Supporting Information for

Heparin-Covalently Grafted Graphene Oxide Hybrid-Modified Polyethersulfone Membranes for Enhanced Toxin Clearance and Hemocompatibility in Hemodialysis

Xianya Wu, Zhijiang Sun, Yanfeng Wei, Mohammed Kamal Hadi, Yumeng Wang, Xiangya Wang, Fen Ran*

Energy Storage Institute, State Key Laboratory of Advanced Processing and Recycling of Non-ferrous Metals, School of Materials Science and Engineering, School of Green Energy and Storage, Gansu Interdisciplinary Center for Energy Storage Materials and Systems, Lanzhou University of Technology, Lanzhou 730050, China

*Corresponding Author: Dr. Prof. Fen Ran (ranfen@lut.edu.cn).

Table S1. *The casting solution composition for different membranes.*

Samples	PES (g)	PVP (g)	GO (g)	GH (g)	DMAc (mL)
PES	1.6	0.1	0	0	8.4
PES/GO	1.6	0.1	0.1	0	8.4
PES/GH	1.6	0.1	0	0.1	8.4

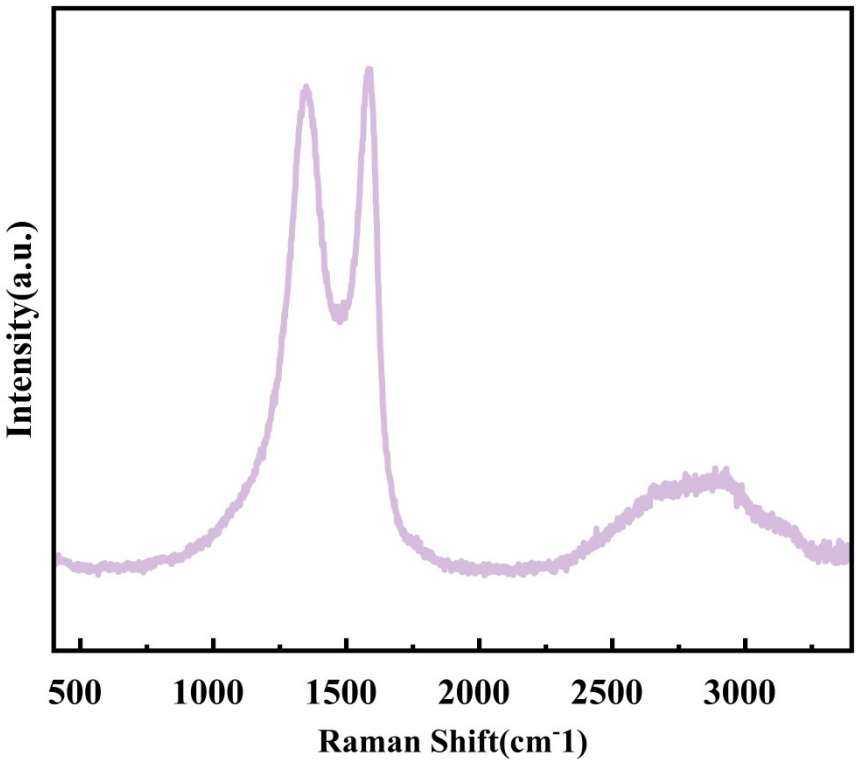

Figure S1. *Raman spectra of the pristine GO powder.*

