Advanced Membrane Separations Technology Module- POSTER #30

T5P1
Poster #: 30

Advanced Membrane Separations Technology Module

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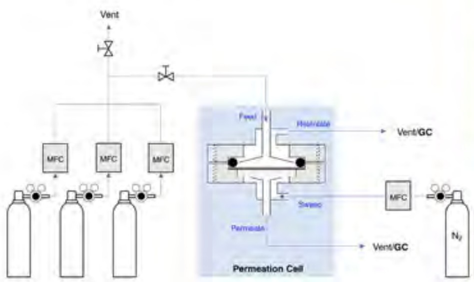
GOALS

- Develop mixed-gas technology module with the ability to test ternary mixtures at any compositions under field conditions.

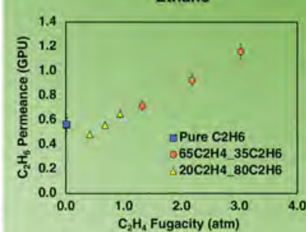


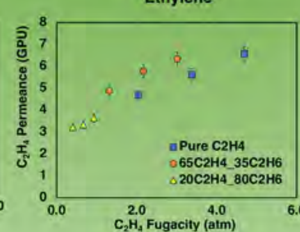
- Provide fast screening capabilities for materials developed by Thrust 6.

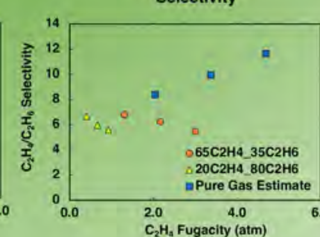
MAIN FINDINGS

C_2H_4/C_2H_6 mixed-gas separation performance in 70% $AgTf_2N$-PEBAX thin-film composite membrane (University of Texas at Austin, Project T6P1)

- ➢ The TFC has great permeance with a C_2H_4/C_2H_6 mixed-gas selectivity around 6.5.
- ➢ C_3H_6/C_3H_8 mixed-gas permeation experiment in progress.

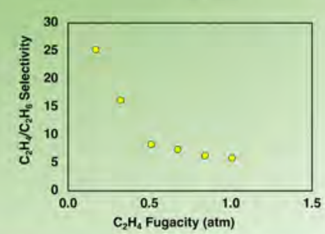




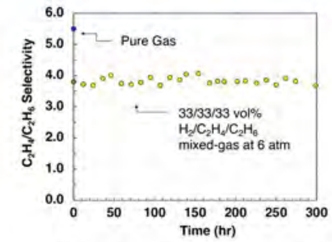


Fast screening capability for potential candidates (University of Texas at Austin, Project T6P1)

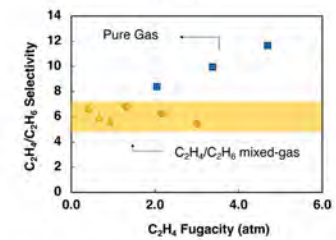
- ➢ 50/50 C_2H_4/C_2H_6 mixed-gas selectivity in a [emim][Tf_2N] SILM containing 45% $AgTf_2N$.



OUTCOMES



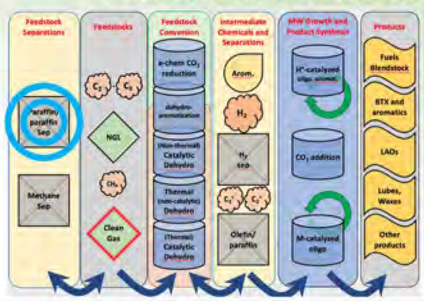
Demonstrated great hydrogen stability in AgTf2N-XLPEGDA developed at UTA (T6P1).

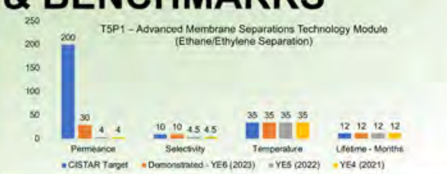


Demonstrated great mixed-gas C_2H_4/C_2H_6 selectivity in $AgTf_2N$-TFC developed at UTA (T6P1).

IP & INNOVATION

SYSTEM DESIGN & BENCHMARKS





Thrust Project Number and Name	CISTAR TRL 4/5 Process Targets. Demonstrated in Technology Module	CISTAR Status – Year End 6
T5P1: Advanced Membrane Separations Technology Module (Ethylene/Ethane)	>200 Barrer Permeability > 10 C_2H_4/C_2H_6 Selectivity > 35 °C Temperature > 1 Year Lifetime	30 Barrer C_2H_4 6.7 C_2H_4/C_2H_6 mixed gas selectivity 35 °C Temperature > 300 hours lifetime (we expect it would be stable for 12 months)

IMPACT & FUTURE

IMPACTS

- Enable evaluation of membrane performance using mixed-gas feeds under simplified field conditions.
- The equipment can reliably provide:
  1. temperature control between 5° and 250°C
  2. pressure control between 1.2 and 30 bar
  3. mass flow control between 20 and 1000 sccm

FUTURE WORK

- Olefin/paraffin separation in highly selective thin film composite membrane developed in UTA (Project T6P1).

This paper/poster is based upon work supported **primarily OR in part** by the National Science Foundation under Cooperative Agreement No. EEC-1647722.
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Reactor Oligomerization Technology Module- POSTER #31

T5P2
Poster #: 31

Technology Module – Oligomerization Reactor

High-Conversion Propylene Oligomerization on CISTAR-Developed Catalyst

Evan Sowinski, Songhyun Lee, Rajamani Gounder, Fabio Ribeiro
Charles D. Davidson School of Chemical Engineering, Purdue University

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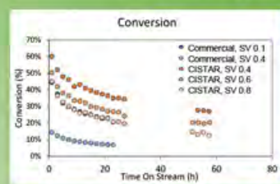
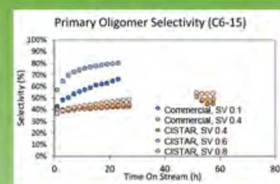
GOALS

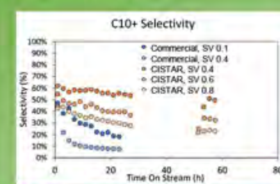
- Select Thrust 2 CISTAR oligomerization catalysts that show promising performance in low-conversion experiments, assess at high conversion and long time-on-stream (>1 week)
- Determine product slate produced at high conversion and over long time-on-stream

MAIN FINDINGS

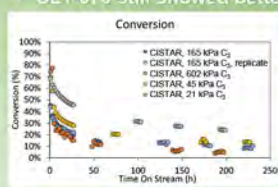
CISTAR-developed small-crystallite MFI zeolite catalyst SL1-070 displays significantly higher rates and product stability compared to commercial catalyst

