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RESEARCH ARTICLE

# Enhanced desulfurization performance of hybrid membranes using embedded hierarchical porous SBA-15

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# Electronic Supplementary Material

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## S1 Nitrogen adsorption-desorption isotherms

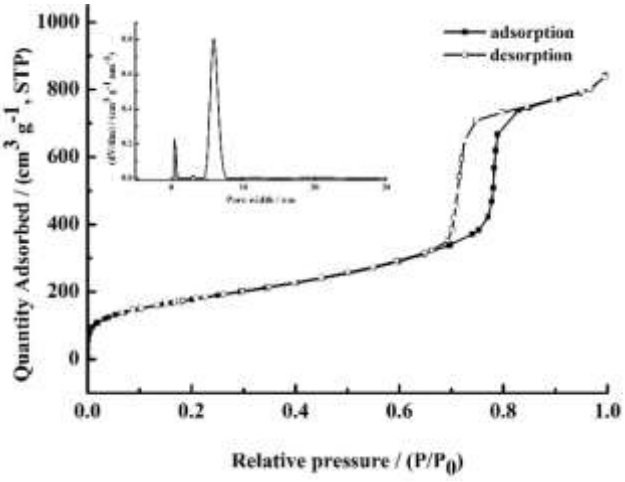


Fig.S1. Nitrogen adsorption-desorption isotherms of SBA-15 (Inset indicates the pore size distribution of SBA-15)

## S2 DSC study of membranes

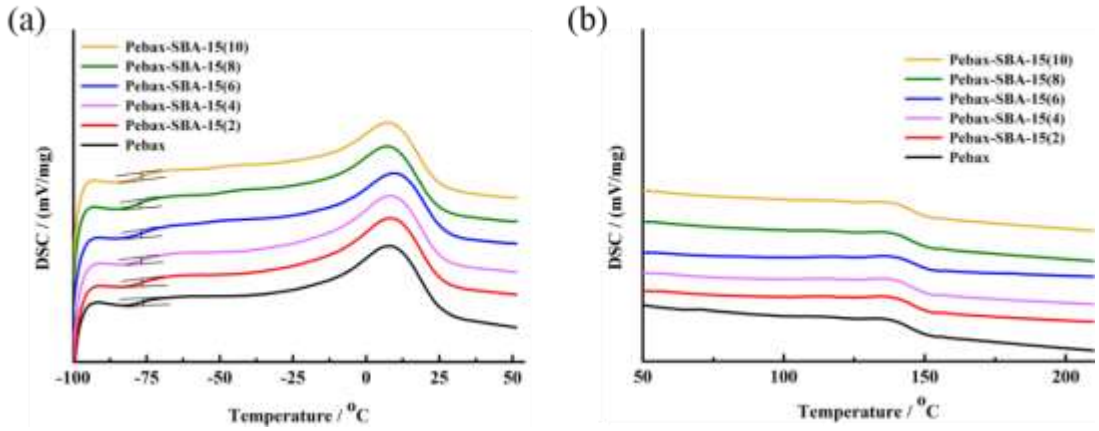


Fig.S2. DSC curves of pristine Pebax membrane and Pebax-SBA-15(*X*) membranes: (a) low-temperature zone; (b) high-temperature zone

**Table S1** $T_g$ and $T_m$ of pristine Pebax membrane and Pebax-SBA-15(*X*) membranes.

| Membrane | $T_G$ [a] / °C | $T_{m1}$ [b] / °C | $T_{m2}$ [c] / °C |
|---|---|---|---|
| **Pebax** | -75.79 | 7.8 | 133.4 |
| **Pebax-SBA-15(2)** | -75.83 | 8.5 | 133.9 |
| **Pebax-SBA-15(4)** | -76.91 | 8.6 | 133.9 |
| **Pebax-SBA-15(6)** | -77.04 | 9.5 | 134.0 |
| **Pebax-SBA-15(8)** | -77.87 | 7.2 | 134.8 |
| **Pebax-SBA-15(10)** | -77.88 | 7.2 | 134.0 |

a) $T_g$: glass-transition temperature; b) $T_{m1}$: melting point of PTMO segments; c) $T_{m2}$: melting point of PA12 segments

# S3 Free volume characteristics of membranes

**Table S2** Free volume characteristics of pristine Pebax membrane and Pebax-SBA-15(*X*) membranes.

| Membrane | $I_3$ [a] / % | $r_3$ [b] / nm | $f_{app}$ [c] |
|---|---|---|---|
| **Pebax** | 21.90 | 0.3414 | 3.6484 |
| **Pebax-SBA-15(2)** | 22.11 | 0.3416 | 3.6737 |
| **Pebax-SBA-15(6)** | 22.32 | 0.3428 | 3.7643 |
| **Pebax-SBA-15(10)** | 22.54 | 0.3402 | 3.7156 |

