Supporting Information

Two-dimensional Ti$_2$CTx MXene membranes with integrated and ordered nanochannels for efficient solvent dehydration

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Legend of Figures

Fig. S1 Schematic illustration of the assumption transformations on surface and cross-section of membrane

Fig. S2 The structure of HPEI molecule

Fig. S3 XRD patterns of (a) Ti$_2$AlC and Ti$_2$CT$_x$ powders; (b) Ti$_3$AlC$_2$ and Ti$_3$C$_2$T$_x$ powders

Fig. S4 Digital photo images of (a) Freestanding MXene (Ti$_3$C$_2$T$_x$) membrane, (b) and (c) the MXene (Ti$_3$C$_2$T$_x$) membrane could be folded into different shapes by glass rod and tweezers, showing good flexibility

Fig. S5 SEM images of PAN substrate

Fig. S6 Digital photos of (a) DI water, (b) MXene-HPEI mixture (0.150mg/mL), (c) MXene-HPEI mixture after stirring for 20 min (0.150mg/mL)

Fig. S7 SEM images of cross-section on (a) Ti$_2$CT$_x$ membrane, (b) Ti$_2$CT$_x$-HPEI membrane, (c) Ti$_2$CT$_x$-HPEI/TMC membrane, corresponding to Fig. 3 (a)-(c)

Fig. S8 XPS spectra of Ti$_2$CT$_x$-HPEI/TMC membrane

Fig. S9 SEM (a) and AFM (b) images HPEI/TMC membrane

Fig. S10 SEM images of Ti$_3$C$_2$T$_x$-HPEI/TMC membrane, (a) surface and (b) cross-section, (MXene deposition 72.21 mg/m$^2$)

Fig. S11 AFM images of Ti$_2$CT$_x$-HPEI/TMC membrane with different MXene deposition (a) 54.16 mg/m$^2$, (b) 72.21 mg/m$^2$, (c) 144.43 mg/m$^2$, (d) 216.65 mg/m$^2$, (e) 361.08 mg/m$^2$, (f)-(j) corresponding 3D images

Fig. S12 AFM images of Ti$_3$C$_2$T$_x$-HPEI/TMC membrane with different MXene deposition (a) 54.16 mg/m$^2$, (b) 72.21 mg/m$^2$, (c) 144.43 mg/m$^2$, (d) 216.65 mg/m$^2$, (e) 361.08 mg/m$^2$, (f)-(j) corresponding 3D images

Fig. S13 Performance on isopropanol dehydration by pervaporation of Ti$_3$C$_2$T$_x$-based membranes (feed: 10 wt% water/isopropanol mixture, 50 °C, MXene deposition 72.21 mg/m$^2$)

Fig. S14 Effect of MXene loading on Ti$_3$C$_2$T$_x$-HPEI/TMC membrane and Ti$_2$CT$_x$-HPEI/TMC membrane for isopropanol dehydration by pervaporation at 50 °C (feed: 10 wt% water/isopropanol mixture)
**Fig. S15** Effect of (a and b) temperature on isopropanol dehydration by pervaporation for Ti$_2$CT$_x$-HPEI/TMC membrane at 50 °C, (b) the Arrhenius graph equation between water and isopropanol permeance and feed temperature (feed: 10 wt% water/isopropanol mixture, MXene loading 72.21 mg/m$^2$)

**Fig. S16** Effect of feed concentration on isopropanol dehydration by pervaporation for Ti$_2$CT$_x$-HPEI/TMC membrane at 50 °C, (MXene loading 72.21 mg/m$^2$)

**Fig. S17** XRD patterns of nylon-supported Ti$_2$CT$_x$-HPEI/TMC membrane before and after immersing into 10 wt% water/isopropanol mixture for 120 h
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**Fig. S4** Digital photo images of (a) Freestanding MXene (Ti$_3$C$_2$Tx) membrane, (b) and (c) the MXene (Ti$_3$C$_2$Tx) membrane could be folded into different shapes by glass rod and tweezers, showing good flexibility.
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**Fig. S12** AFM images of Ti$_3$C$_2$Tx-HPEI/TMC membrane with different MXene deposition: (a) 54.16 mg/m$^2$, (b) 72.21 mg/m$^2$, (c) 144.43 mg/m$^2$, (d) 216.65 mg/m$^2$, (e) 361.08 mg/m$^2$, (f)-(j) corresponding 3D images.
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Fig. S15  Effect of (a and b) temperature on isopropanol dehydration by pervaporation for Ti_2CT_{x}-HPEI/TMC membrane at 50 °C, (b) the Arrhenius graph equation between water and isopropanol permeability and feed temperature(feed: 10 wt% water/isopropanol mixture, MXene loading 72.21 mg/m²)

For the sake of understanding the relationship between flux and temperature, we used Arrhenius equation to reveal it.

\[ P_i = J_i \frac{p_i - p_{il}}{\gamma_i x_i} = J_i \frac{p_i^{sat} - p_{il}}{\gamma_i x_i} \]

(1)

\[ P_i = A \exp \left( -\frac{E_a}{R T} \right) \]

(2)

Where \( P_i \) represents the permeance of individual component \( i \) (GPU), \( J_i \) is the permeation flux of component \( i \) (g m\(^{-2}\) h\(^{-1}\)), \( p_{il} \) and \( p_i \) are the partial pressure of component \( i \) in the feed side and permeate side (Pa), \( \gamma_i \) is the activity coefficient of component \( i \) in the feed side. \( x_i \) is the mole fraction of component \( i \) in the feed side. \( p_i^{sat} \) is the saturated vapor pressure of pure component \( i \). \( A \) is the preexponential factor (g m\(^{-2}\) h\(^{-1}\)), \( E_a \) stands for the activation energy (kJ mol\(^{-1}\)), \( R \) belongs to the gas constant (kJ mol\(^{-1}\) K\(^{-1}\)) and \( T \) refers to the feed temperature (K).

From Fig. S12a, the activation energy of water and isopropanol were calculated as -19.82 and 8.67 kJ/mol, respectively.
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