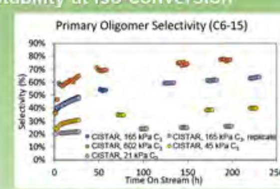


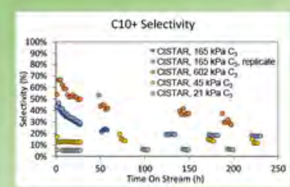




- Reaction conditions: 260 °C, 165 kPa C_3, space velocity in mol C_3/mol H^+/s
- SL1-070 had significantly higher conversion and product stability at identical reaction conditions compared to CBV2314 commercial catalyst
- SL1-070 still showed better stability at iso-conversion



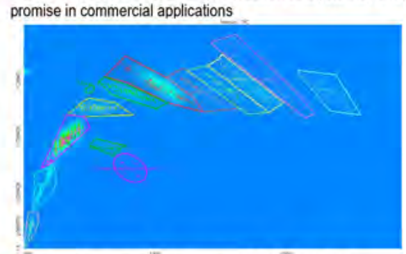




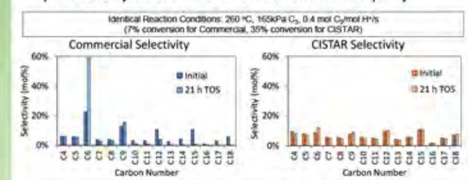
- Reaction conditions: 260 °C, 0.8 mol C_3/mol H^+/s
- Selectivity trends were still consistent at very long times-on-stream (>1 week)
- Changing pressure changes the selectivity to primary oligomers and heavies, allowing for process optimization of the product slate

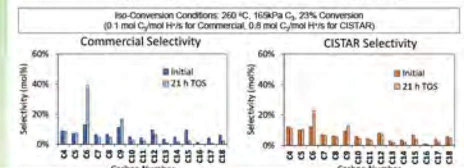
OUTCOMES

- Small-crystallite MFI zeolite oligomerization catalysts may show promise in commercial applications



- In collaboration with Dr. Kentämaa at Purdue, detailed GCxGC/FID and EI-TOF composition analysis of the liquid product can yield estimates of fuel and/or chemical quality



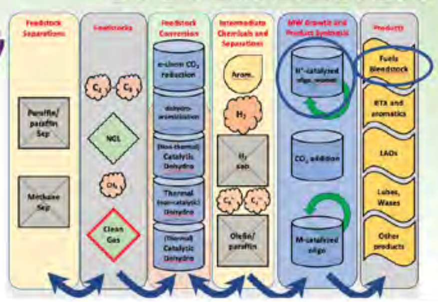


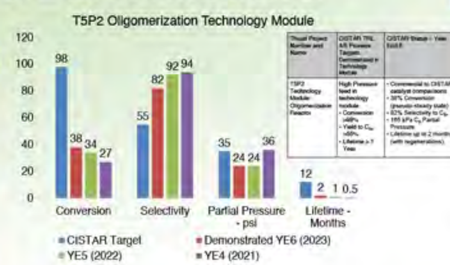
IP & INNOVATION

Provisional patent filed

- Title: "Stable Product Oligomer Selectivity From Olefin Oligomerization on ZSM-5 Zeolites and Zeotypes"
- Filing number: 63/445,206
- Filing date: Feb 13, 2023
- For more information on the provisional patent, please see Peter Keeling

SYSTEM DESIGN & BENCHMARKS





IMPACT & FUTURE

- The technology module connects fundamental research from Thrust 2 with the overall goals of the Testbeds, advancing the TRL of Thrust 2 projects
- Similar experiments are planned on other promising Thrust 2 catalyst technologies, such as core-shell and additional small-crystallite samples

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Reactor Dehydrogenation Technology Module- POSTER #32

T5P3
Poster #: 32

Technology Module – Dehydrogenation Reactor

Propane Dehydrogenation: Comparison of CISTAR Catalysts

Evan Sowinski, Fabio Ribeiro
Charles D. Davidson School of Chemical Engineering, Purdue University

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Center for Innovative and Strategic Transformation of Alkane Resources

GOALS

- Comparison of CISTAR catalysts to commercial catalysts at high conversion and industrial-like WHSV
- Determine selectivity and stability with time-on-stream

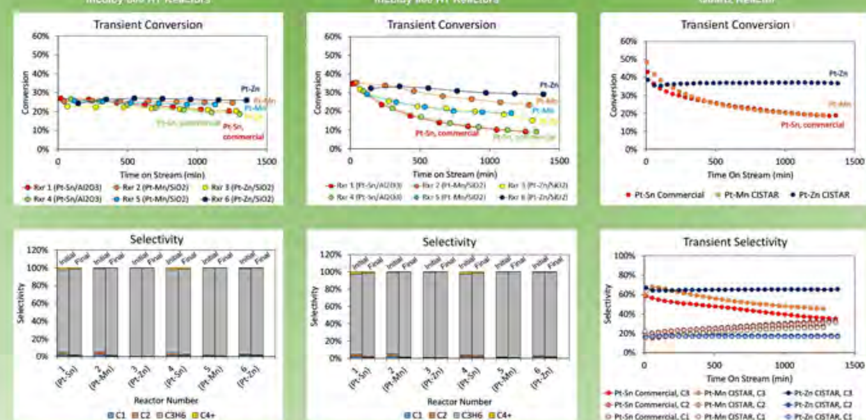
MAIN FINDINGS

CISTAR-developed Pt-Mn/SiO_2 and Pt-Zn/SiO_2 propane dehydrogenation catalysts displayed greater stability compared to a commercially available Pt-Sn/Al_2O_3 catalyst

Conditions: 500 °C, 1 bar (Total Pressure)
Space Velocity: 4.5 h^{-1} WHSV
Feed: 90% C_3H_8, 10% N_2
Incoloy 800 HT Reactors

Conditions: 550 °C, 1 bar (Total Pressure)
Space Velocity: 4.5 h^{-1} WHSV
Feed: 90% C_3H_8, 10% N_2
Incoloy 800 HT Reactors

Conditions: 600 °C, 1 bar (Total Pressure)
Space Velocity: 4.5 h^{-1} WHSV
Feed: Pure C_3H_8
Quartz Reactor

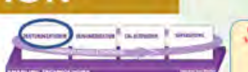


- At 500 °C, all catalysts were reasonably stable, and selectivity did not change significantly with time on stream.
- At 550 °C, the commercial Pt-Sn catalyst experienced significantly more deactivation than either of the CISTAR catalysts.
- At 600 °C, the Pt-Sn commercial and Pt-Mn catalysts experienced similar deactivation, but the Pt-Zn CISTAR catalyst had stable conversion for the entire experiment. Selectivity for all catalysts at this temperature was not as stable and selectivity to C_3H_6 was significantly lower than at lower temperatures.

