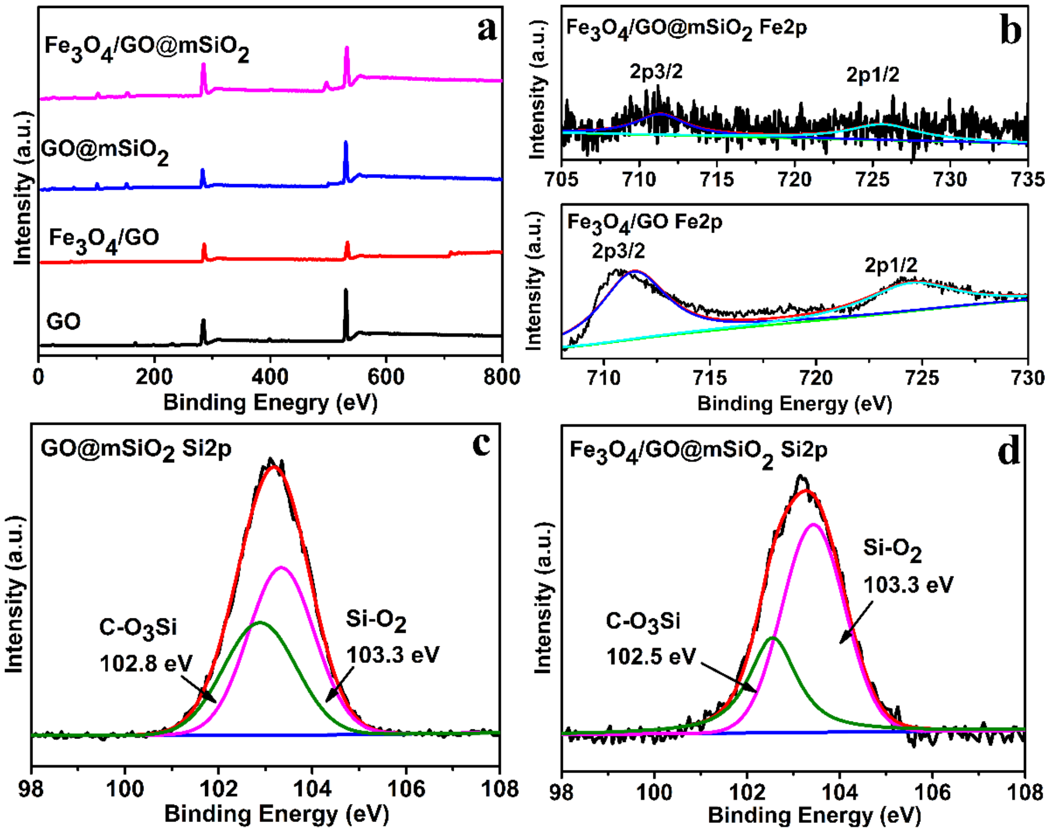

Fig.S3 XPS spectra of GO, Fe_3O_4/GO, GO@mSiO_2 and Fe_3O_4/GO@mSiO_2

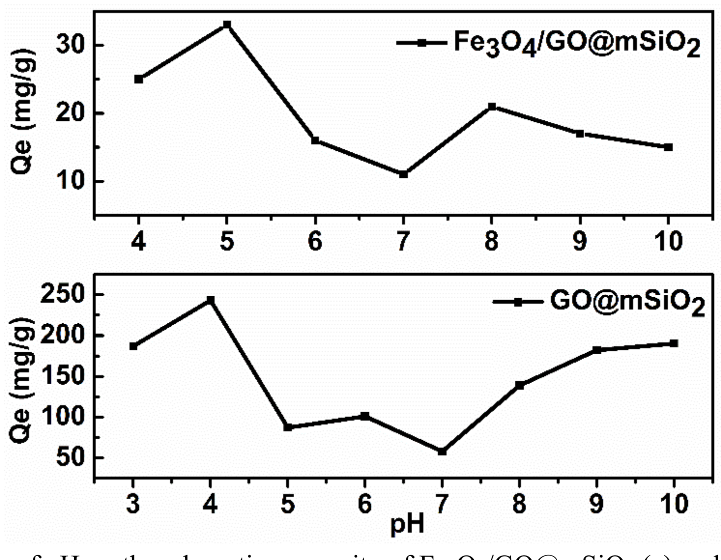

Fig.S4 Influence of pH on the adsorption capacity of Fe_3O_4/GO@mSiO_2 (a) and GO@mSiO_2 (b)

