

**Ion-Modulated Graphene Oxide and GO@MXene Hydrogels:
Enhanced Adsorption Performance and Stability for Methylene Blue
Removal**

Xiaojing Chen^{a,b,\$}, Jia Li^{a,\$}, Caojie Zhao^a, Wen Zhou^a, Jin Yang^{a,b}, Qingjun Liu^{a,*},
Wenshuai Jiang^{a,b,c,*}

^a *School of Medical Engineering, Xinxiang Medical University, Xinxiang, Henan
453003, People's Republic of China*

^b *Xinxiang Key Laboratory of Neurobiosensor, Xinxiang, Henan 453003, People's
Republic of China*

^c *Henan Engineering Technology Research Center of Neural Sensing and Control,
Henan 453003, People's Republic of China*

\$ These authors contributed equally to this work.

* Corresponding author. E-mail addresses: 171024@xxmu.edu.cn (W.S. Jiang),
qjliu@zju.edu.cn (Q.J. Liu).

Fig. S1-Fig. S7

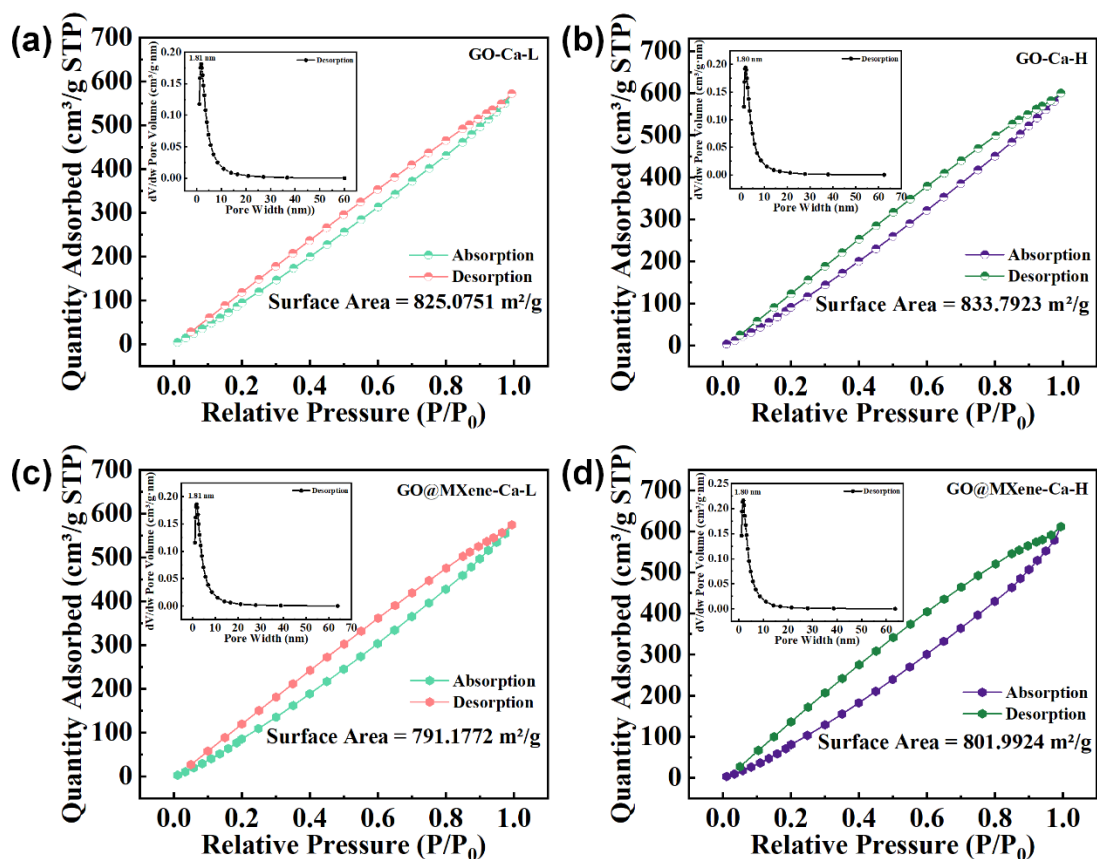


Fig. S1. Nitrogen adsorption and desorption profiles of ion-crosslinked GO-Ca and GO@MXene-Ca hydrogels.