OUTCOMES

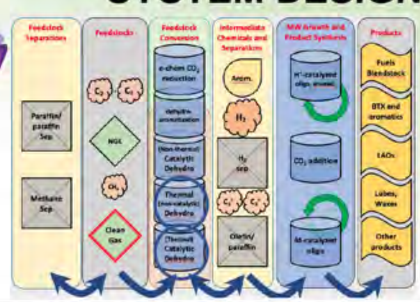
- All catalysts showed similar performance at 500 °C
- CISTAR developed Pt-Zn and Pt-Mn catalysts showed enhanced stability at 550 °C
- CISTAR Pt-Zn catalyst showed great stability even at temperatures as high as 600 °C
- At 600 °C, selectivity was less ideal than at lower temperatures
- Temperatures higher than 550 °C caused severe coking in stainless steel reactors, so quartz was used for 600 °C experiments

IP & INNOVATION

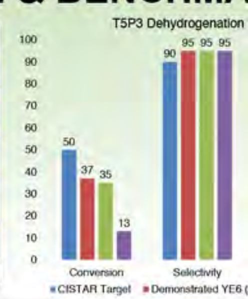


- Pt-Zn/SiO2 catalyst in particular displays great stability for ~24 hours at temperatures up to at least 600 °C, compared to a commercially available Pt-Sn/Al_2O_3 catalyst

SYSTEM DESIGN & BENCHMARKS



T5P3 Dehydrogenation Technology Module



Thrust Project Number and Name	CISTAR TRL-4/5 Process Targets Demonstrated in Technology Module	CISTAR Status – Year End 5
T5P3 Technology Module: Dehydrogenation Reactor	- >50% Conversion - >90 % Selectivity - > 1 Year Catalyst Lifetime - > 15 psi C_3 & $C_3^=$ Partial Pressure	- Propane Dehydrogenation - 37% Conversion - >95% Selectivity - 15 psi C_3 & $C_3^=$ Partial Pressure

IMPACT & FUTURE

- Continued testing and comparison of CISTAR catalysts to commercial
- Modification of the technology module unit as necessary to allow for expanded reaction conditions, namely changing reactor material of construction to lessen coking at elevated temperatures

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T6P1 - POSTER #33

T6P1
Poster #: 33

Scalable and Hydrogen-stable Thin Film Composite Membranes for Olefin/Paraffin Separations

Matthew N. Davenport[1], Tangqiumei Song[1], Joan F. Brennecke[1], and Benny D. Freeman[1]
[1]John J. McKetta Jr. Department of Chemical Engineering, The University of Texas at Austin

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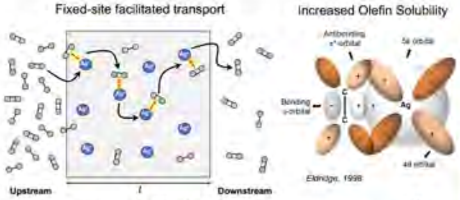
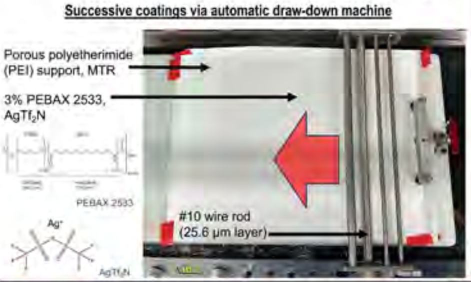
GOALS

- Ag^+ facilitated transport membrane with high olefin-paraffin selectivity and resistance to poisoning by reducing gases, such as H_2.
- Mixed gas testing in technology module
- Scalable high-flux thin film composite (TFC)



Permeability: $P_A = \frac{N_A \times l}{\Delta P} = D_A \times S_A$, Selectivity: $\alpha_{A/B} = \frac{P_A}{P_B}$

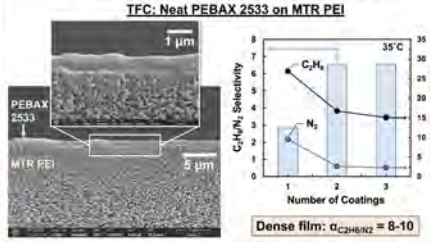
Successive coatings via automatic draw-down machine



MAIN FINDINGS

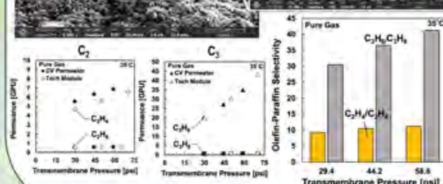
Utilizing the draw-down process previously described, defect-free TFCs of neat PEBAX 2533 and 70% $AgTf_2N$-PEBAX2533 coated on MTR PEI were synthesized. 3 coatings was found to be sufficient.

TFC: Neat PEBAX 2533 on MTR PEI

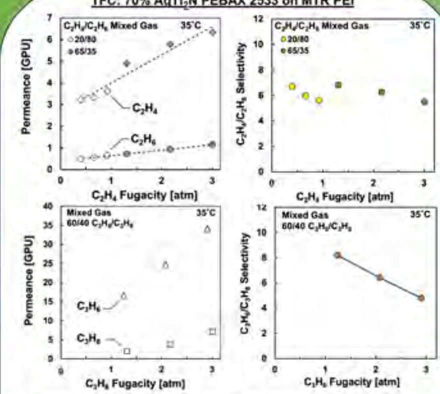


Dense film: $\alpha_{C2H4/N2}$ = 8-10

TFC: 70% $AgTf_2N$ PEBAX 2533 on MTR PEI

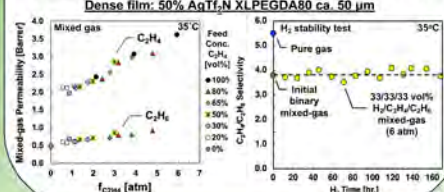


TFC: 70% $AgTf_2N$ PEBAX 2533 on MTR PEI



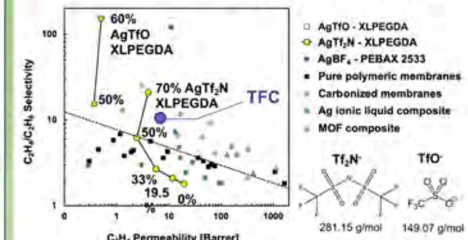
- Previously-studied dense films (ca. 50 µm) of $AgTf_2N$ in XLPEGDA, a crosslinked polyether, also show C_2H_4 plasticization in mixed-gas testing
- $AgTf_2N$-XLPEGDA performance is stable to one week of H_2 mix. permeation