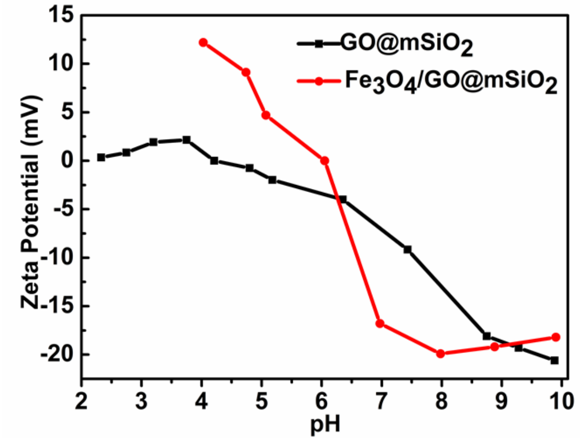

Fig. S5 Zeta potential vs. pH curves of Fe_3O_4/GO@mSiO_2 and GO@mSiO_2

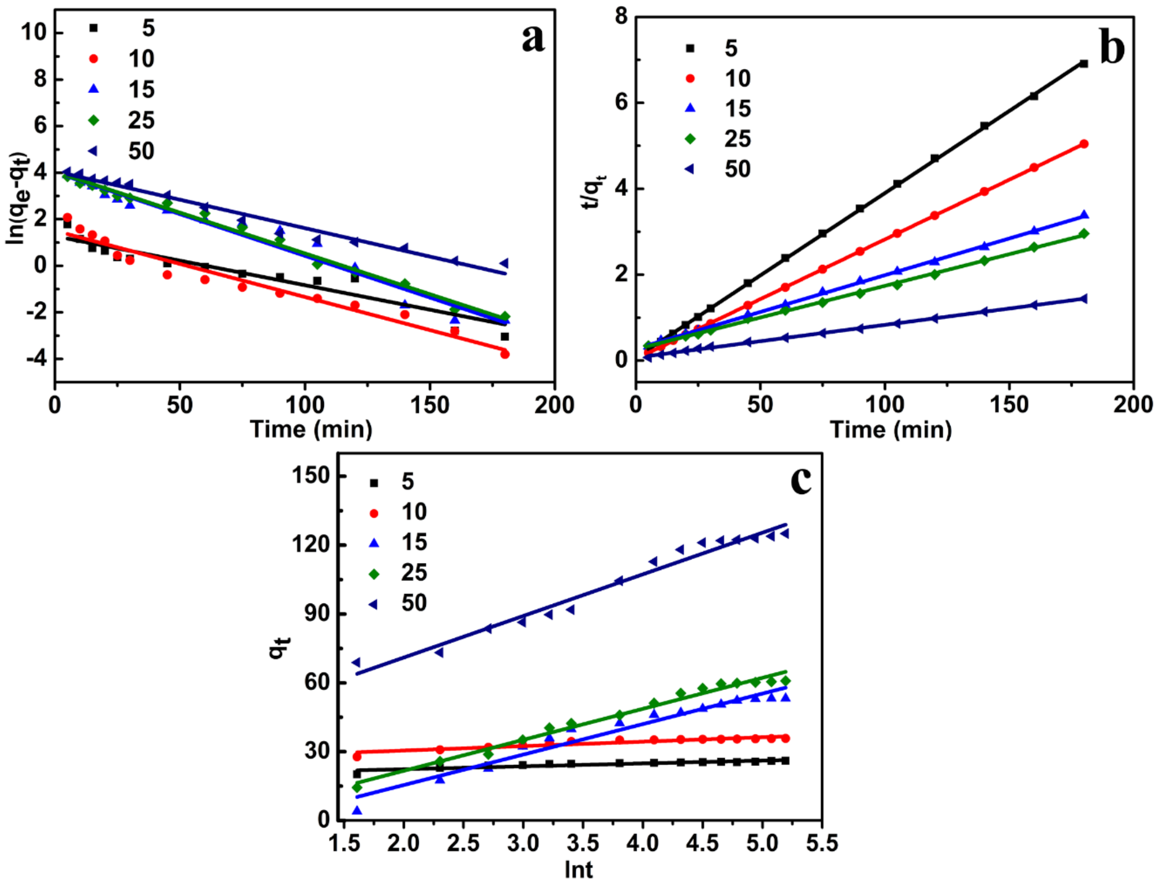

Fig.S6 Adsorption models of pseudo-first-order (a), pseudo-second-order (b), Elovich (c) onto Fe_3O_4/GO@mSiO_2

