Front. Chem. Sci. Eng.

DOI 10.1007/s11705-018-1784-x

RESEARCH ARTICLE

Cube-octameric silsesquioxane (POSS)-capped magnetic iron oxide nanoparticles for the efficient removal of methylene blue

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Received June 19, 2018; Accepted September 27, 2018

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Electronic Supplementary Material

Contents:

Figure S1: EDX Analysis of a) Fe_3O_4@POSS, and b) Fe_3O_4@POSS-COOH hybrid magnetic nanoparticles

Figure S2: EDX Fe and Si maps of Fe_3O_4@POSS

Figure S3: EDX Fe, Si and S maps of Fe_3O_4@POSS-COOH

Figure S4: Nitrogen adsorption−desorption isotherms of a) bare Fe_3O_4, b) Fe_3O_4@POSS-COOH and the pore size distribution curves of c) bare Fe_3O_4, d) Fe_3O_4@POSS-COOH.

Figure S5: TEM image of acid treated Fe_3O_4@POSS-COOH

Figure S6: TGA and DTG curves of a)Fe_3O_4@POSS-COOH and b) TGA Curve of bare Fe_3O_4

Figure S7: Comparison between the adsorption of MB by different amounts of Fe_3O_4@POSS and Fe_3O_4@POSS-COOH nanoparticles

Table S1: Thermodynamic parameters of the adsorption of MB by Fe_3O_4@POSS and Fe_3O_4@POSS-COOH

Table S2: Comparison of Fe_3O_4@POSS-COOH adsorbent with other reported systems

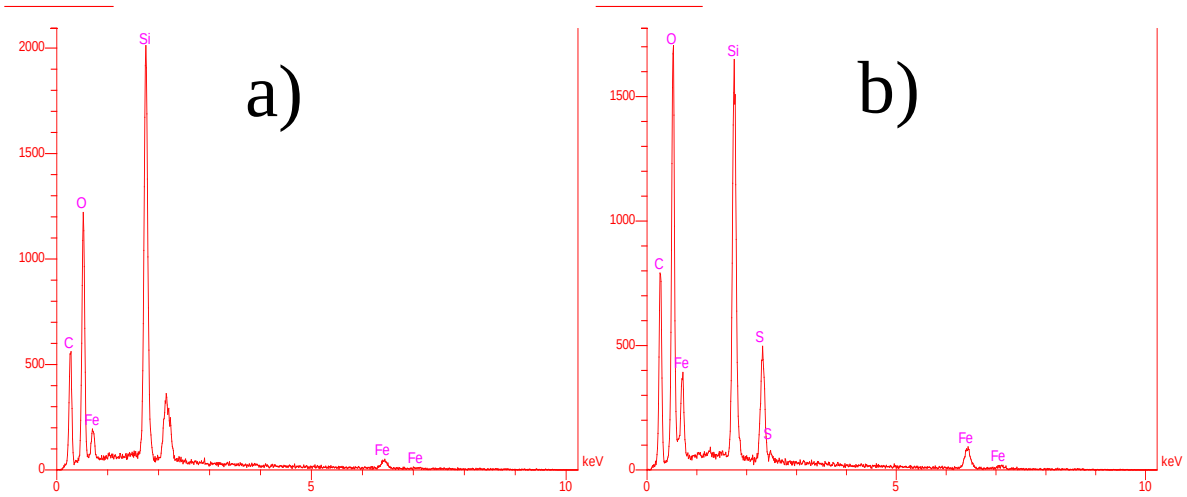
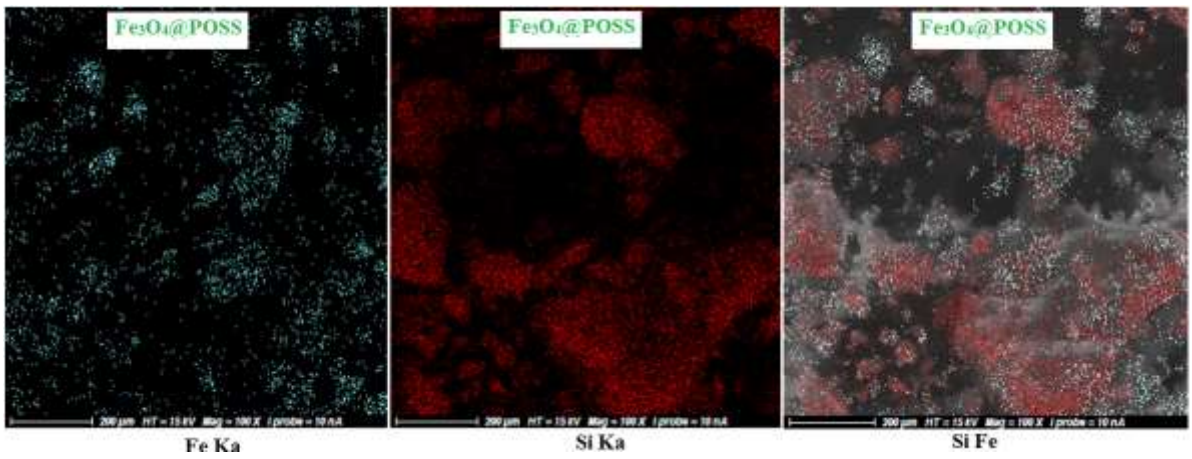