Dense film: 50% $AgTf_2N$ XLPEGDA80 ca. 50 µm

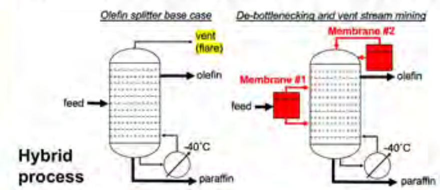


OUTCOMES

- Defect-free $AgTf_2N$-PEBAX 2533 TFC
- Mixed-gas C_2H_4/C_2H_6 and C_3H_6/C_3H_8 testing on CISTAR technology module
- Selectivity surpasses C_2 upper bound
- Demonstrated stability to H_2 and C_2H_2.



- 70% $AgTf_2N$-PEBAX2533 TFC shows lower pure-gas C_2 selectivity than dense 70% $AgTf_2N$-XLPEGDA film potentially due to substructure resistance
- Techo-economic analysis shows C_2H_4/C_2H_6 Selectivity ($\alpha_{C2H4/C2H6}$) = 10 would be feasible for a hybrid membrane-distillation process (Motelica, et al., 2012)

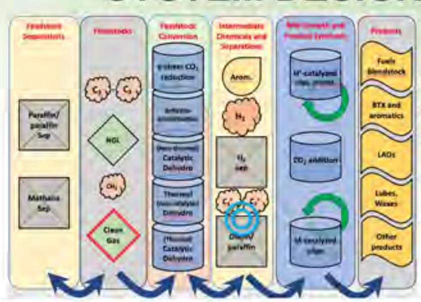


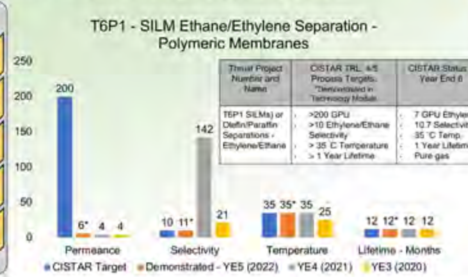
IP & INNOVATION

- H_2- and C_2H_2-stable Ag^+ facilitated transport membrane with good selectivity (patent filed)
- Defect-free $AgTf_2N$-PEBAX 2533 TFC coating for scale-up and mixed-gas testing
- TRL 3/4

Davenport, et al., Journal of Membrane Science, 2022.

SYSTEM DESIGN & BENCHMARKS





Thrust Project Number and Name	CISTAR TRL 4-5 Process Targets: *Demonstrated in Technology Module	CISTAR Status - Year End 6
T6P1 SILMs) or Olefin/Paraffin Separations - Ethylene/Ethane	>200 GPU >10 Ethylene/Ethane Selectivity > 35 C Temperature > 1 Year Lifetime	7 GPU Ethylene 10.7 Selectivity 35 °C Temp. 1 Year Lifetime Pure gas

IMPACT & FUTURE

- The TFC morphology is readily scalable into pilot-scale spiral-wound modules
- Development of TFC membranes with other Ag salts to improve α and H_2-stability testing
- Optimization of support membrane to reduce sub-structure resistance
- Testing of 'live' mixed-gas sample from partner plant on CISTAR technology module

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T6P2 - POSTER #34

T6P2
Poster #34

Strategies for Mitigating Membrane Fouling Via Coke Formation During PDH in a Catalytic Membrane Reactor

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[1]Department of Chemical & Biological Engineering and the Center for Micro Engineered Materials, The University of New Mexico
[2]Chemical Engineering Program and Graduate School of Advanced Science and Engineering, Hiroshima University

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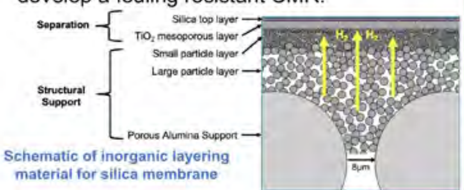
GOALS

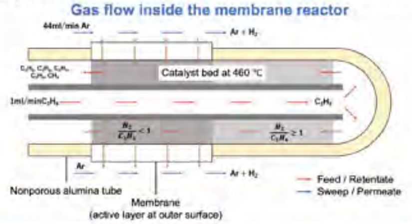
- Develop and integrate a thermally stable, high flux membrane for the selective removal of H_2 from C2-C5 alkanes in a high temperature catalytic membrane reactor.
- Modify or substitute membrane components to develop a fouling resistant CMR.



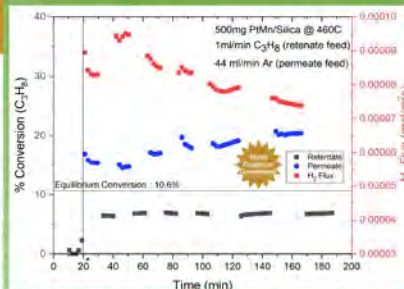
Schematic of inorganic layering material for silica membrane

Amorphous silica membrane on a porous alumina support

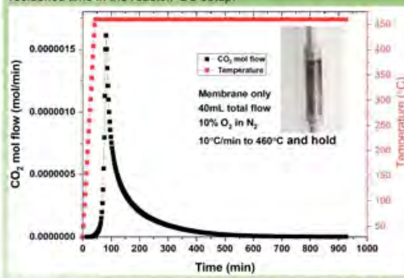
Gas flow inside the membrane reactor



MAIN FINDINGS



PDH reaction at 460 °C and 1mL/min propane feed. Conversions above equilibrium conversions can be seen on the permeate side.
* A transient reaction can be observed in the first 20 min due to a long residence time in the reactor/ GC setup.



Temperature programmed oxidation performed on the membrane after seeing 10% C_3H_8 in N_2 for 17.3 hrs at 460 °C. Approximately 2mg of coke came off in the form of CO_2.

Sample	Surface Area m²/g	Coke wt%	g C/m²
Bare α-Al_2O_3 (200 nm)	7.01	0.103	1.47E-04
1wt% Sr on α-Al_2O_3 (200 nm)	7.01	0.113	1.64E-04
10wt% Sr on α-Al_2O_3 (200 nm)	7.01	0.069	9.87E-05
Davisil 646 (amorphous)	277.86	0.025	9.15E-07
Quartz Sand	2.44	0.0005	2.11E-06

BET surface area, weight % coke deposition, and grams of coke per surface area for bare and Sr modified α-alumina particles, Davisil 646(amorphous silica), and quartz sand.