Table S1 Coefficients of a pseudo-first-order and Elovich kinetic models for MB on Fe_3O_4/GO@mSiO_2

C_0 (mg/L)	$q_{e,\,exp}$ (mg/g)	Pseudo–first order $q_{e,cal}$ (mg/g)	k_1 (min^{-1})	R^2	Elovich α (mg/g·min)	β ($g\cdot mg^{-1}$)	R^2
5	34.0	18.8	0.02108	0.8710	400.28	0.079	0.8242
10	42.0	31.9	0.02844	0.9478	1.11×10^4	0.5168	0.8427
15	53.2	32.8	0.03586	0.9579	0.4501	0.075	0.9437
25	60.8	63.6	0.03505	0.9901	33.47	0.0702	0.9796
50	125.1	114.8	0.02443	0.9716	1444.23	0.074	0.9676

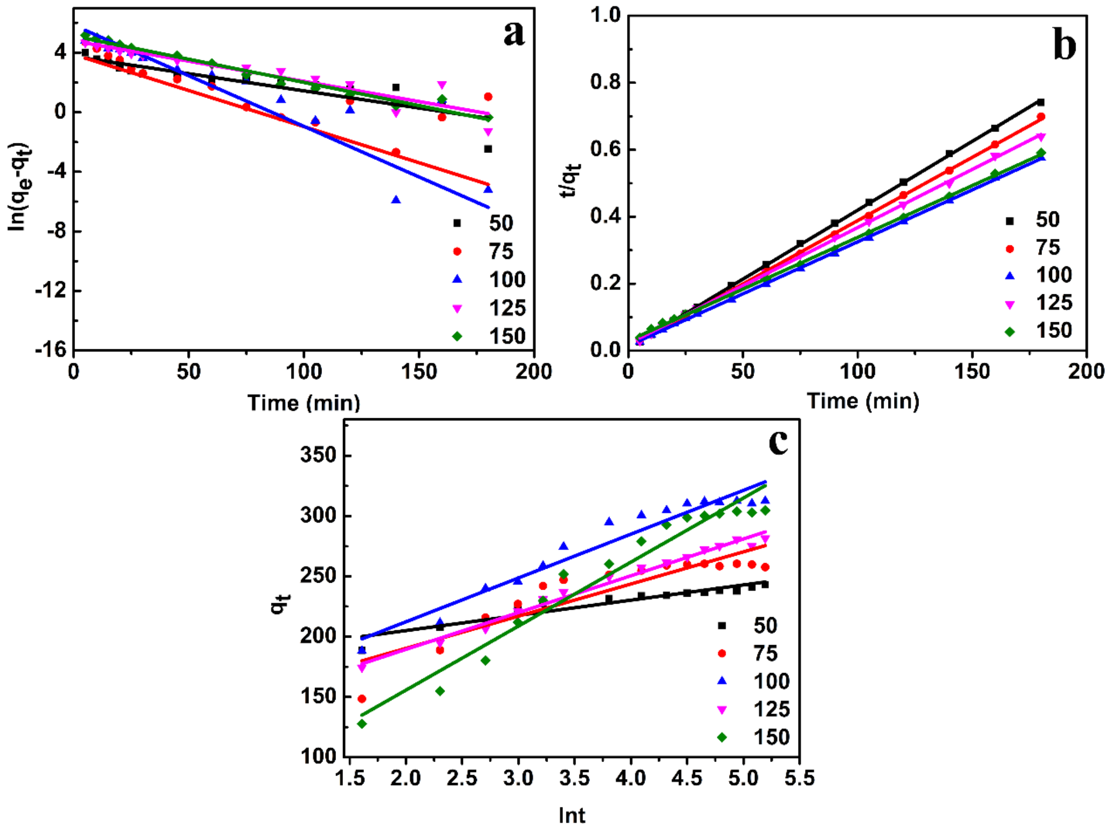

Fig.S7 Adsorption models of pseudo-first-order (a), pseudo-second-order (b), Elovich (c) onto GO@mSiO_2

Table S2 Coefficients of a pseudo-first-order and Elovich kinetic models for MB on GO@mSiO_2

