

Efficient Enantioselective Separation via a Homochiral Graphene Oxide Membrane

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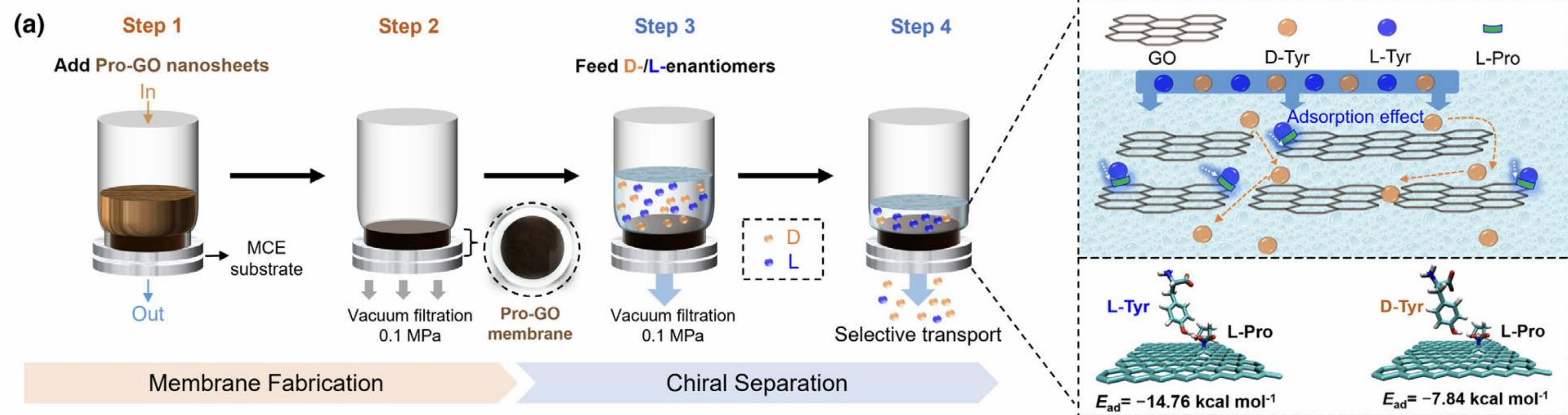
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Introduction



Chiral enantiomers are mirror images with identical physical properties yet divergent biological activities, making their efficient separation a fundamental challenge. Graphene oxide (GO) membranes possess tunable lamellar nanochannels that enable molecular sieving; however, existing chiral GO membranes remain limited by low separation factors (≤ 4.76) [1]. Here, we report a proline-functionalized GO membrane that leverages **differential adsorption energies** between the chiral channel walls and enantiomers, achieving a separation factor of **20.1** and a flux of **4.5 mmol m⁻² h⁻¹**, substantially surpassing the state-of-the-art.

[1] H. Tan et al., *Anal. Chem.* **2020**, *92*, 13630.