Bare, 1 wt%, 10wt% Sr on α-alumina particles

Davisil 646 & Quartz sand

Aerosol assisted EISA mesoporous silica films. Top image from 2023 and bottom image from 1999 (Lu et al)

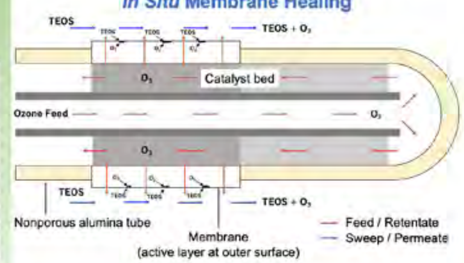
Aerosol assisted evaporation induced self-assemble silica layer with uniform 3nm pores can potentially replace intermediate particle layers reducing coking and increasing flux.

Sample	Spraying Distance (mm)	N_2 Permeance (MPU)
Blank Anodisc 1	-	528.24
Blank Anodisc 2	-	525.81
Blank Anodisc 3	-	549.51
Blank Anodisc 4	-	553.45
Spray Sample 3	15	126.24
Spray Sample 4	15	176.04
Spray Sample 9	19	398.40
Spray Sample 5	23	388.79
Spray Sample 6	23	395.67
Spray Sample 7 *	26	1607.18
Spray Sample 8	26	148.92

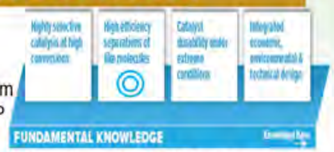
OUTCOMES

- Above-equilibrium conversions can be obtained
- Provides promising platform for tandem catalysis
- Mapped out material modifications and substitutions that can be made to prevent fouling.
- Redox cycling generates defects. Defects can be healed by secondary membrane formation.

In Situ Membrane Healing

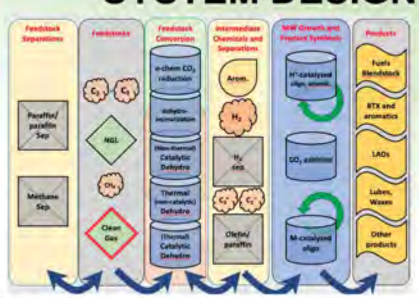


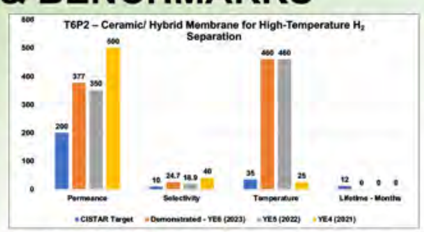
IP & INNOVATION



- Exceeds equilibrium for a given T and P
- Provides a unique platform for tandem catalysis to further improve conversion and reduce need for separation
- Patent application in progress

SYSTEM DESIGN & BENCHMARKS





Thrust Project Number and Name	CISTAR TRL 4/5 Process Targets. Demonstrated in Technology Module	CISTAR Status – Year End 5
T6P2- Ceramic/ Hybrid Membrane for High-Temperature H_2 Separation	· >200 Barrer Permeability · > 10 Ethylene/Ethane Selectivity · > 35 °C Temperature · > 1 Year Lifetime	· 350 Barrer Hydrogen · 24.7 Selectivity · 460 °C Temperature · Undetermined- Lifetime

IMPACT & FUTURE

- CMR reduces needed energy input for a given conversion
- Reduction of membrane fouling increases the time between regenerations.
- Tandem catalysis offers to provide a direct route for propane to liquid fuels
- *In Situ* membrane healing

This paper/poster is based upon work supported primarily OR in part by the National Science Foundation under Cooperative Agreement No. EEC-1647722.
Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation

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T6P3 - POSTER #35

T6P3
Poster #: 35

Improving the Pressure-Stability of Supported Ionic Liquid Membranes (SILMs) for the Fractionation of Light Paraffins

Justin J. Rosenthal[1], Joan F. Brennecke[1], Benny D. Freeman[1]
[1] John J. McKetta Jr. Department of Chemical Engineering, The University of Texas at Austin

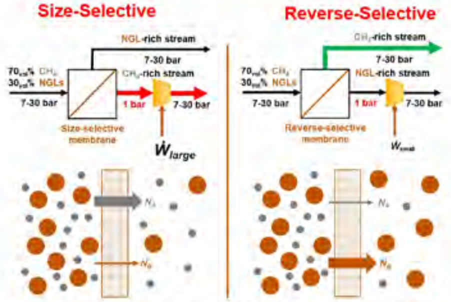
CISTAR
NSF Engineering Research Center
Center for Innovative and Strategic Transformation of Alkane Resources

GOALS

- **Light paraffin fractionation** with reverse-selective supported ionic liquid membranes **(SILMs)**
- Membrane **stability (i.e., "blowout resistance")** at industrial operating pressures of 7-30 bar
- **SILMs** suitable for large-scale manufacturing and incorporation into low-footprint modules for decentralized natural gas processing

Benefit of Reverse-Selectivity

Solubility-selective ionic liquids **(ILs)** are reverse-selective which helps to avoid costly recompression

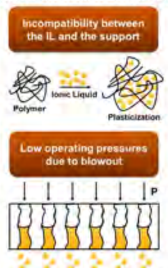


Supported Ionic Liquid Membrane Synthesis

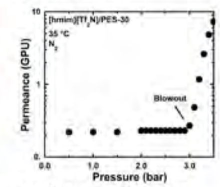
MAIN FINDINGS

Limitations of SILMs

Plasticization of the support by the IL and high operating pressures are common challenges:

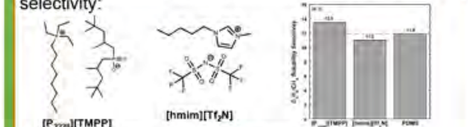


The IL can swell the polymer support if their interactions are too favorable

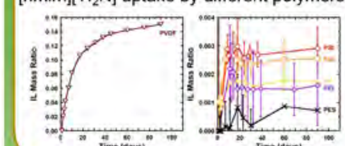


Selection of IL and Polymer Support

ILs were chosen based on their C_3H_8/CH_4 ideal solubility-selectivity:



[hmim][Tf_2N] uptake by different polymers:



PES shows lowest IL uptake

Liu et al., Ind. Eng. Chem. Res., 53, 363-368, (2014)