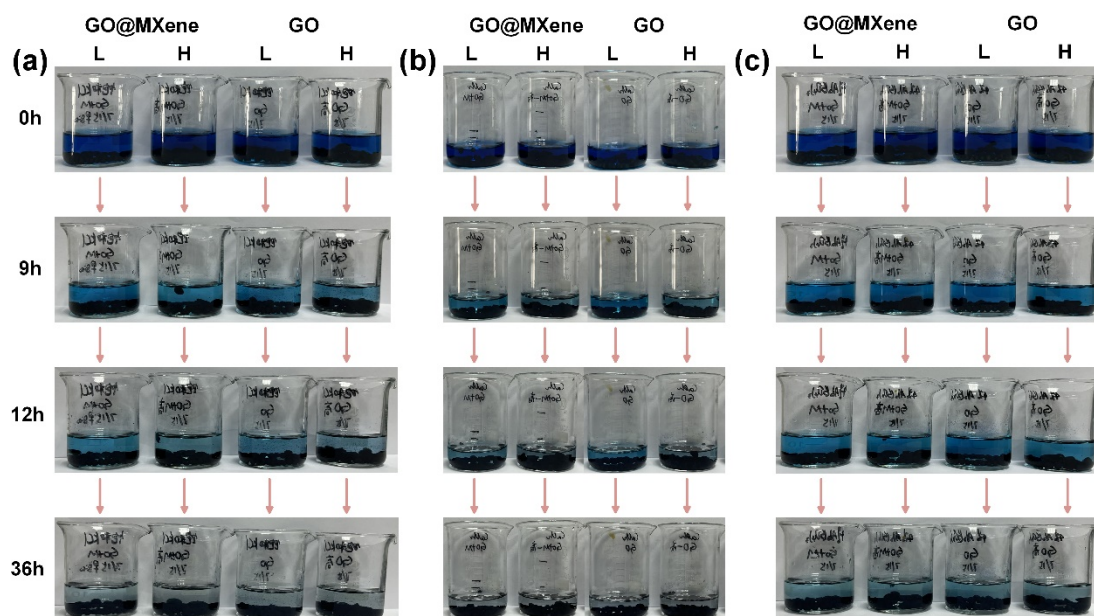


Fig. S2. MB adsorption experiments of hydrogels prepared at different heights. (a) K, (b) Ca, (c) Al. L indicates a preparation height of 0.5 cm and H indicates a preparation height of 3.5 cm.

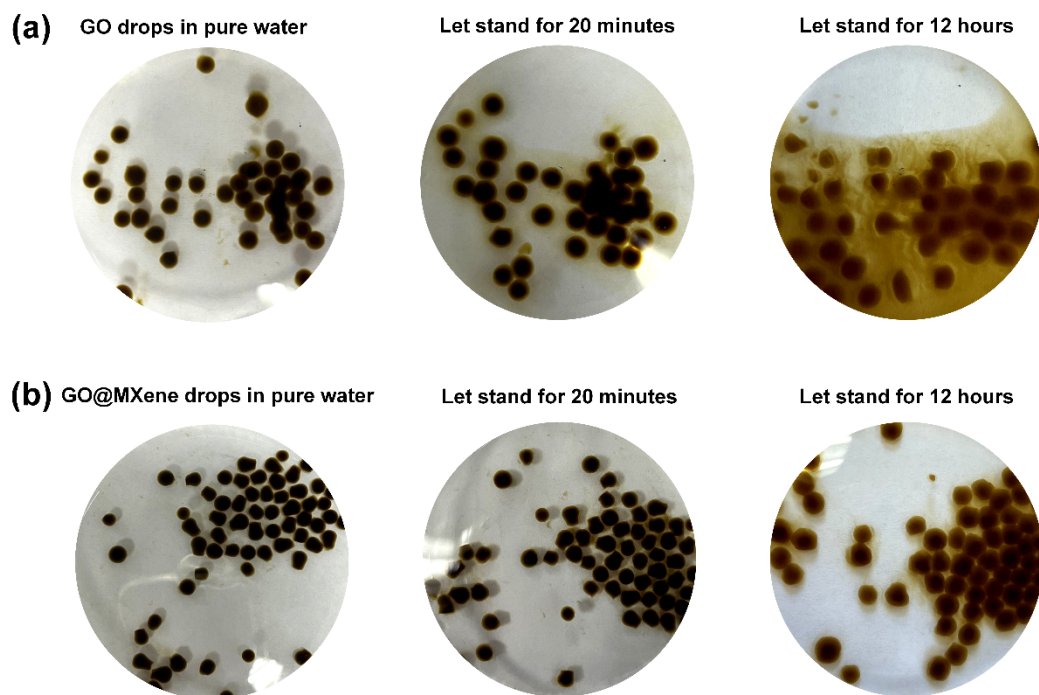


Fig. S3. GO hydrogels (a) and GO@MXene hydrogels (b) prepared without the introduction of ions in water.