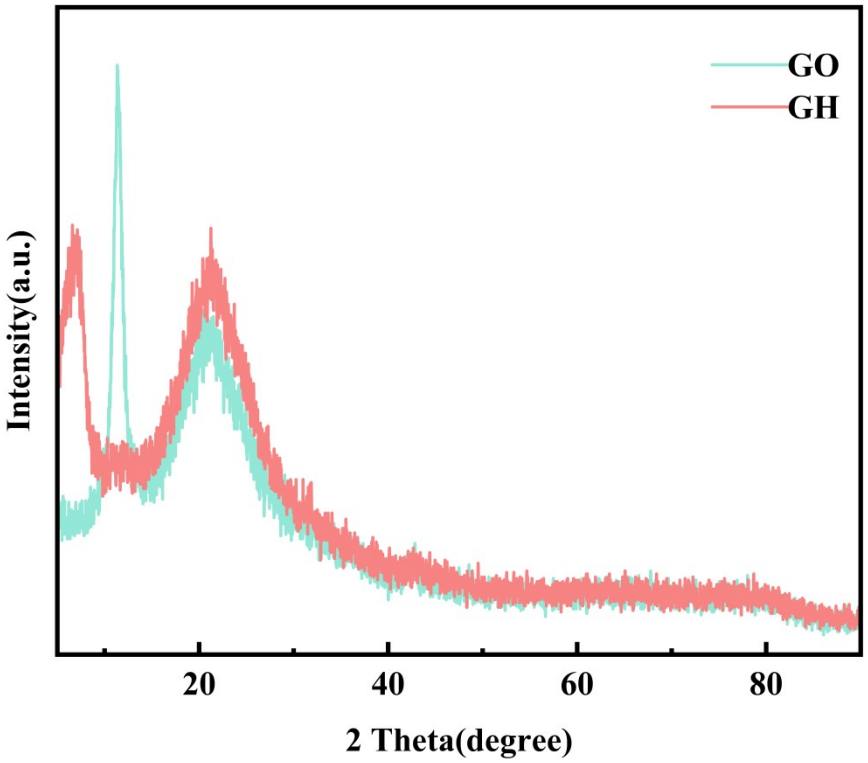

Figure S2. *XRD spectra of GO and GH.*

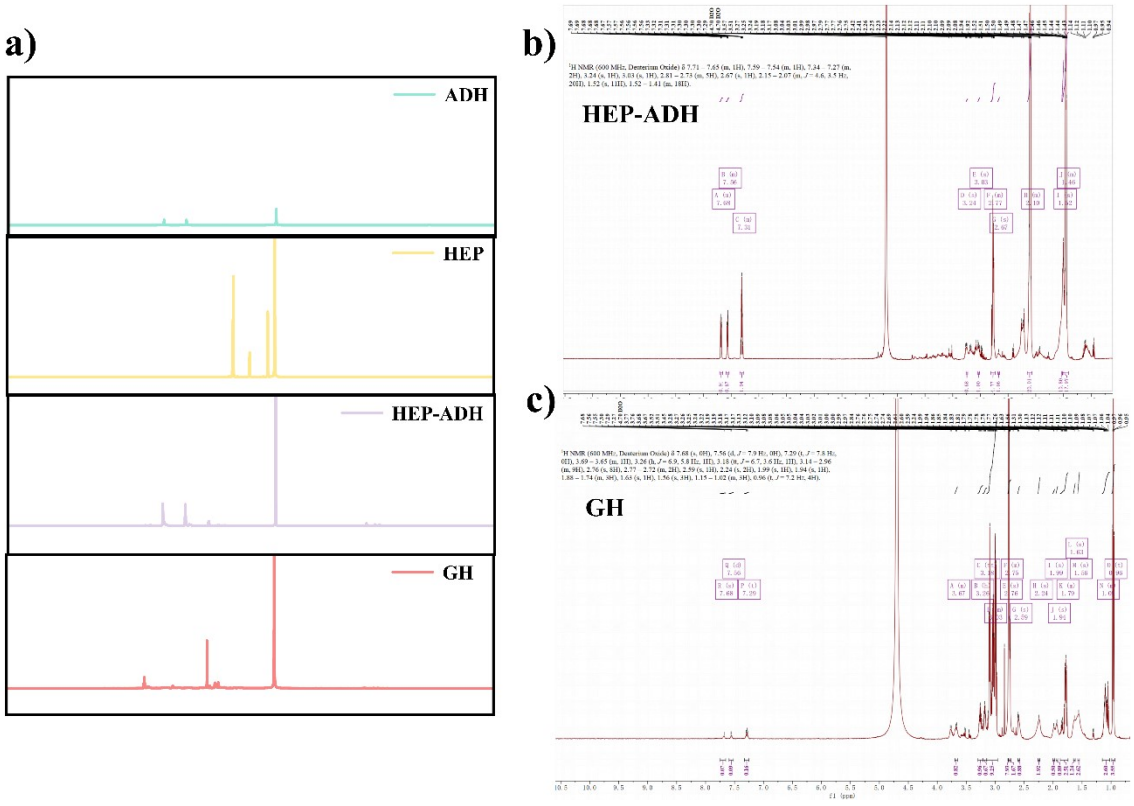

Figure S3. *a) [1]H NMR spectra of ADH, HEP, HEP-ADH, and the synthesized GH hybrid. (600 MHz, D_2O) b) [1]H NMR spectra of HEP-ADH. [1]H NMR (600 MHz, Deuterium Oxide) δ 7.71 – 7.65 (m, 1H), 7.59 – 7.54 (m, 1H), 7.34 – 7.27 (m, 2H), 3.24 (s, 1H), 3.03 (s, 1H), 2.81 – 2.73 (m, 5H), 2.67 (s, 1H), 2.15 – 2.07 (m, J = 4.6, 3.5 Hz, 20H), 1.52 (s, 11H), 1.52 – 1.41 (m, 18H). c) [1]H NMR spectra of GH. [1]H NMR (600 MHz, Deuterium Oxide) δ 7.68 (s, 0H), 7.56 (d, J = 7.9 Hz, 0H), 7.29 (t, J = 7.8 Hz, 0H), 3.69 – 3.65 (m, 1H), 3.26 (h, J = 6.9, 5.8 Hz, 1H), 3.18 (tt, J = 6.7, 3.6 Hz, 1H), 3.14 – 2.96 (m, 9H), 2.76 (s, 8H), 2.77 – 2.72 (m, 2H), 2.59 (s, 1H), 2.24 (s, 2H), 1.99 (s, 1H), 1.94 (s, 1H), 1.88 – 1.74 (m, 3H), 1.63 (s, 1H), 1.56 (s, 3H), 1.15 – 1.02 (m, 3H), 0.96 (t, J = 7.2 Hz, 4H).*