Figure S1



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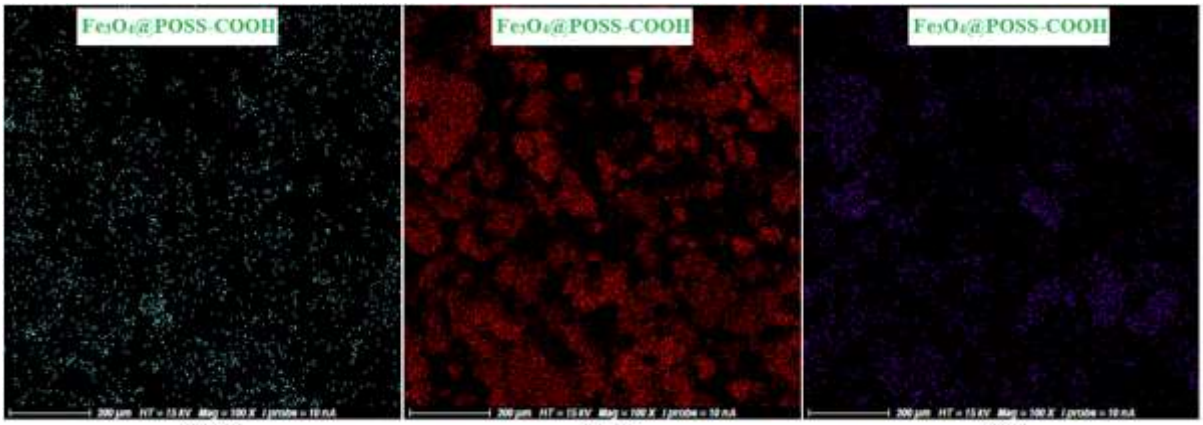
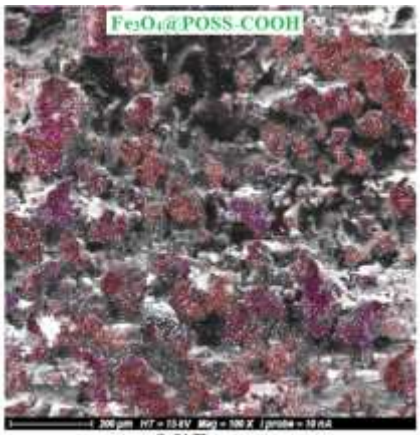