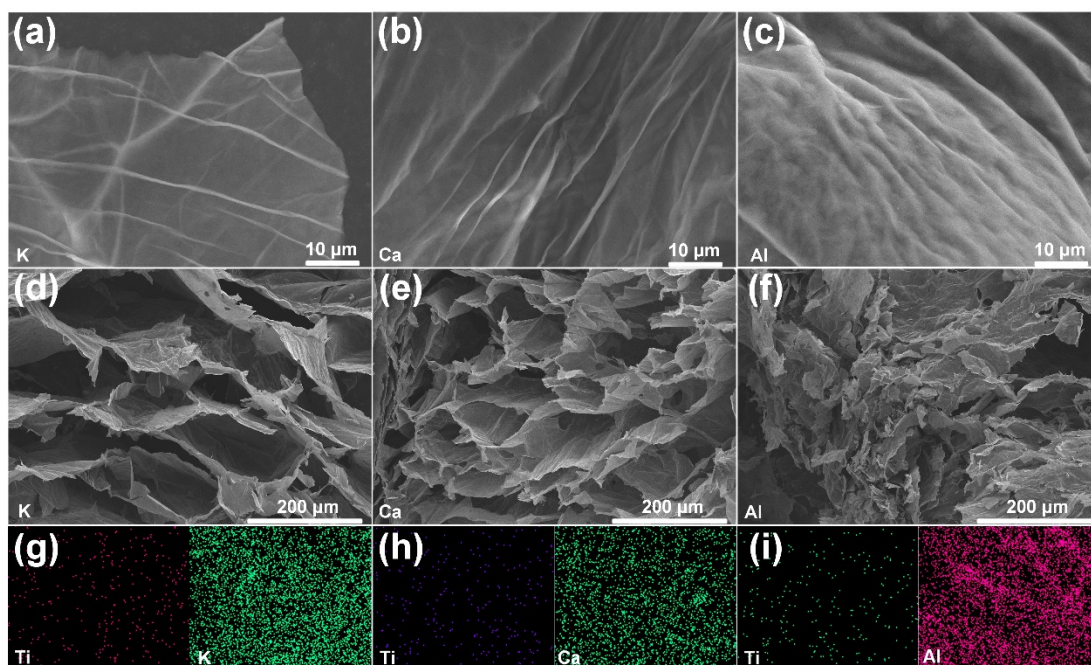


Fig. S4. SEM images of the surface (a–c) and cross-sectional (d–f) morphology of the GO-M hydrogel. (g–i) EDS results of GO@MXene–M hydrogels (M: K, Ca, Al).

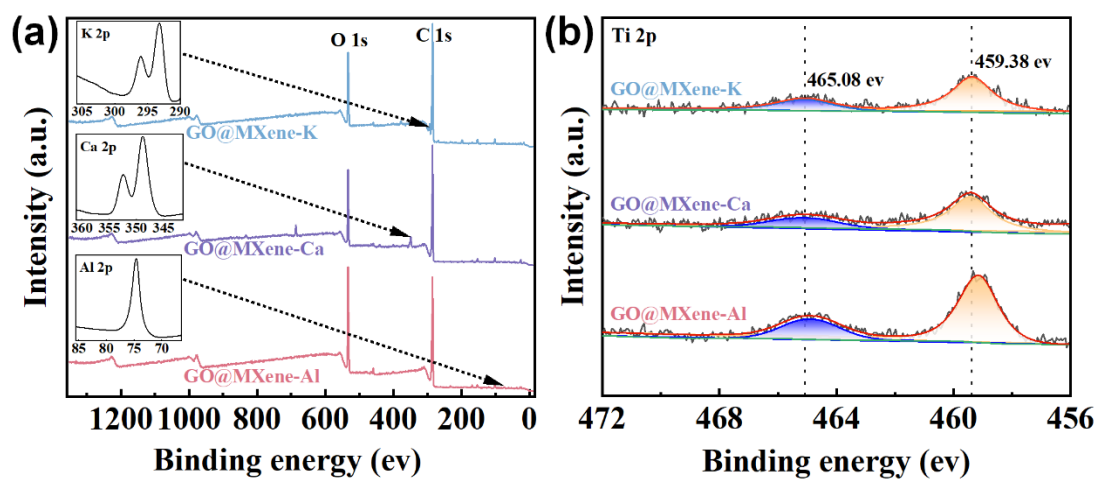


Fig. S5. The XPS results of GO@MXene-M (M: K, Ca, Al).