Predicting Blowout Pressures

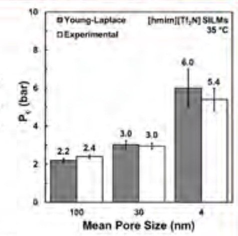
The Young-Laplace **(YL)** equation is a helpful predictor of possible operating conditions:

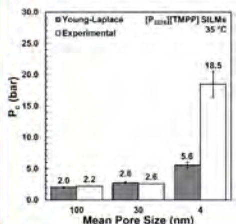
$$P_c = \frac{2\gamma\cos(\theta)}{r}$$

P_c = Blowout Pressure (Pa)
γ = Surface Tension (N/m)
θ = Contact Angle (radians)
r = Pore Radius (m)

Want high surface tension, low contact angle, and small pore radius for highest blowout (i.e. operating) pressure

Blowout predictions for **[hmim][Tf_2N]** on various **PES** supports **appears accurate:**

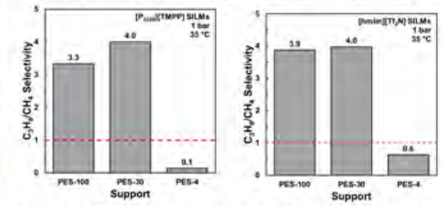




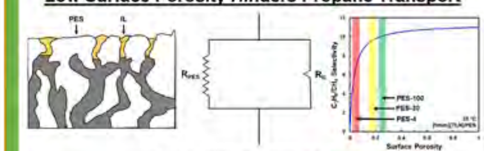
Blowout predictions for **[P_{2228}][TMPP]** on various **PES** supports is accurate for larger pores. There is a **large deviation with the 4 nm support:**

OUTCOMES

Nanoconfinement Leads to Loss of Selectivity

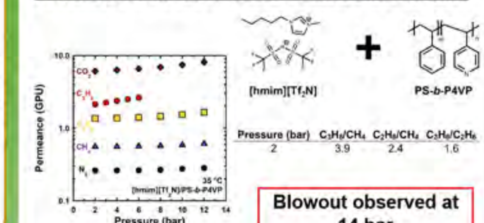


Low Surface Porosity Hinders Propane Transport



Henis, J.; Tripodi, M. J. Memb. Sci., 1981

Isoporous SILMs are Pressure-Stable and Selective

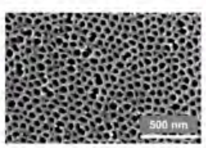


Pressure (bar)	C_3H_8/CH_4	C_2H_6/CH_4	C_3H_8/C_2H_6
2	3.9	2.4	1.6

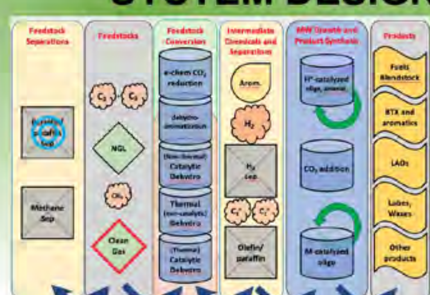
Blowout observed at 14 bar

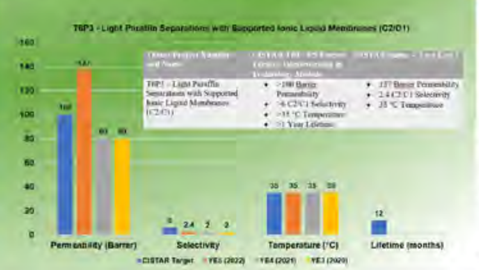
IP & INNOVATION

- Most stable SILM utilizing **commercially available supports**
- **Isoporous SILMs** provide the necessary **pressure-stability** and **reverse-selectivity** for this separation



SYSTEM DESIGN & BENCHMARKS





IMPACT & FUTURE

- Evaluation of the IL interactions with the support are necessary for a stable SILM
- Nanoconfinement can improve stability but leads to a loss in reverse-selectivity
- Isoporous SILMs offer both good pressure-stability and the desired reverse-selectivity
- Future: Characterize isoporous SILMs with [hmim][Tf_2N], [P_{2228}][TMPP], and [emim][SCN]
- Future: Develop poly(ionic liquid) membranes

This paper/poster is based upon work supported **primarily OR in part** by the National Science Foundation under Cooperative Agreement No. EEC-1647722.
Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

T6P4 - POSTER #36

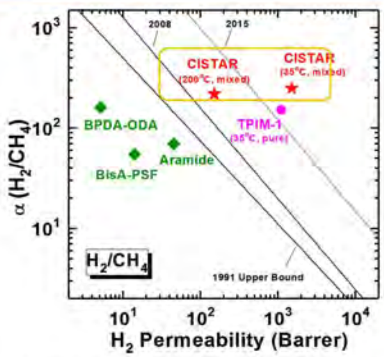
T6P4
Poster #:37

Microporous Iptycene-based Polybenzoxazole Membranes for H_2/C_1-C_3 Separations

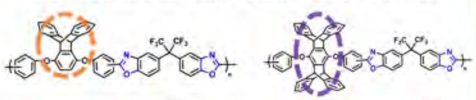
Agboola Suleiman, Zihan Huang, Ruilan Guo
Department of Chemical & Biomolecular Engineering, University of Notre Dame

CISTAR
NSF Engineering Research Center
Center for Innovative and Strategic Transformation of Alkane Resources

GOALS

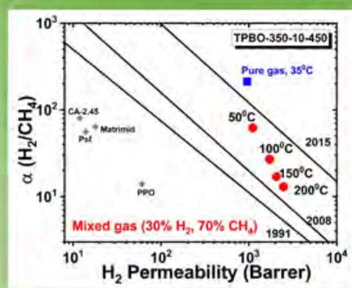


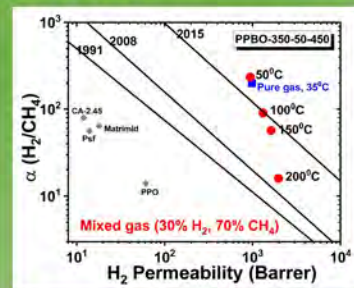
- Develop polymeric membranes tailored for H_2/C_1-C_3 separations.
- Investigate their performance with increasing temperatures (up to 200°C).
- Hypothesis: Iptycenes should minimize selectivity losses at high temperatures due to their configuration-free volume.