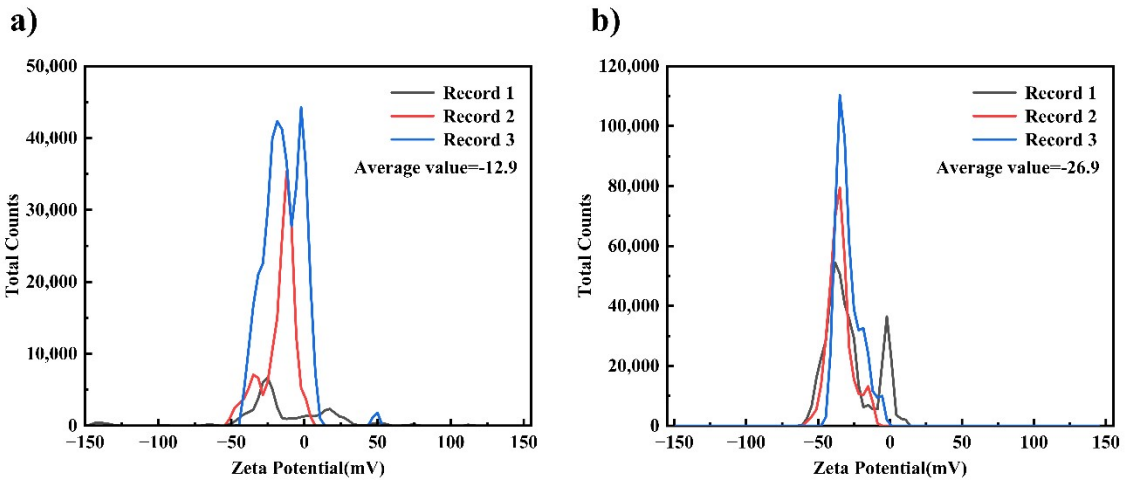

Figure S4. *Zeta potential values of a) GO and b) GH.*

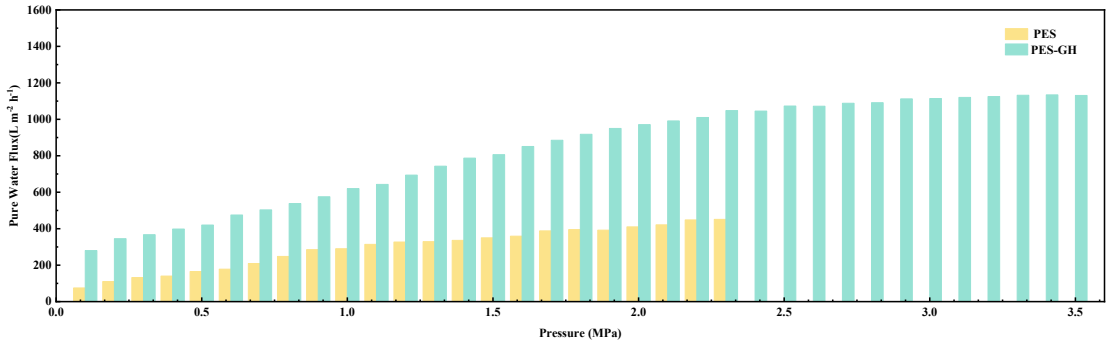

Figure S5. *Ultimate pressure resistance testing results for the pristine PES, PES-GO, and PES-GH composite membranes.*

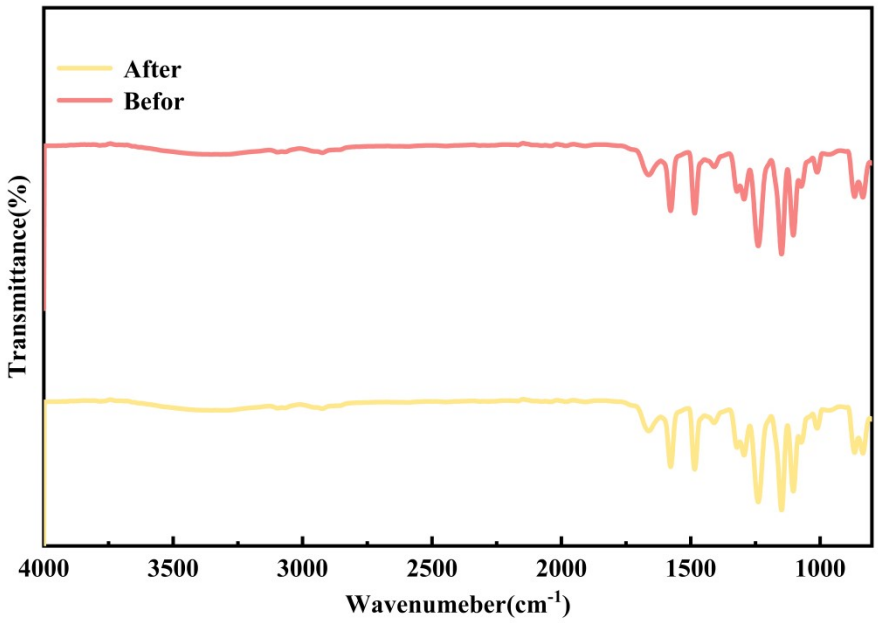

Figure S6. *ATR-FTIR spectra of the PES-GH membrane before and after the simulated reuse cleaning protocol (using a clinical-grade disinfectant). The consistent characteristic peaks confirm the chemical stability and retention of the covalently grafted GH hybrid on the membrane surface.*