C_0 (mg/L)	$q_{e,\,exp}$ (mg/g)	Pseudo–first order $q_{e,cal}$ (mg/g)	k_1 (min^{-1})	R^2	Elovich α (mg/g·min)	β ($g\cdot mg^{-1}$)	R^2
50	243.3	42.2	0.02306	0.7544	1.96×10^7	0.07927	0.8837
75	260.7	48.4	0.04846	0.2956	4548	0.03751	0.7923
100	270.4	345.7	0.06793	0.6669	1698	0.02753	0.9346
125	281.8	119.8	0.02711	0.8634	2052	0.03277	0.9841
150	305.3	166.2	0.03113	0.9727	134.9	0.01883	0.9486

Table S3 Comparison of the adsorption capacities of MB onto various adsorbents

Adsorbent	q_{max} (mg/g)	BET (m^2/g)	Q_m (mg/m^2)	Conc. (mg/L)	pH	Isotherm	Ref
graphene–Fe_3O_4@carbon	73.3	-	-	50	acid	Langmuir	[1]
Fe_3O_4-SiO_2-GO	97.0	-	-	25-35	-	Langmuir	[2]
Fe_3O_4-G-MWCNT	65.8	-	-	10-30	6.4	Freundlich	[3]
magnetic-GO	64.2	-	-	-	8	Langmuir	[4]
MCM-22	57.6	490	0.118	-	-	Langmuir	[5]
SBA-15	49.0	659	0.074	-	5.5	Freundlich	[6]
MCM-41	48.0	1,059	0.045	-	11	Redlich-peterson model	[7]
Fe_3O_4/GO@mSiO_2	125.1	179	0.698	5-50	5	Langmuir	Present work
GO@mSiO_2	305.3	634	0.369	50-150	4	Langmuir	Present work

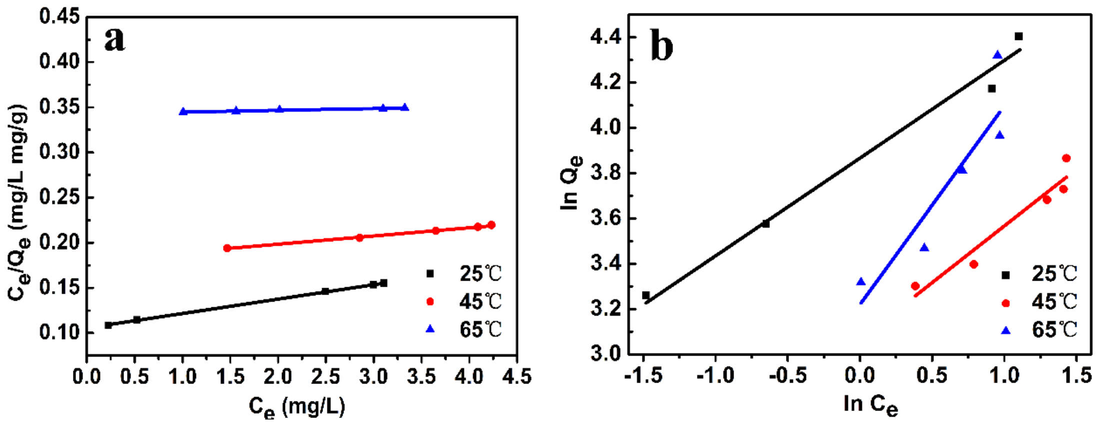

Fig.S8 Langmuir (a) and Freundlich (b) adsorption isotherm for MB onto Fe_3O_4/GO@mSiO_2

Table S4 Parameters of Langmuir and Freundlich adsorption for MB onto Fe_3O_4/GO@mSiO_2

T (℃)	**Langmuir**			**Freundlich**		
	q_{max} **(mg/g)**	***b*** **(L/g)**	R^2	n	***K***	R^2
25	62.7	592.80	0.9994	0.432	7354.5	0.6813
45	110.0	0.0016	0.9989	1.995	1164.7	0.9193
65	121.7	1511.5	0.9922	1.137	1657.2	0.7794