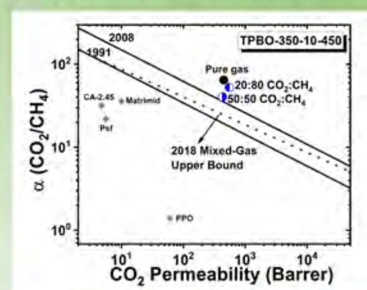
Triptycene PBO (TPBO) Pentiptycene PBO (PPBO)

MAIN FINDINGS





- The Iptycene – PBOs have exceptional performance at 35°C for single gas.
- Both polymers show a similar performance α (PPBO) > α (TPBO).
- High selectivities at 200°C for binary gas mixtures confirm the hypothesis.

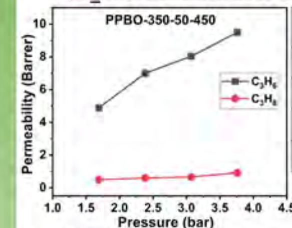


- Iptycene units mitigated the selectivity losses at high temperatures – configuration free volume are less sensitive to the high temperatures.
- Excellent plasticization resistance in mixed-gas conditions for CO_2.

QR Code for Full Paper

OUTCOMES

H_2/Hydrocarbons Separations

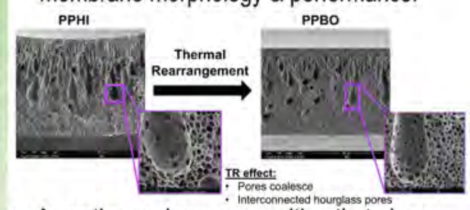


Gas Pairs	Selectivity
H_2/CH_4	180
H_2/C_3H_8	3491
H_2/C_3H_6	300
C_3H_6/C_3H_8	12

- PPBO shows promising selectivities for C_3H_6, C_3H_8, and CH_4.

Asymmetric membrane fabrication

- A complex process: simultaneous occurrence of different mechanisms on membrane morphology & performance.

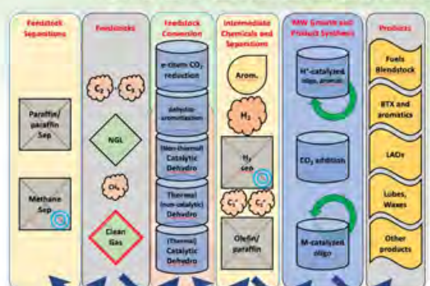


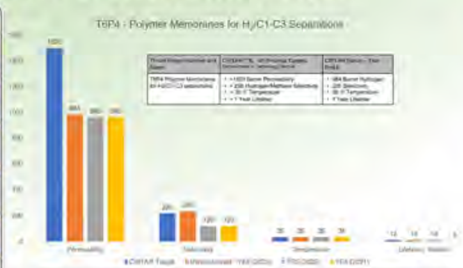
- An optimum dope composition that gives similar dense film selectivity is being studied.

IP & INNOVATION

- Developing first-of-its-kind high-performance polymer membranes for separations up to 200°C.

SYSTEM DESIGN & BENCHMARKS





IMPACT & FUTURE

- Better heat integration of CISTAR process and separation conditions.
- Promising performance for H_2/C_3H_6, H_2/C_3H_8.
- Asymmetric fabrication of these materials is ongoing.
- Novel non-fluorinated materials are being investigated.

This paper/poster is based upon work supported **primarily OR in part** by the National Science Foundation under Cooperative Agreement No. EEC-1647722.
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T6P6
Poster #: 37

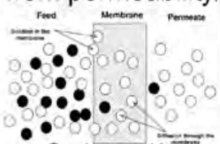
Olefin/Paraffin Separation Performance of Amine-modified PIM-1 Membrane

Bo Wei Cynthia Chen[1], Casey P. O'Brien[1]
[1]Department of Chemical and Biomolecular Engineering, University of Notre Dame

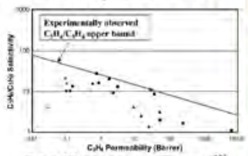
CISTAR NSF Engineering Research Center
Center for Innovative and Strategic Transformation of Alkane Resources

GOALS

- Gas separation using polymeric membrane reduce energy consumption
- Simple polymeric membrane suffer from permeability/selectivity trade-off

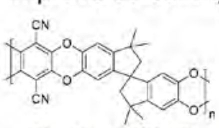


Gas transport in dense membrane[1]

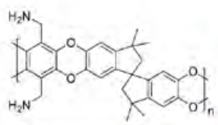


C_3H_6/C_3H_8 Upper Bound[2]

- Polymer of Intrinsic Microporosity (PIM) are known for high permeability
- Modification of polymer design can improve selectivity



Structure of PIM-1[3]

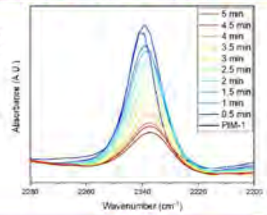


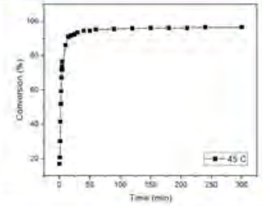
Structure of PIM-NH_2[3]

Reference: [1] Farsi, A. (2015). Mass transport in inorganic meso- and microporous membranes; [2] J. Membr. Sci. 2003, 211, 299-309; [3] Rodriguez, K. M.; et. al. Angew. Chem. Int. Ed. 2021, 60, 6593-6599;

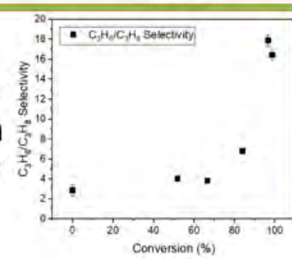
MAIN FINDINGS

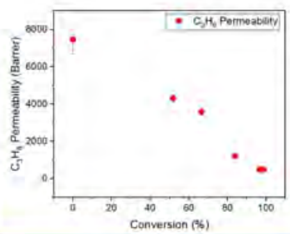
- Synthesized of PIM-NH_2 confirmed using FT-IR
- Reaction is controlled to produce PIM-NH_2 at different conversions

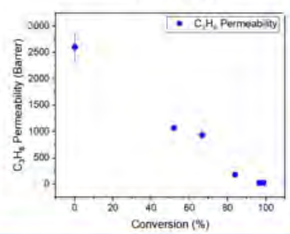




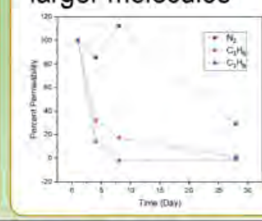
- Permeability has a linear relationship with total amine conversion
- Selectivity is inversely effected by amine