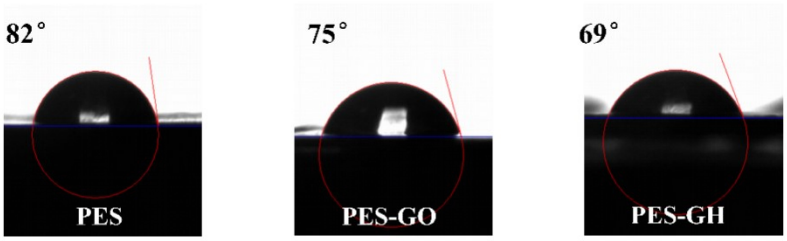

Figure S7. *Images of water contact angle with different membranes.*

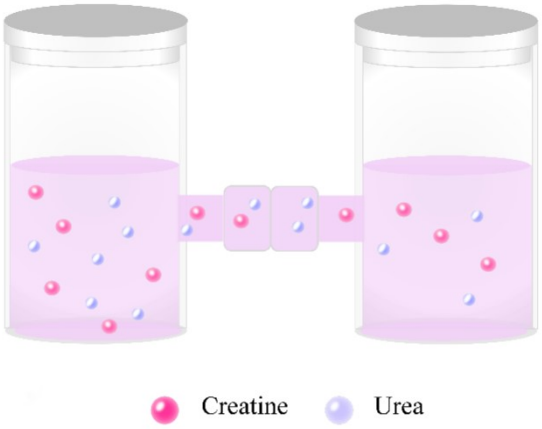

Figure S8. *Permeability dialysis experiment setup for clearance measurement of urea and creatine.*

