

Supporting Information

Synthesis of La-Fe₃O₄@Polydopamine Core-Shell Magnetic Composites for Enhanced Phosphate Removal from Aqueous Solutions

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Table S1 XPS quantitative analysis results of 2.5%La-Fe₃O₄ particles at different etching depths

Etch depth (nm)	La atomic percentage (%)	Fe atomic percentage (%)	La/Fe atomic ratio (%)
0	0.10	5.20	1.92
30	0.21	18.29	1.15
60	0.33	22.19	1.49

Table S2 Room-temperature magnetic parameters of Fe₃O₄ and 2.5%La-Fe₃O₄@PDA

Sample	Saturation magnetization M_s (emu g ⁻¹)	Remanent magnetization M_r (emu g ⁻¹)	Coercivity H_c (Oe)
Fe ₃ O ₄	62.72	1.90	37.56
2.5%La-Fe ₃ O ₄ @PDA	43.72	2.18	67.37

Measurement conditions: Room temperature (~295 K), field range ±20 kOe.

Table S3 Kinetics adsorption parameters of phosphate by 2.5%La-Fe₃O₄@PDA

Model	Parameter	
Pseudo-First Order	C ₀ (mg P L ⁻¹)	100
	q _e ^{exp} (mg P g ⁻¹)	123.44
	k ₁ ×10 ⁻³ (min ⁻¹)	7.18
	q _e ^{cal} (mg P g ⁻¹)	51.90
	R ²	0.97167
Pseudo-Second Order	k ₂ ×10 ⁻⁴ (g·mg P ⁻¹ ·min ⁻¹)	4.209
	q _e ^{cal} (mg P g ⁻¹)	126.74
	R ²	0.99958

Table S4 The D-R, Freundlich, and Sips isotherm parameters for the adsorption of phosphate by 2.5%La-Fe₃O₄@PDA

Model	Parameter	
D-R model	qd (mol g ⁻¹)	4.75×10 ⁻³
	Kd (mol ² kJ ⁻²)	4.242×10 ⁻⁴
	Ed (kJ mol ⁻¹)	34.32
	R ²	0.94588
Freundlich model	K (mg g ⁻¹)	1.216
	n	1.221
	R ²	0.91234
Sips model	β	3.886
	b [L (mg P) ⁻¹]	2.208×10 ⁻²
	R ²	0.97711

Table S5 XPS binding energies and spectral parameters of 2.5%La-Fe₃O₄@PDA before and after phosphate adsorption

Sample	La 3d _{5/2} BE (eV)	La 3d _{5/2} satellite BE (eV)	ΔE (eV)	Satellite/main intensity ratio	Fe 2p _{3/2} BE (eV)	P 2p BE (eV)
Before adsorption	835.1	838.4	3.3	0.44	710.5	-
After adsorption	835.6	839.0	3.4	0.51	710.5	133.6 (weak)

Table S6 Comparison of adsorption capacities among different adsorbents for phosphate

Adsorbent	Adsorption capacity (mg P g ⁻¹)	Equilibrium Time (min)	References
ACF-ZrFe	26.3	900	1
Al-modified biochar	57.49	1440	2
Fe-Mn-La tri-metal composite sorbent	61.80	600	3
Fe ₃ O ₄ @La(OH) ₃	63.72	20	4
La-Fe-CSR	74.87	120	5
Zr@CSQ beads	142.95	60	6
2.5%La-Fe ₃ O ₄ @PDA	123.44	180	This study

Table S7 Estimated raw material cost for the synthesis of 2.5% La-Fe₃O₄@PDA (per gram of product)

Raw material	Amount (g)	Unit price (USD g ⁻¹)	Cost (USD)
FeCl ₃ ·6H ₂ O	0.425	0.024	0.0102
NaOAc	0.75	0.0148	0.0111
EDTA-2Na	0.02125	0.0149	0.00032
La(NO ₃) ₃ ·6H ₂ O	0.00675	0.0322	0.00022
Dopamine hydrochloride	0.025	0.8926	0.0223
Total			0.0441