Results

Chiral Channel Construction and Structural Verification

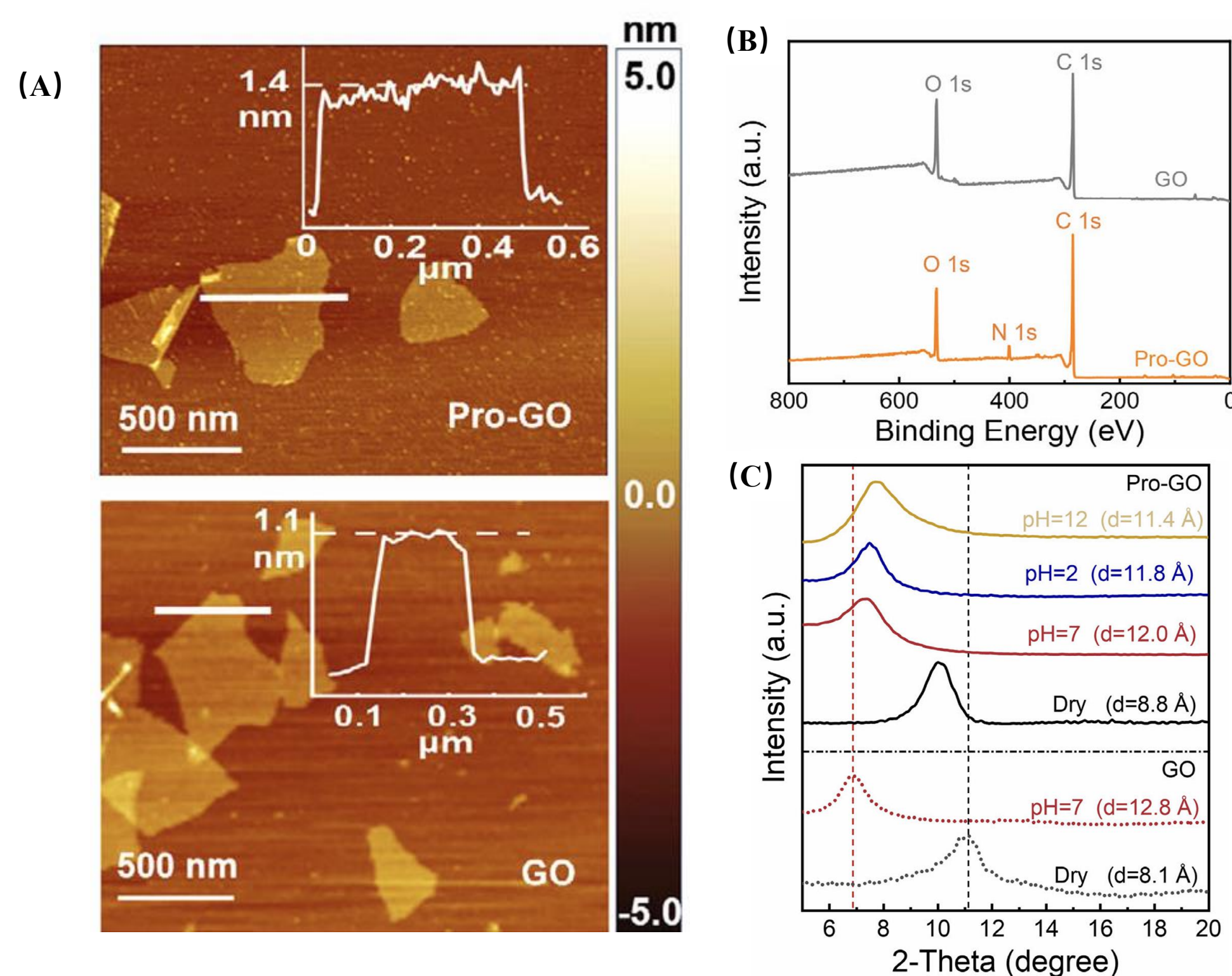


Fig. A: AFM height images of Pro-GO and GO nanosheets Fig. B: XPS survey spectra of Pro-GO and GO membranes Fig. C: XRD patterns of Pro-GO membranes at varying pH

High-density chiral functionalization and tunable lamellar channels are confirmed. AFM shows a 0.3 nm thickness increase upon proline grafting; XPS quantifies 5.97% nitrogen content, fivefold above conventional membranes; XRD reveals pH-responsive interlayer spacing (11.4–12.0 Å), establishing the physical basis for selective transport.