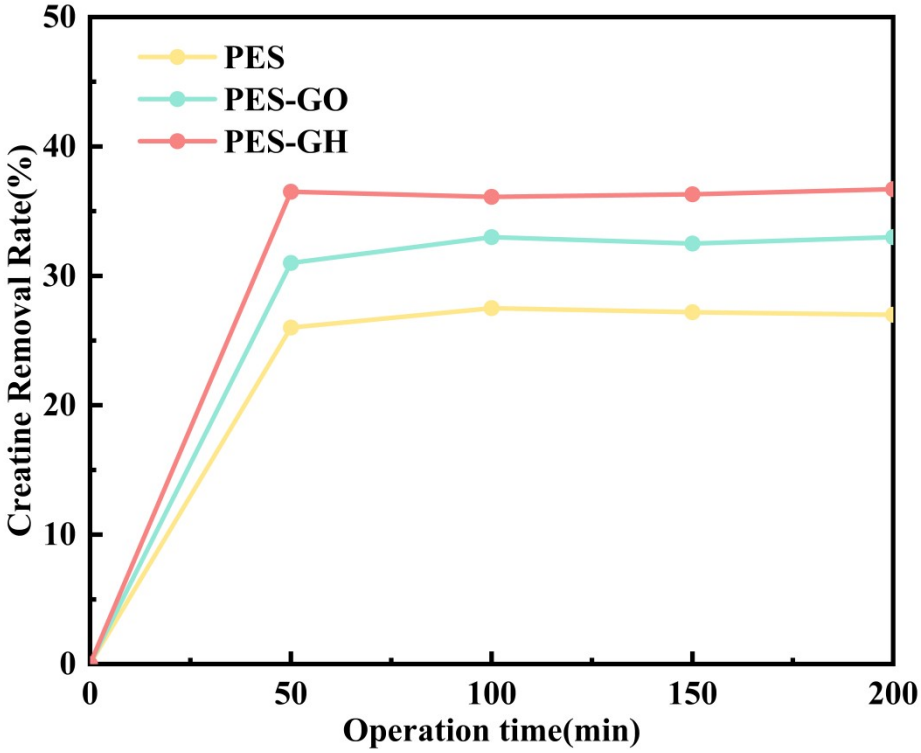

Figure S9. *The urea removal rate of different membranes.*

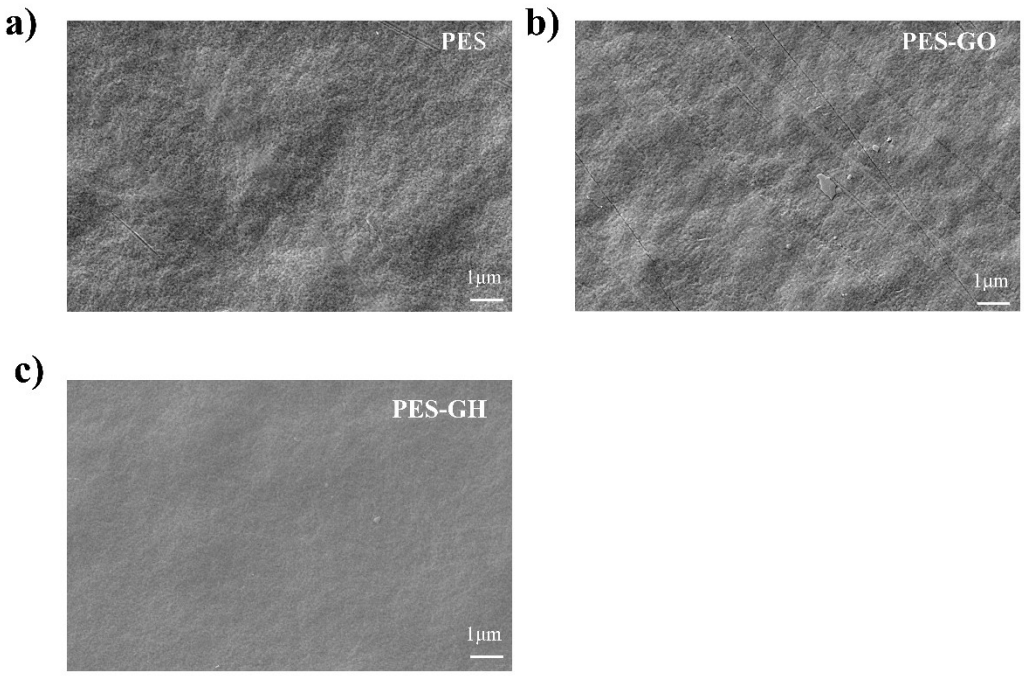

Figure S10. *The SEM images of PES,PES-GO and PES-GH membranes.*