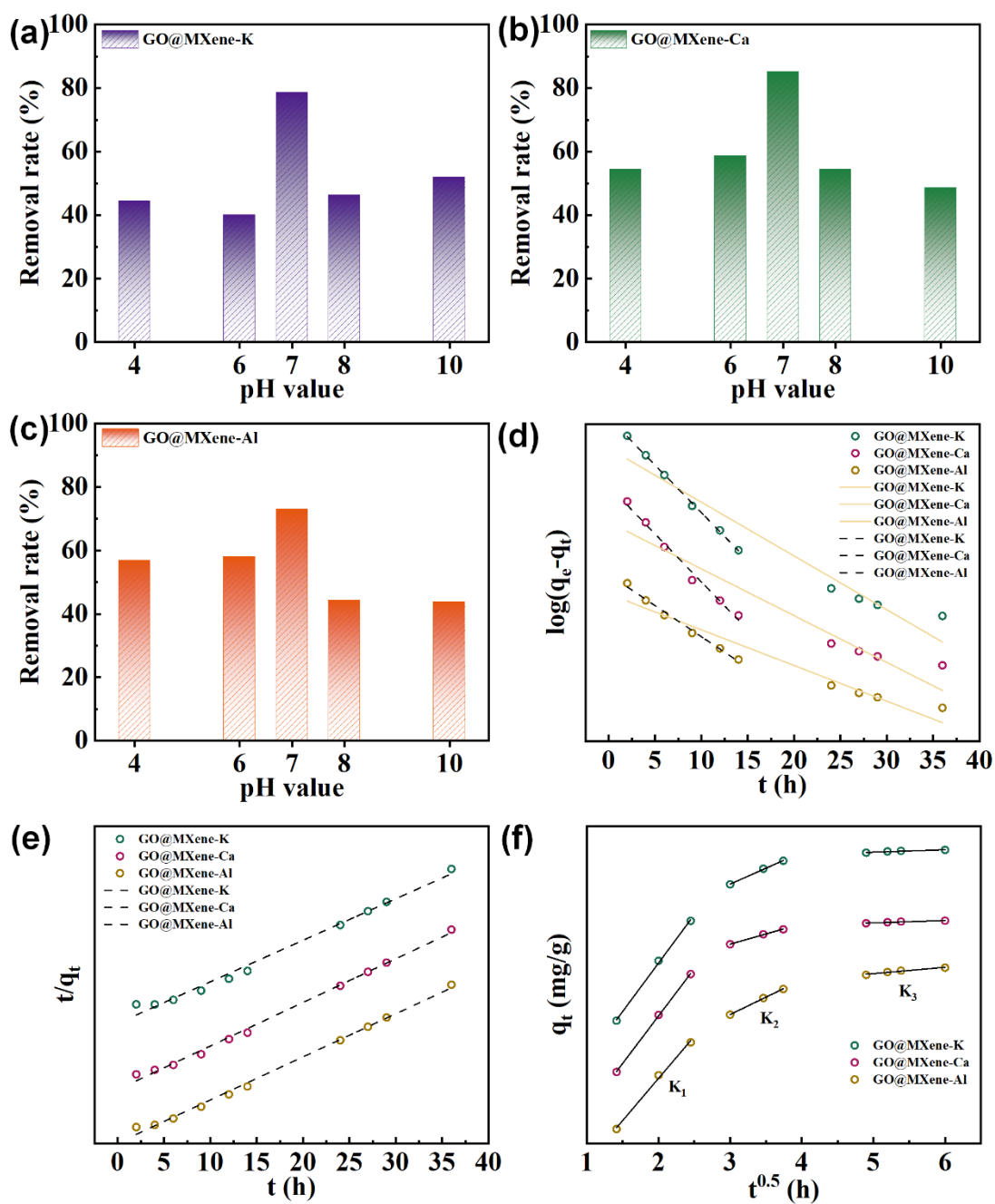


Fig. S6. Effect of solution pH on MB removal by GO@MXene-M hydrogels (data for the 12 h reaction of the adsorption system) (a-c). Pseudo-first-order model (d) and Pseudo-second-order model (e) for GO@MXene-M adsorbed MB. Intraparticle diffusion model for GO@MXene-M(f) (M: K, Ca, Al).