Fe Ka Si Ka S Ka



S Si Fe

Figure S3

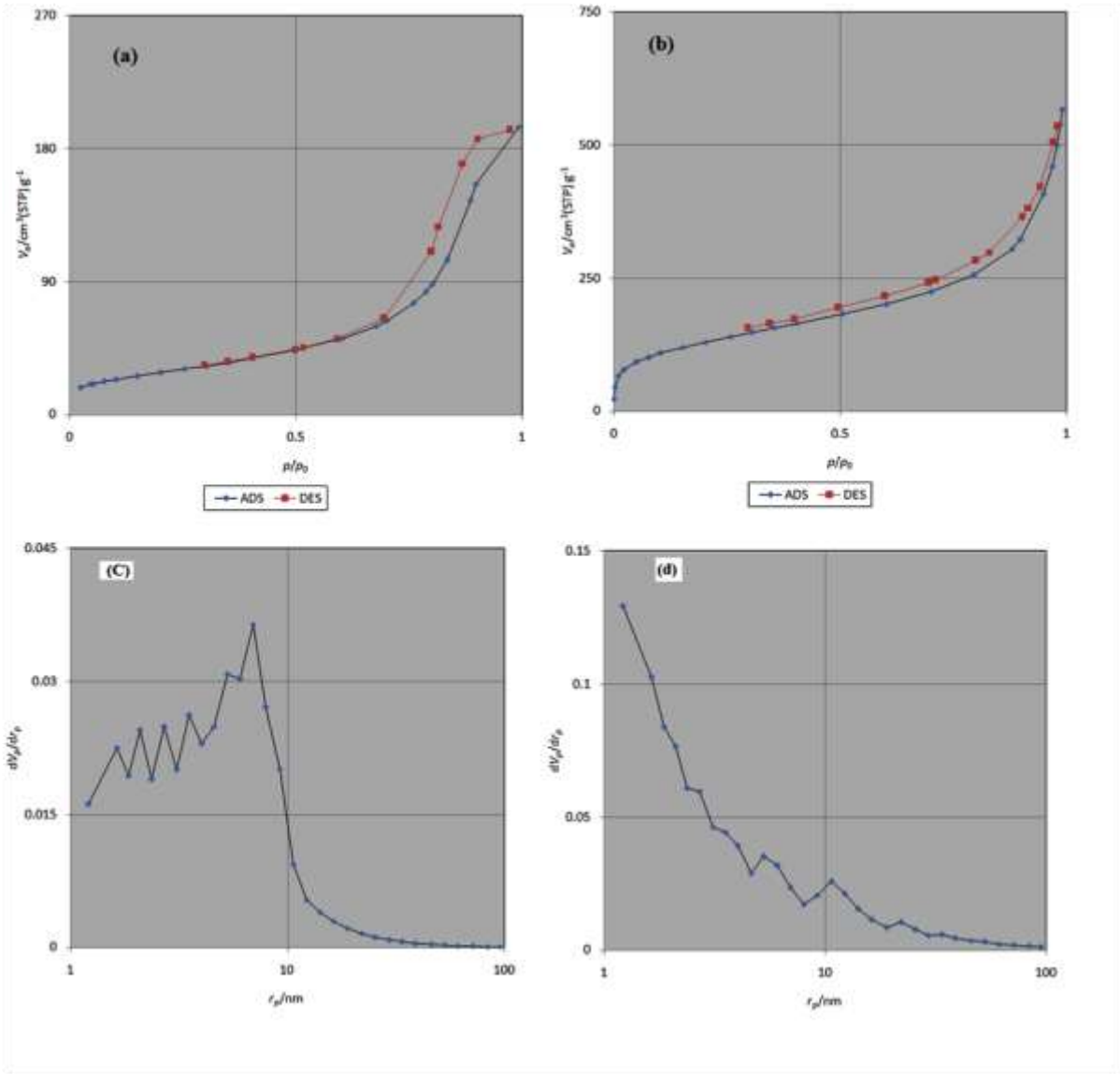


Figure S4

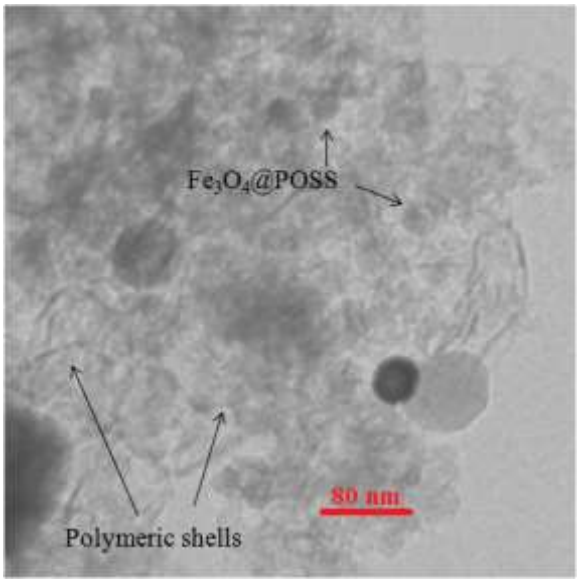


Figure S5

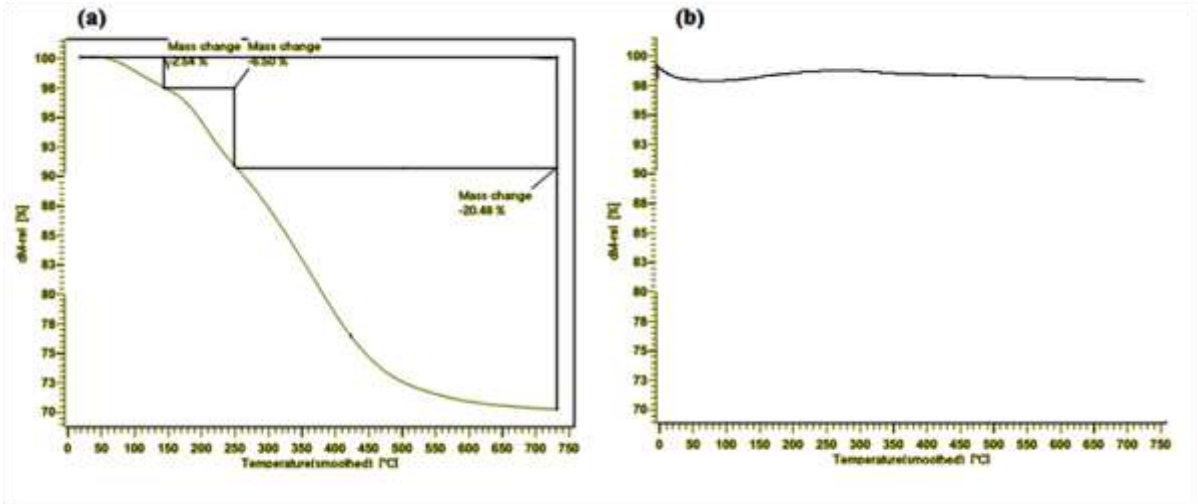


Figure S6

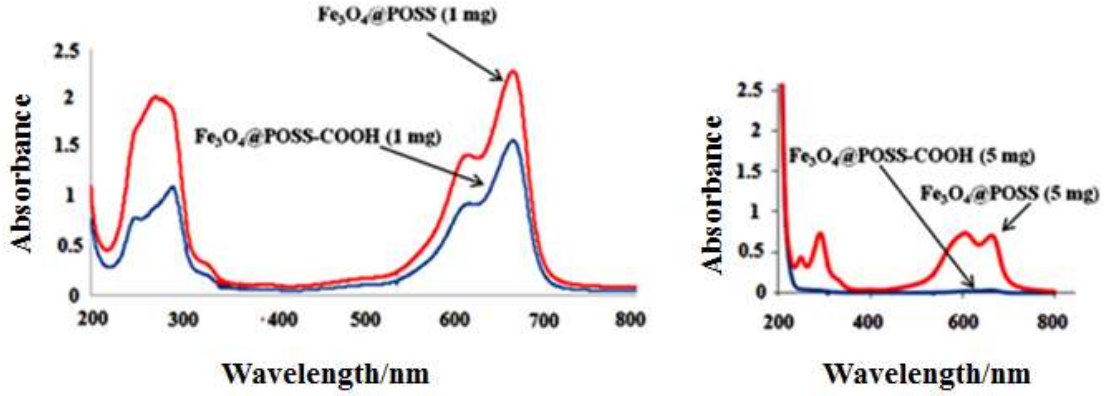


Figure S7

Table S1

nanocomposite	T (K)	$\Delta G°$(KJ mol^{-1})	$\Delta H°$ (KJ mol^{-1})	$\Delta S°$ (J mol^{-1}K^{-1})
Fe_3O_4@POSS	298	-18.5	46.2	0.21
	318	-20.6		
Fe_3O_4@POSS-COOH	298	-22.0	88.3	0.37
	318	-29.5		

Table S1

Materials	Preparation Method	Adsorption conditions and Time	Physical Parameters	Remarks	Ref
SH-mSi@Fe_3O_4	Sol-gel method	Water, pH:6-7; Time: 180 min; reusability: 6 runs	S_{BET}: 321 m^2/g; Pore diameter: 2.5 nm; Particle size: 500 nm	Long adsorption time; Surfactant involved; Limited by silanes	[1]
Thiol functionalized Magnetic-SBA-15	Sol-gel method and Silylation	Water, pH:8.2; Time: 24 h; reusability: 10 runs	S_{BET}: 297 m^2/g; Pore diameter: 6.7 nm; Particle size: No reported	Long adsorption time; Block copolymer involved; Limited by silanization	[2]