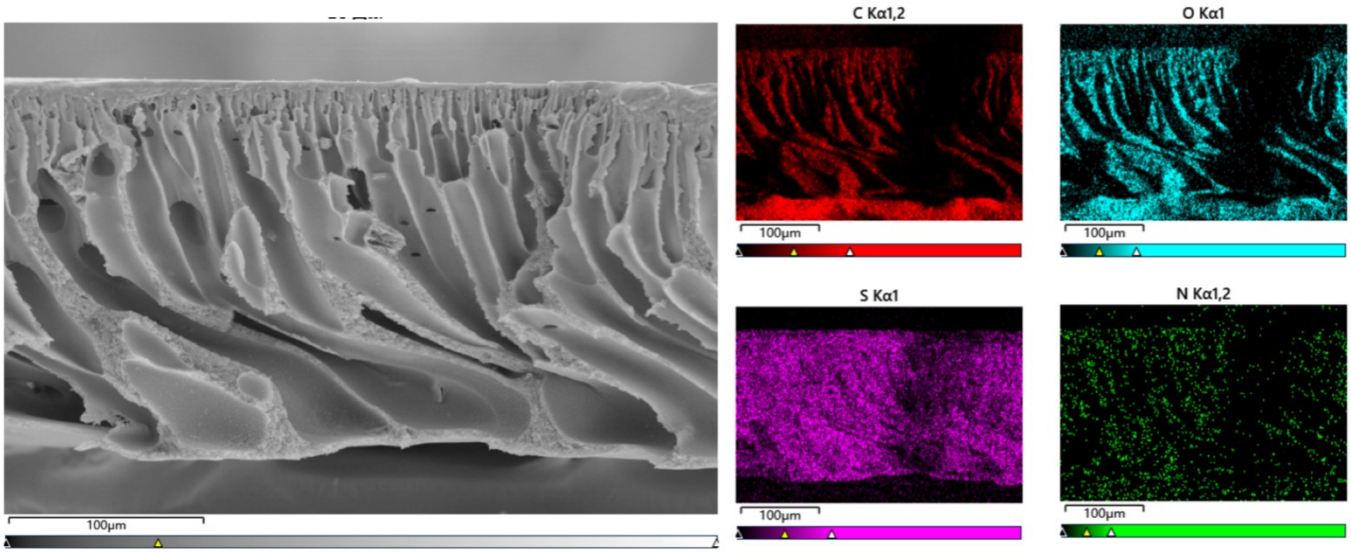

Figure S11. *Mapping images of cross-sectional views of PES-GH.*

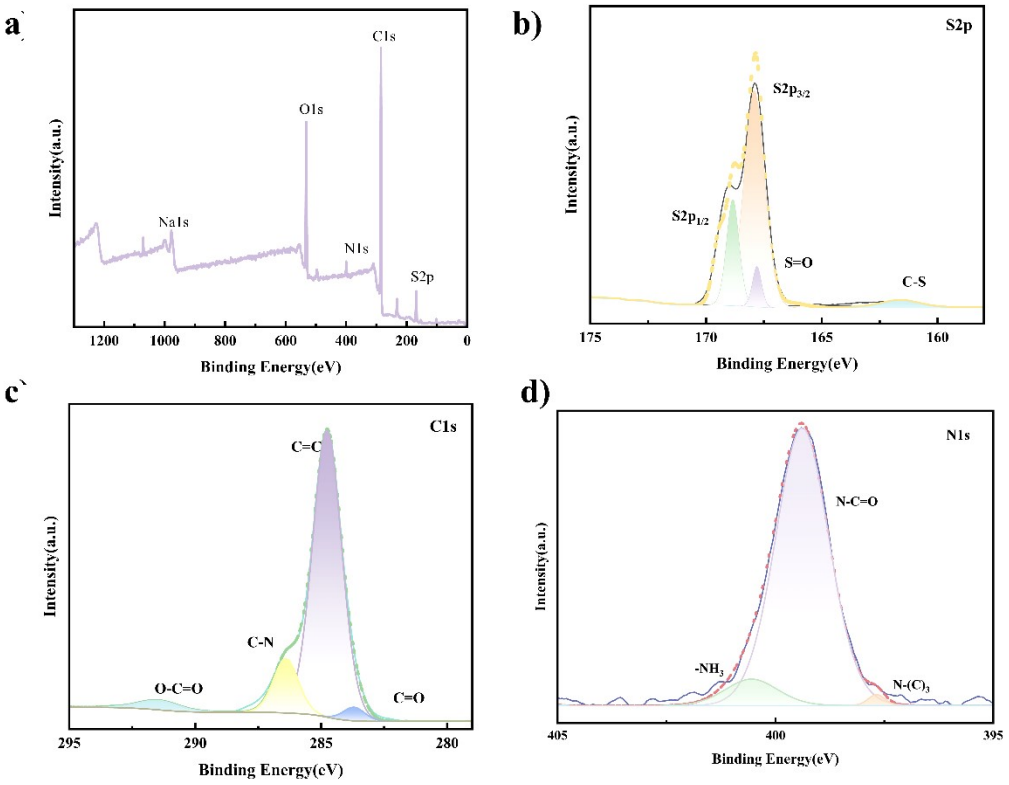

Figure S12. *XPS spectra of the GH hybrid membrane: (a) S 2p region showing characteristic peaks of sulfonic acid groups (~167–169 eV); (b) C 1s region showing amide linkages (~286–287 eV). These spectra confirm the successful covalent integration of heparin onto the GO framework.*