Selective Transport Mechanism and pH-Modulated Energetics

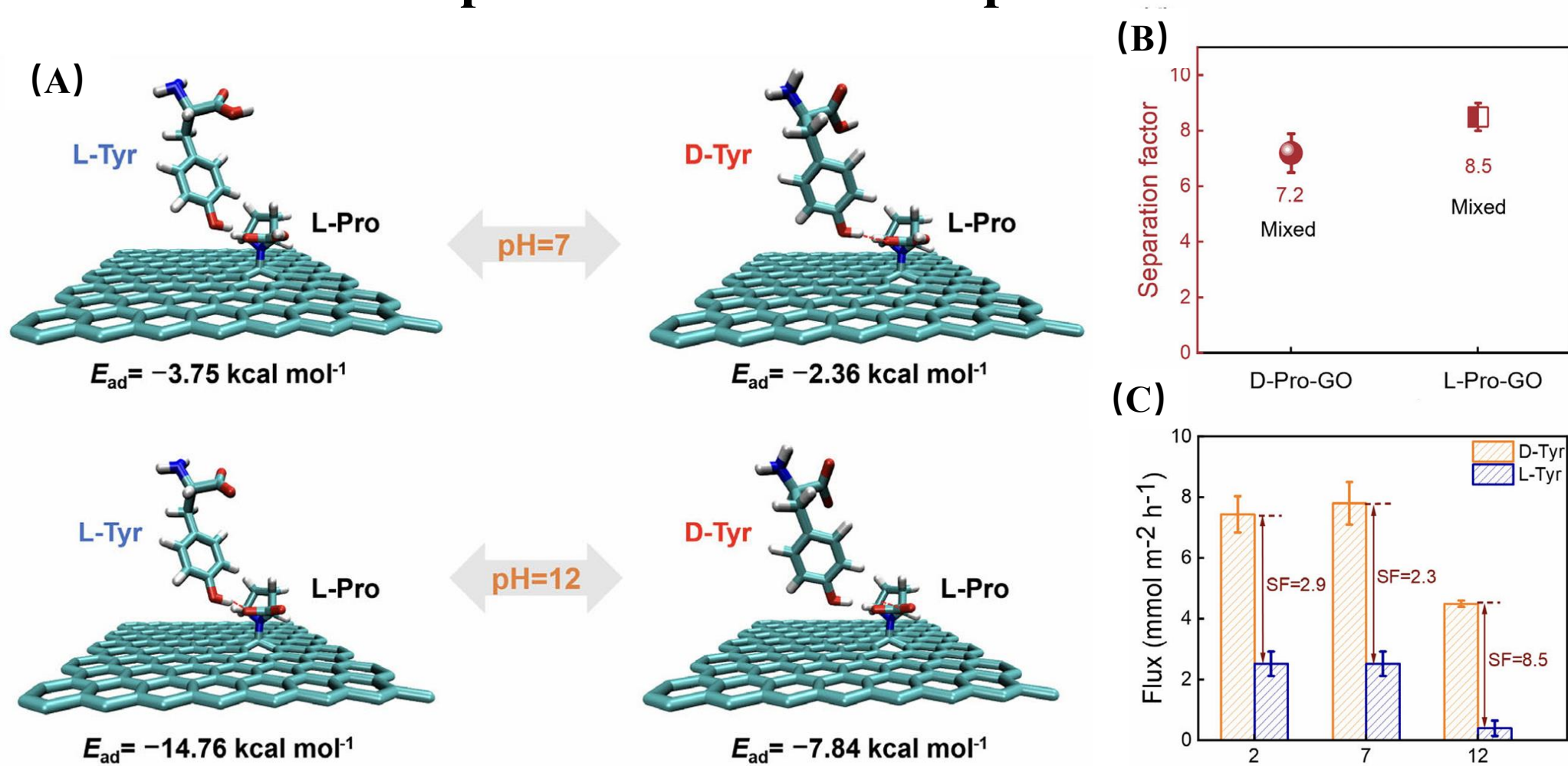


Fig. A: DFT adsorption energy diagrams of Tyr enantiomers on L-Pro-GO Fig. B: Single-pass separation factors of D- and L-Pro-GO membranes Fig. C: pH-dependent enantiomer fluxes and separation factors

Differential adsorption energies govern the selectivity. At pH 12, the energy gap between L-Tyr and D-Tyr reaches 6.92 kcal mol⁻¹, fivefold larger than at pH 7. This amplified potential asymmetry yields a single-pass separation factor of 8.5, with alkaline conditions markedly outperforming neutral and acidic environments.

Performance Benchmark and FPLC (Fast Protein Liquid Chromatography) Column Device