Fe_3O_4/SiO_2/CTAB	Sol-gel method and Silylation	Water, pH:2; Time: 300 min; reusability: 6 runs	S_{BET}: 49.96 m^2/g; Pore diameter: 2.57 nm; Particle size: 290 nm	Long adsorption time; Surfactant involved; Limited by silanization	[3]
Fe_3O_4@nSiO_2@ mSiO_2	Sol-gel method	Buffer, pH:8; Time: 1 h; reusability: 3 runs	S_{BET}: 496 m^2/g; Pore diameter: 2.44 nm	Surfactant involved; Limited by silanization	[4]

Fe_3O_4@POSS-SO_3H	Polymerization and Thiol-ene addition reaction	Water, pH:1-6; Time: 4 h; reusability: 5 runs	S_{BET}: 649 m^2/g; Pore diameter: 2.98 nm;	High surface area; Surfactant free; Very long time adsorption	[5]
Fe_3O_4@POSS-COOH	Polymerization and Thiol-ene addition reaction	Water, pH:6-10; Time: 5 min; reusability: 5 runs	S_{BET}: 447 m^2/g; Pore diameter: 15 nm; Particle size: 10-20 nm	High surface area; Surfactant free; Very short time adsorption	This Work

[1] G. Li, Z. Zhao, J. Liu, G. Jiang, Effective heavy metal removal from aqueous systems by thiol functionalized magnetic mesoporous silica, Journal of hazardous materials, 192 (2011) 277-283.
[2] B.C. Kim, J. Lee, W. Um, J. Kim, J. Joo, J.H. Lee, J.H. Kwak, J.H. Kim, C. Lee, H. Lee, Magnetic mesoporous materials for removal of environmental wastes, Journal of hazardous materials, 192 (2011) 1140-1147.
[3] L. Lian, X. Cao, Y. Wu, D. Lou, D. Han, Synthesis of organo-functionalized magnetic microspheres and application for anionic dye removal, Journal of the Taiwan Institute of Chemical Engineers, 44 (2013) 67-73.
[4] D. He, X. He, K. Wang, Y. Zhao, Z. Zou, Regenerable multifunctional mesoporous silica nanocomposites for simultaneous detection and removal of mercury (II), Langmuir, 29 (2013) 5896-5904.
[5] X. Wang, R. Peng, H. He, X. Yan, S. Zhu, H. Zhao, D. Deng, Y. Qiongwei, Y. Lei, L. Luo, Nanomagnetic polyhedral oligomeric silsesquioxanes composite derived sulfur-containing adsorbents for effective elimination of hexavalent chromium and organic cationic dyes from water, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 550 (2018) 1-8.