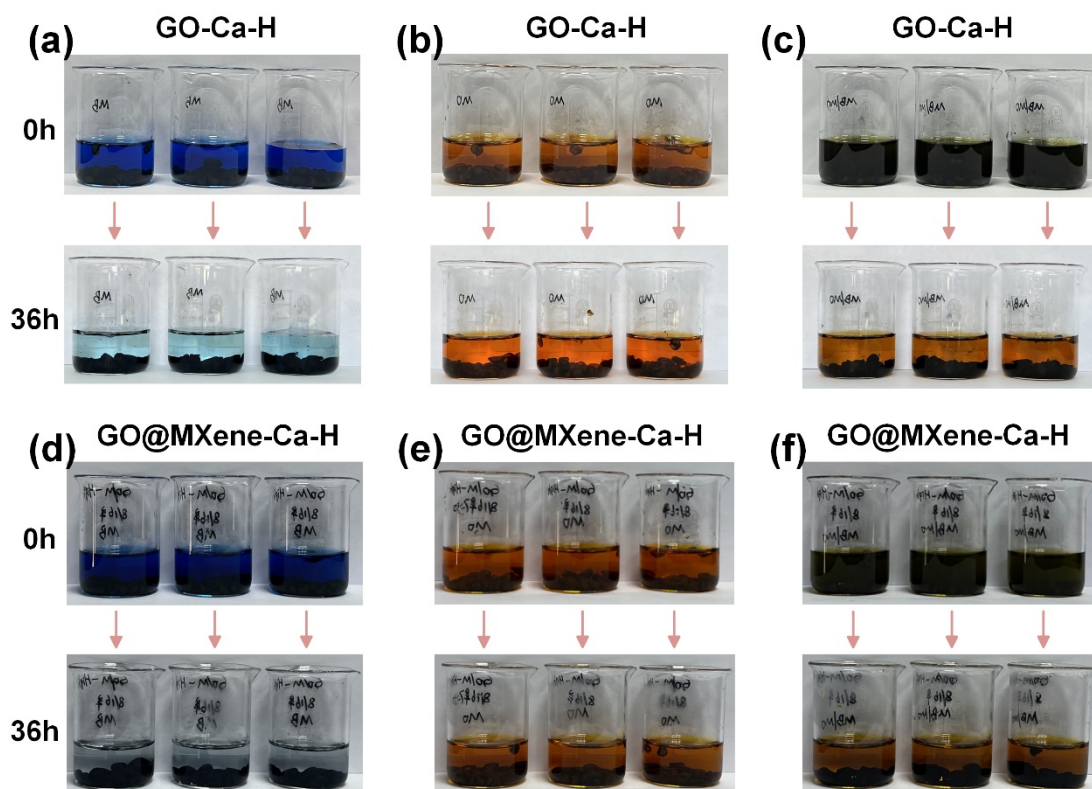


Fig. S7. Adsorption experiments of cationic dye MB and anionic dye methyl orange (MO) by GO-Ca-H hydrogels (a-c) and GO@MXene-Ca-H hydrogels (d-f) in single and mixed systems. (a, d) Single system with MB. (b, e) Single system with MO. (c, f) Mixed systems containing MB and MO. H indicates a preparation height of 3.5 cm.

Table S1- Table S3

Table S1. Pore structure analysis.

Sample	BET (m ² /g)	Pore volume (cm ³ /g)	Pore diameter (nm)
GO@MXene-K-L	792.5920	0.884724	2.9590
GO@MXene-Ca-L	791.1772	0.882750	3.2737
GO@MXene-Al-L	873.8592	0.921423	3.6258
GO@MXene-Ca-H	801.9924	0.935954	3.0896

Table S2. Absorption kinetic modeling correlation coefficients for MB adsorption on ion-modulated GO@MXene hydrogels.

Absorbent	Pseudo-first-order kinetic			Pseudo-second-order kinetic			Linear relation	
	k_1 h^{-1}	q_{e1} mg/g	R_1^2	k_2 $\text{g}/(\text{mg}\cdot\text{h})$	q_{e2} mg/g	R_2^2	R_1^2	R_2^2
GO@MXene-K	0.19	99.04	0.99 5	0.0019	116.37	0.97 4	0.922	0.988
GO@MXene-Ca	0.23	97.85	0.99 8	0.0026	111.69	0.97 8	0.873	0.995
GO@MXene-Al	0.18	93.78	0.99 9	0.0019	110.65	0.99 1	0.930	0.995

Table S3. Parameters for modeling intraparticle diffusion for MB adsorption on ion-modulated GO@MXene hydrogels.

Absorbent	Stage I			Stage II			Stage III		
	K_1	C_1	R_1^2	K_2	C_2	R_2^2	K_3	C_3	R_3^2
GO@MXene-K	41.	-32.45	0.9 2	13.	42.	0.99 57 85 6	1.04	91. 99	0.88
GO@MXene-Ca	40.	-23.54	0.9 34	8.6	61.	0.99 9 67 6	0.99	91. 88	0.91
GO@MXene-Al	35.	-24.10	0.9 84	14.	30.	0.99 80 38 9	2.69	78. 74	0.95