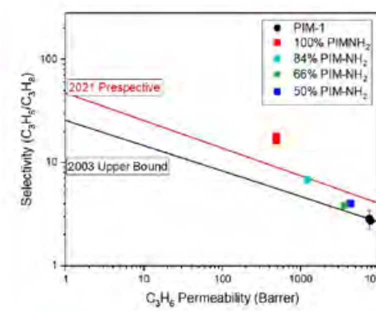


- Membrane aging is observed at initial testing day
- Nitrogen tested as comparison showing slower aging than larger molecules



OUTCOMES

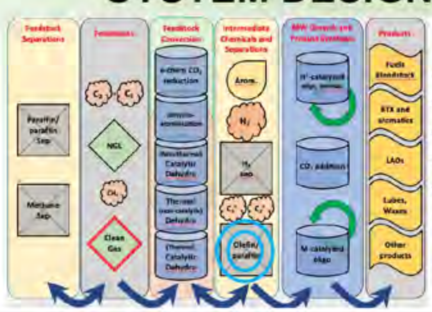
- C_3H_6/C_3H_8 separation performance using PIM-NH_2 is above upper bound
- Gas separation performance can be optimized by manipulating polymer design
- Fast membrane aging occurs during initial time period

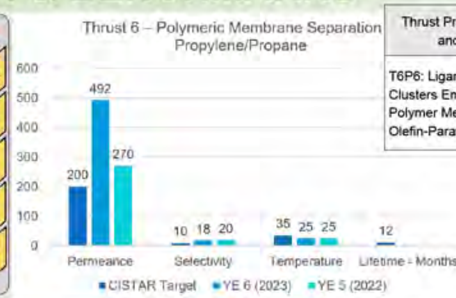


IP & INNOVATION

- PIM-NH_2 is a promising novel material for high efficiency separation
- Characteristic study of PIM-NH_2 to understand gas transport and separation properties

SYSTEM DESIGN & BENCHMARKS





IMPACT & FUTURE

Thrust Project Number and Name	CISTAR TRL. 4/5 Process Targets. Demonstrated in Technology Module	CISTAR Status – Y6 End
T6P6: Ligand Protected Clusters Embedded in Polymer Membranes for Olefin-Paraffin Separation	• >200 Barrer Permeability • 10 Propylene/Propane Selectivity • 35 °C Temperature • > 1 Year Lifetime	• 492 Barrer Permeability • 18 Propylene/Propane Selectivity • 25 °C Temperature • Lifetime study in progress

- Fundamental study polymer property to optimize gas separation efficiency using molecular design
- Aging mitigation study in the future

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T6P7 - POSTER #38

T6P7
Poster #: 38

Engineering Mechanically Tough Poly(ethylene oxide) Membranes for Olefin/Paraffin Separations

Tiffany Jeng[1], Gabriel E. Sanoja[1]

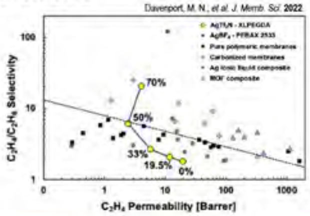
[1]McKetta Department of Chemical Engineering, The University of Texas at Austin

CISTAR
NSF Engineering Research Center
Center for Innovative and Strategic Transformation of Alkane Resources

GOALS

- Engineer polymer membranes of high fracture toughness
- Understand the relationship between membrane structure and bulk mechanical and transport properties for olefin/paraffin separations

Davenport, M. N., et al. J. Memb. Sci. 2022



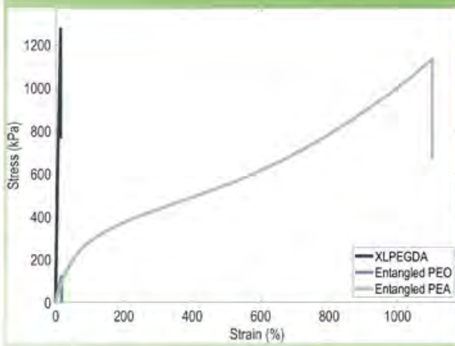
Highly crosslinked, low M_n polymer chains

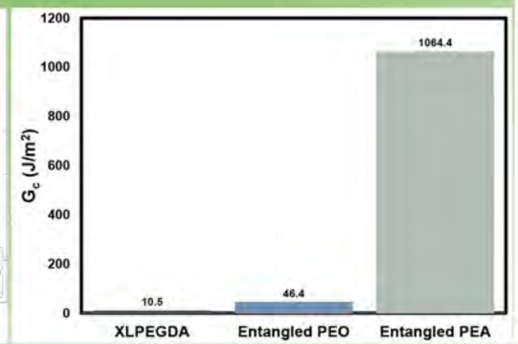
Highly entangled, high M_n polymer chains

Nian, G. et al. Adv. Mater. 2022.

MAIN FINDINGS

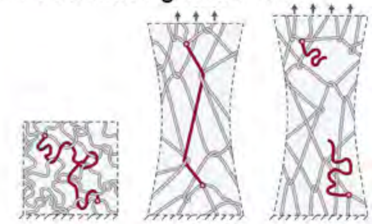
- $XLPEGDA/AgTf_2N$ membranes are stiff (E ~ 10 MPa) and brittle ($\mathcal{G}_c$ ~ 10-100 J/m²)
- Highly entangled polymers yield elastic, yet tough membranes





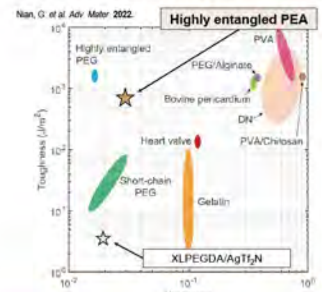
OUTCOMES

- Alternative polymer network architectures toughen membranes
- Entanglements dissipate energy without causing brittleness



Kim, J. et al. Science 2021.

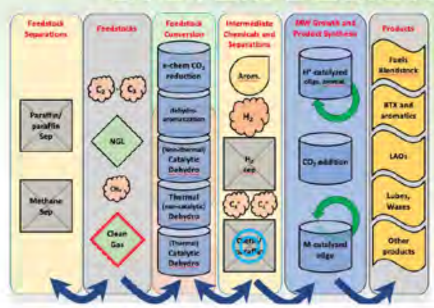
Nian, G. et al. Adv. Mater. 2022.



IP & INNOVATION

- Molecular understanding of the mechanical properties of $PEO/AgTf_2N$ membranes

SYSTEM DESIGN & BENCHMARKS



IMPACT & FUTURE

- Longer-lasting, mechanically tough membranes
- $PEO/AgTf_2N$ requires refined molecular design
- Toward highly entangled polymer membranes utilizing alternative chemistries

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