(a) $I_3$: intensity of ortho-positronium; b) $r_3$: the free volume cavities; c) $f_{app}$: the free volume

## S4 Comparison of the membrane separation performance

**Table S3** Comparison of the membrane separation performance in this study with previous desulfurization membranes in literatures.

| Membrane | Temperature /K | Sulfur content in feed/ppm | Thickness/μm | Permeation flux/(kg/(m$^2$h)) | Enrichment factor | Reference |
|---|---|---|---|---|---|---|
| Pebax-SBA-15(6)/PSf | 333 | 500 | 2 | 22.07 | 6.76 | This study |
| Pure Pebax | 333 | 500 | 2 | 16.99 | 4.49 | This study |
| Pebax-$Cu^{+}Fe^{2+}$@CNs-5/PSf | 333 | 500 | 2 | 13.42 | 7.11 | [1] |
| Pebax-$MoS_2$-4/PSf | 333 | 500 | 1.8 | 11.42 | 9.11 | [2] |
| Pebax-$Ag^{+}$@SNW-1-9/PSf | 333 | 500 | 2 | 16.35 | 6.80 | [3] |
| PDMS-MIL101(Cr)-6/PVDF | 313 | 500 | 15 | 5.2 | 5.6 | [4] |
| PDMS-$NH_3$-(TMOS)16/PSf | 303 | 500 | / | 7.36 | 4.98 | [5] |
| Pebax/PVDF | 313 | 1280 | 11 | 3.8 | 4.0 | [6] |
| PDMS-dopamine/Cu/PSf | 303 | 500 | 16 | 7.42 | 4.81 | [7] |
| PDMS-DATi(2.2.2.2)/PSf | 313 | 500 | 18 | 6.61 | 4.80 | [8] |
| Ethyl Cellulose-$C_{60}$ | 348 | 300 | / | 2.32 | 4.72 | [9] |
| PEG-CuY | 383 | 1190 | / | 3.19 | 2.95 | [10] |
| PDMS-$Ag^{+}$-$SiO_2$/PES | 306 | 500 | 14 | 7.76 | 4.3 | [11] |
| PES/Pluronic F127 | 303 | 500 | 200 | 3.1 | 3.5 | [12] |
| PDMS-$Ni^{2+}$Y/PS | 303 | 500 | / | 3.26 | 4.84 | [13] |
| PDMS–DAAg/5–5.0/PSf | 313 | 500 | 16~25 | 8.22 | 5.03 | [14] |
| PDMS-$Ag^{+}$/$TiO_2$(0.01)-5.0/PSf | 313 | 500 | / | 4.14 | 8.56 | [15] |
| PDMS–GNS(0.2)/PVDF | 313 | 500 | 20 | 6.22 | 3.58 | [16] |
| PDMS–CuBTC-8/PVDF | 313 | 500 | 35 | 6.47 | 5.20 | [17] |
| PDMS-AgY/PAN | 323 | / | 15 | 8.15 | 3.50 | [18] |
| PEG/PU | 383 | 1200 | / | 2.5 | 4.03 | [19] |
| Cl-PBPP | 353 | 400 | 12.4 | 1.38 | 5.6 | [20] |
| Pebax-CuBTC/PSf | 343 | 500 | 2 | 16.45 | 4.04 | [21] |
| Pebax-Ag-PDA/GNS-6/PSf | 313 | 500 | 6 | 4.42 | 8.76 | [22] |
| Pebax-Ag-PDA/GNS-6/PSf | 333 | 500 | 6 | 14 | 6.48 | [22] |
| Pebax-HPSiNT(2)/PSf | 333 | 500 | 1.8 | 19.0 | 5.6 | [23] |

### Abbreviation note:

**CNs**: Carbon nitride nanosheets **SNW-1**: N-rich Schiff based porous organic framework

**MIL101(Cr)**: Materials of Institute Lavoisier Frameworks 101

**TMOS**: Tetramethyl orthosilicate **PVDF**: Polyvinylidene difluoride

**DATi**: Dopamine/titanium(IV) bis-(ammonium lactate) dihydroxide

**$C_{60}$**: Fullerene **PEG**: Poly(ethylene glycol) **PES**: Poly(ether sulfone)

**PS**: Polysulfone **DAAg**: Dopamine-silver nanoparticles **GNS**: Graphene nanosheets

**CuBTC**: Metal-organic framework from Hong Kong University of Science and Technology

**PAN**: Polyacrylonitrile **PU**: Polyurethane

**Cl-PBPP**: Chlorine incompletely substituted poly [bis (phenoxy) phosphazene]

**PDA**: Polydopamine **HPSiNT**: Hierarchical porous organosilica nanotubes

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