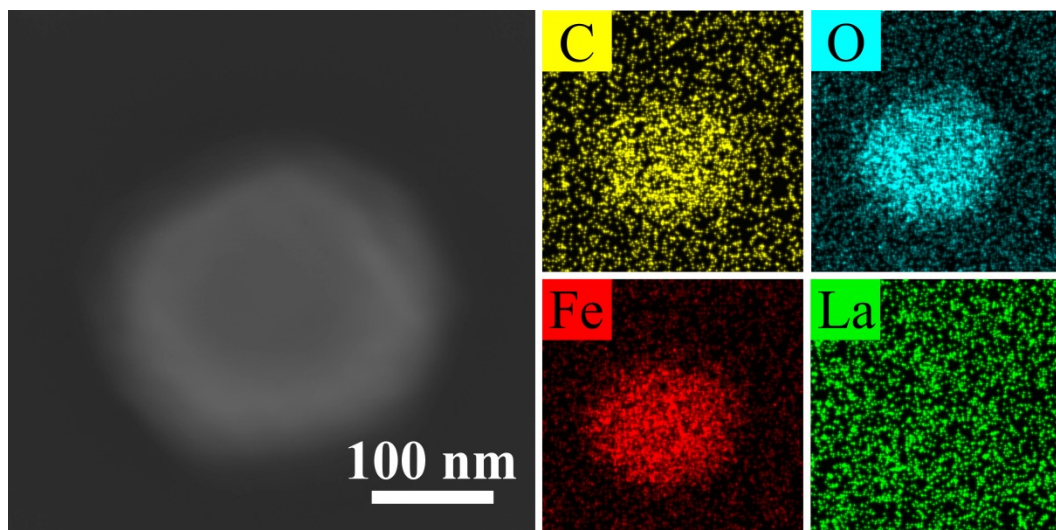


Fig. S1 Elemental mapping of La-Fe₃O₄.