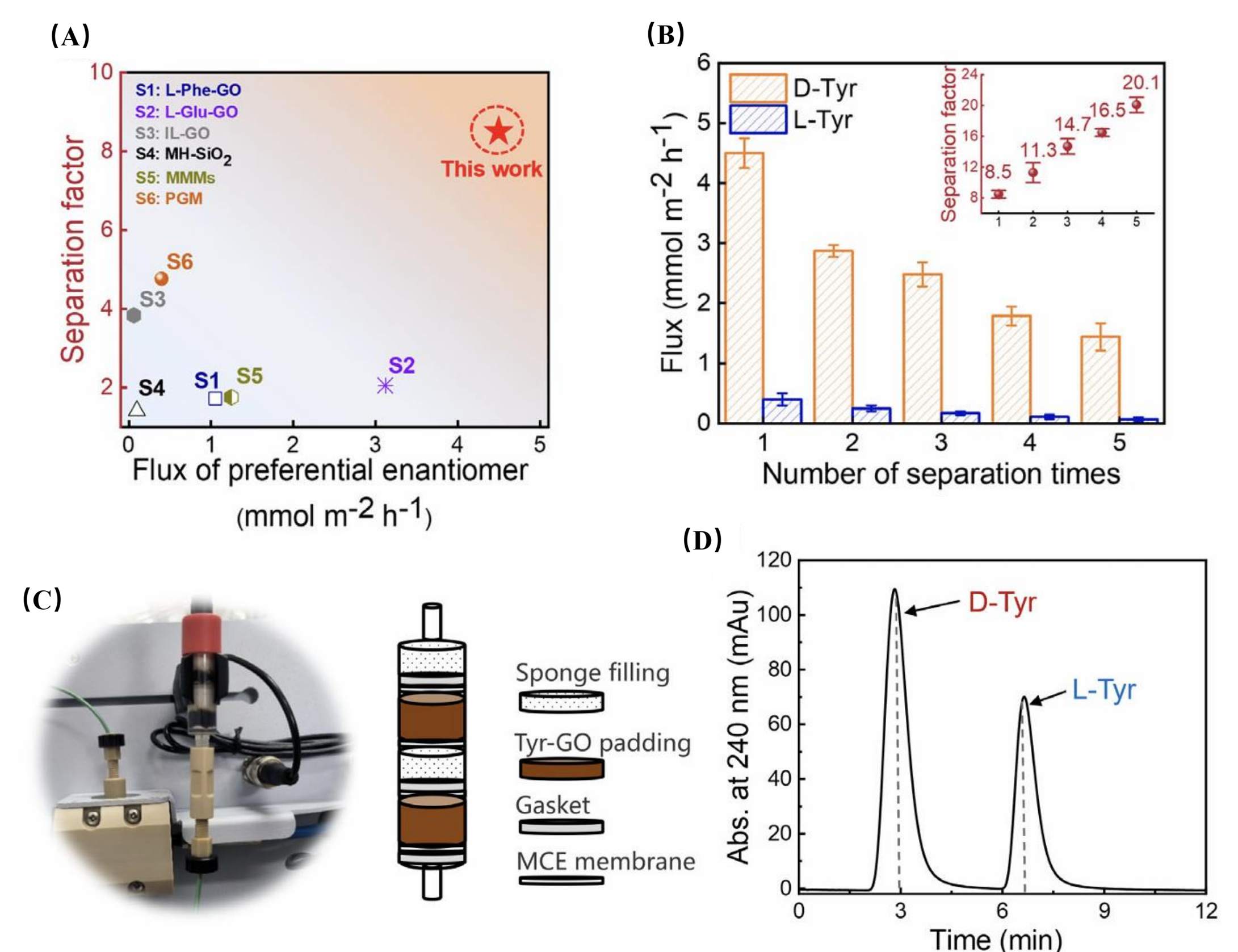


Fig. A: Performance benchmark plot of GO-based chiral membranes Fig. B: Separation factors over five consecutive purification cycles Fig. C: Schematic and photograph of the Pro-GO FPLC column Fig. D: FPLC elution chromatogram of D-/L-Tyr racemates

The Pro-GO membrane occupies the top-right frontier in separation factor versus flux, reaching 20.1 after five cycles. Integrated into an FPLC-compatible column, it achieves baseline resolution of D-/L-Tyr at merely ~0.5 MPa, demonstrating a scalable, low-cost route from materials to devices.

Conclusions

Structural Foundation

A homochiral GO membrane with high-density proline functionalization (N content 5.97%) and pH-tunable lamellar nanochannels (11.4–12.0 Å) was successfully constructed, providing a robust physical scaffold for enantioselective sieving.

Physical Mechanism

Differential adsorption energies between the chiral channel walls and D-/L-enantiomers are the microscopic origin of selectivity. Under alkaline conditions (pH 12), the energy gap amplifies to 6.92 kcal mol⁻¹, translating into a single-pass separation factor of 8.5.

Performance & Scalability

Cascade purification pushes the separation factor to **20.1**, while the first FPLC-compatible chiral column achieves baseline resolution at ~0.5 MPa, offering a low-cost, scalable alternative to conventional HPLC systems for industrial and laboratory chiral separation.