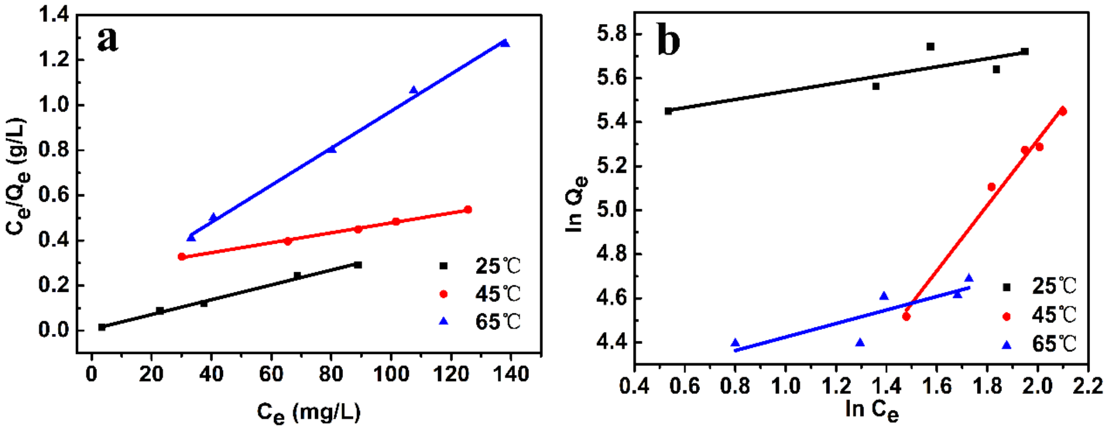

Fig.S9 Langmuir (a) and Freundlich (b) adsorption isotherm for MB onto GO@mSiO_2

Table S5 Parameters of Langmuir and Freundlich adsorption for MB onto GO@mSiO_2

T (℃)	**Langmuir**			**Freundlich**		
	q_{max} **(mg/g)**	***b*** **(L/mg)**	R^2	n	***K***	R^2
25	312.5	0.5423	0.9916	5.38	211.6	0.6684
45	454.5	0.0085	0.9960	0.67	10.48	0.9813
65	121.7	0.0541	0.9958	3.25	61.35	0.6146

Table S6 Thermodynamic parameters for MB adsorbed onto Fe_3O_4/GO@mSiO_2

T (K)	Q_e (mg/g)	K_d	ΔG (kJ/mol)	ΔH (kJ/mol)	ΔS (J/mol·K)
298	26.1	4.16	-11.7		
318	24.1	1.83	-8.83	-1928.1	-5547.1
338	22.8	1.05	-8.74		

Table S7 Thermodynamic parameters for MB adsorbed onto GO@mSiO_2

T (K)	Q_e (mg/g)	K_d	ΔG (kJ/mol)	ΔH (kJ/mol)	ΔS (J/mol·K)
298	243.3	4.22	-10.3		
318	91.61	1.11	-4.84	-65.40	186.73
338	81.09	0.89	-2.95		

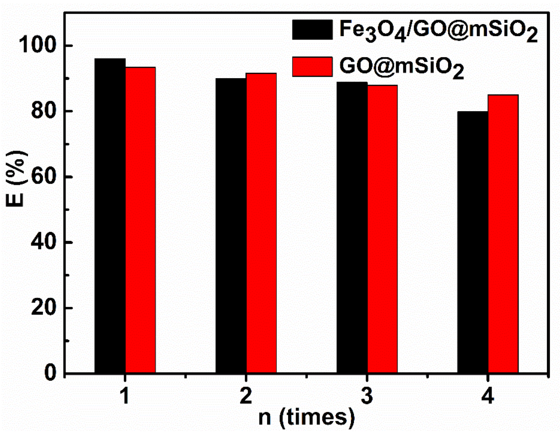

Fig. S10 Multicyclic adsorption efficiency of Fe_3O_4/GO@mSiO_2 and GO@mSiO_2

References

1 W. Fan,W. Gao,C. Zhang,W. Tjiu,J. Pan and T. Liu, *J. Mater. Chem.*, 2012, **22**, 25108-25115.
2 Y. Yao, S. Miao, S. Yu, L. Ma, H. Sun and S. Wang, *Colloid. Interf. Sci.*, 2012, **379**, 20-27.
3 P. Wang, M. Cao, C. Wang, Y. Ao, J. Hou and J. Qian, *Appl. Surf. Sci.*, 2014, **290**, 116-124.
4 J. Deng, X. Zhang, G. Zeng, , J. Gong, Q. Niu and J. Liang, *Chem. Eng. J.*,2013, **226**, 189-200.
5 S. Wang, H. Li and L. Xu, *J. Colloid. Interf. Sci.*, 2006, **295**, 71-78.
6 C. H. Huang, K. P. Chang, H. D. Ou, Y. C. Chiang and C. F. Wang, *Micropor. Mesopor. Mat.*, 2011, **141**, 102-109.
7 P.Monash and G. Pugazhenthi, *Korean. J. Chem. Eng.,* 2010, **27**, 1184-1191.