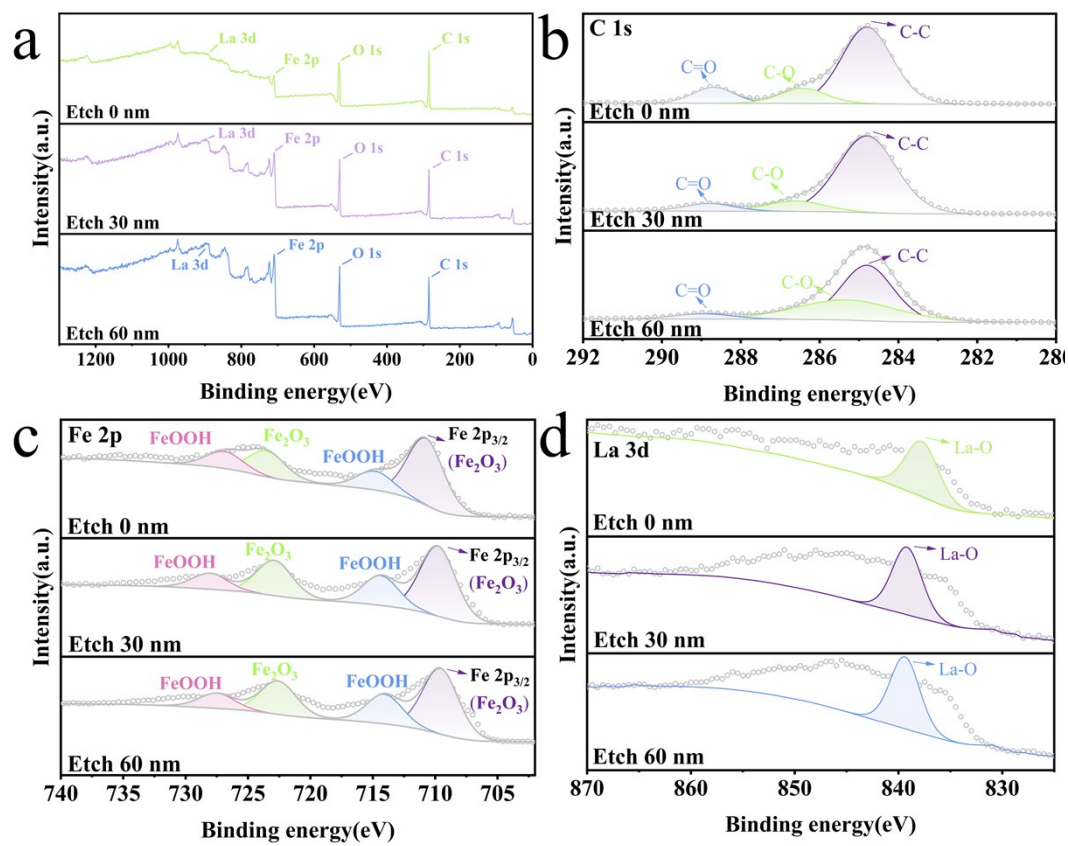


Fig. S2 High-resolution XPS spectra of 2.5%La-Fe₃O₄ particles at different etching depths.

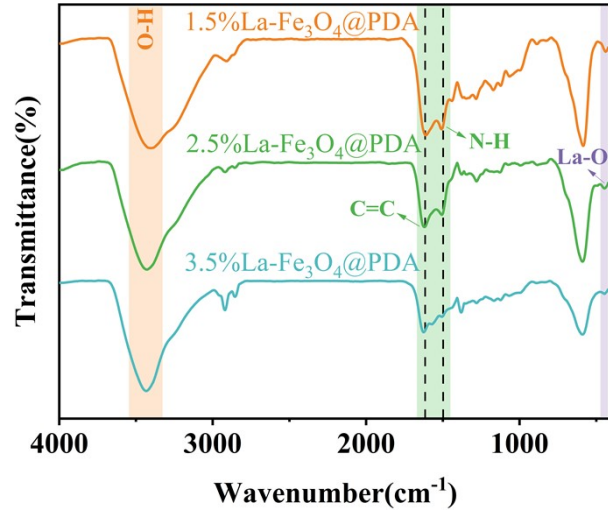


Fig. S3 FT-IR spectra of different La doping ratios.

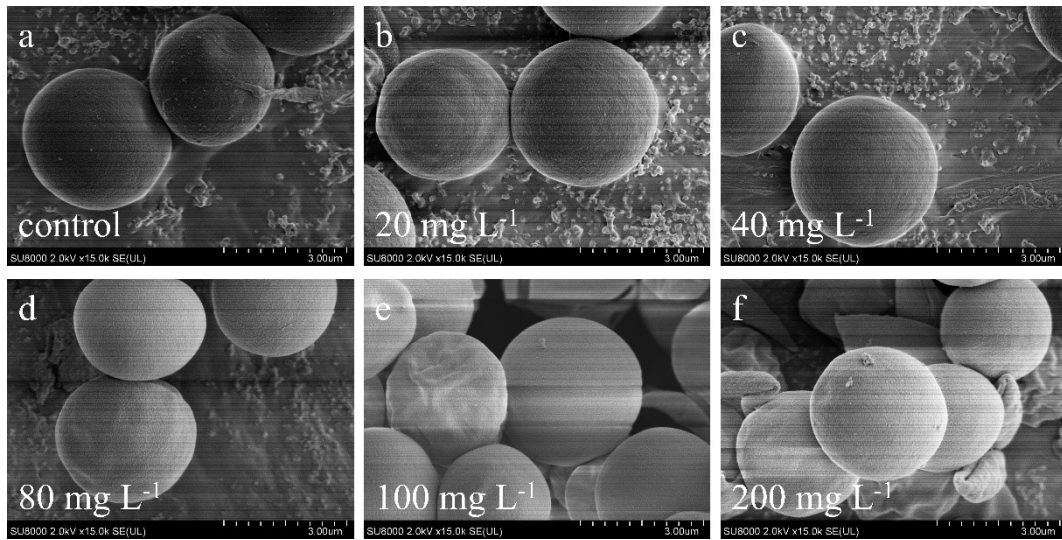


Fig. S4 Scanning electron microscope (SEM) images of *Chlorella* sp. exposed to different concentrations of 2.5%La-Fe₃O₄@PDA for 30 days. (a) Control, (b) 20 mg L⁻¹, (c) 40 mg L⁻¹, (d) 80 mg L⁻¹, (e) 100 mg L⁻¹, (f) 200 mg L⁻¹. Scale bars = 3.00 μm.

Notes and references

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