**One-step fabrication of hydrophilic lignosulfonate-decorated reduced graphene oxide to enhance the pervaporation performance of calcium alginate membranes**

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**Figure S1.** Swelling degree of CaAlg, rGO/CaAlg and rGO@NaLS/CaAlg hydrogel membranes in water



**Figure S2.** Tyndall effect of the rGO material solution.

The activation energies of water and ethanol for the SA and SA/mMXene MMMs were qualitatively analyzed based on the Arrhenius equation as following:

where *J*, *A0, Ep, R*, and *T* referred to flux, pre-exponential factor, apparent activation energy, gas constant, and temperature, respectively.

**Table S1.** Comparison of dehydration performance of membrane

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Membrane** | Temperature/℃ | Ethanol content/wt% | Flux/g·m-2·h-1 | Separation factor | PSI×105 | References |
| **SA-ZIF-L** | 76 | 90 | 1218 | 1840 | 22.40 | [S1] |
| **SA-MoS2** | 76 | 90 | 1839 | 1229 | 22.58 | [S2] |
| **SA/PEGDA-GO** | 70 | 90 | 2400 | 480 | 11.49 | [S3] |
| **GO-SA** | 76 | 90 | 1604 | 1559 | 24.99 | [S4] |
| **GO-Al2O3** | 70 | 90 | 1300 | 250 | 3.24 | [S5] |
| **GO-PEI** | 60 | 98 | 1770 | 77 | 1.35 | [S6] |
| **GO-PVA** | 70 | 90 | 350 | 1250 | 4.37 | [S7] |
| **SA-NaLS@rGO** | 70 | 90 | 712 | 5780 | 41.15 | This study |

The PSI value is a comprehensive index showing the performance of the membrane, and the calculation formula is as follows:

where *J* represents the permeation flux(g/m2h), and ɑ represents the separation factor.

**Table S2.** CaAlg, rGO/CaAlg, rGO@NaLS/CaAlg membrane mass changes with time in aqueous solution.

|  |  |  |  |
| --- | --- | --- | --- |
| Time | CaAlg membrane (m/g) | rGO/CaAlg membrane (m/g) | rGO@NaLS/CaAlg membrane (m/g) |
| 0 min | 0.047 | 0.043 | 0.027 |
| 2 min | 0.069 | 0.065 | 0.041 |
| 5 min | 0.082 | 0.073 | 0.048 |
| 10 min | 0.097 | 0.083 | 0.056 |
| 15 min | 0.107 | 0.089 | 0.062 |
| 25 min | 0.108 | 0.093 | 0.061 |
| 35 min | 0.108 | 0.092 | 0.065 |
| 60 min | 0.108 | 0.093 | 0.065 |

where *ωt* (g/g) is the dissolved amount in *t* seconds, *mt* (g) is the mass of the membrane in *t* seconds, and *m0* (g) is the mass of the dry membrane.

**Table S3.** CaAlg, rGO/CaAlg, rGO@NaLS/CaAlg membrane thickness.

|  |  |
| --- | --- |
| Membrane | Thickness (h/μm) |
| CaAlg | 8.494 |
| rGO/CaAlg | 12.19 |
| rGO@NaLS/CaAlg | 16.27 |



**Figure S3**. Stability of the rGO@NaLS/SA membrane for dehydration of ethanol solution (90 wt%) at 70℃

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