Recyclable biopolymer-based membrane contactor for CO_2 capture and utilization

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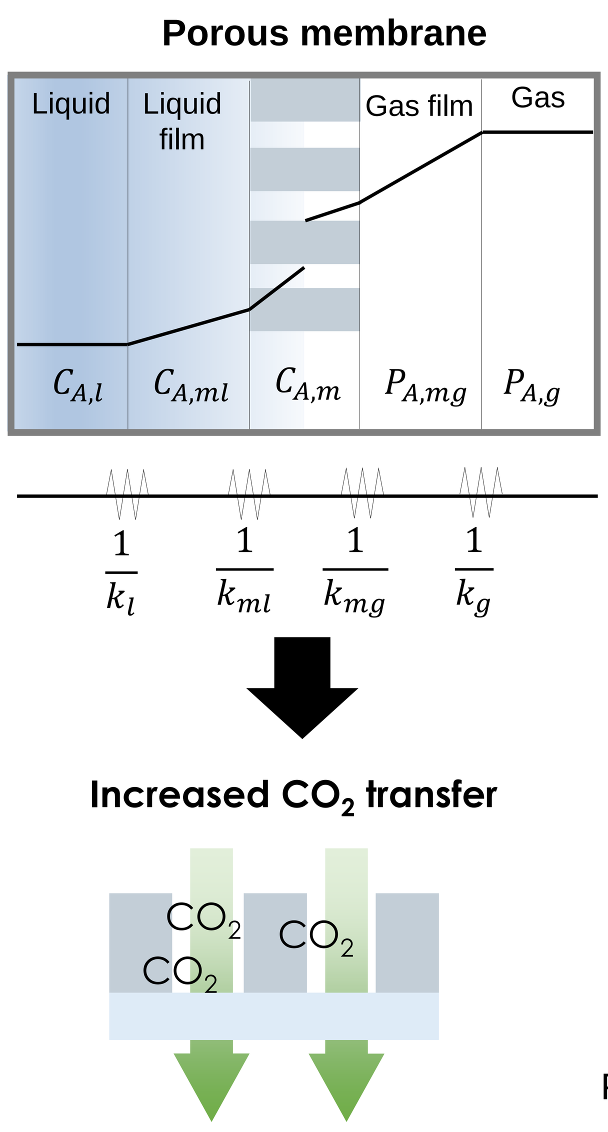
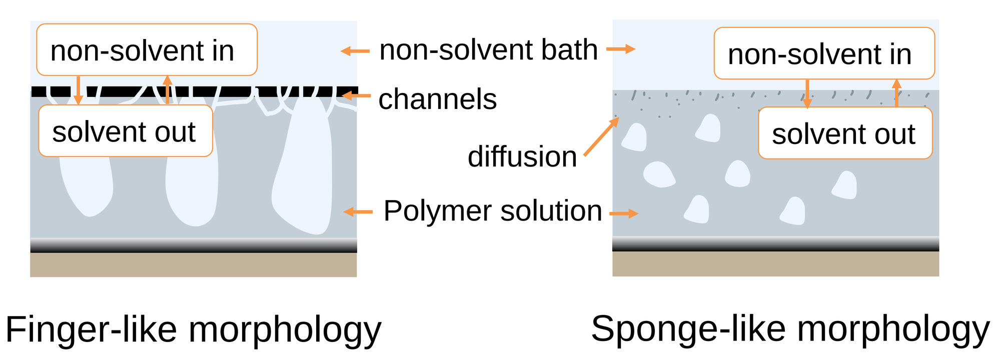
Introduction

Sustainable membranes must be developed to support truly carbon-negative technologies

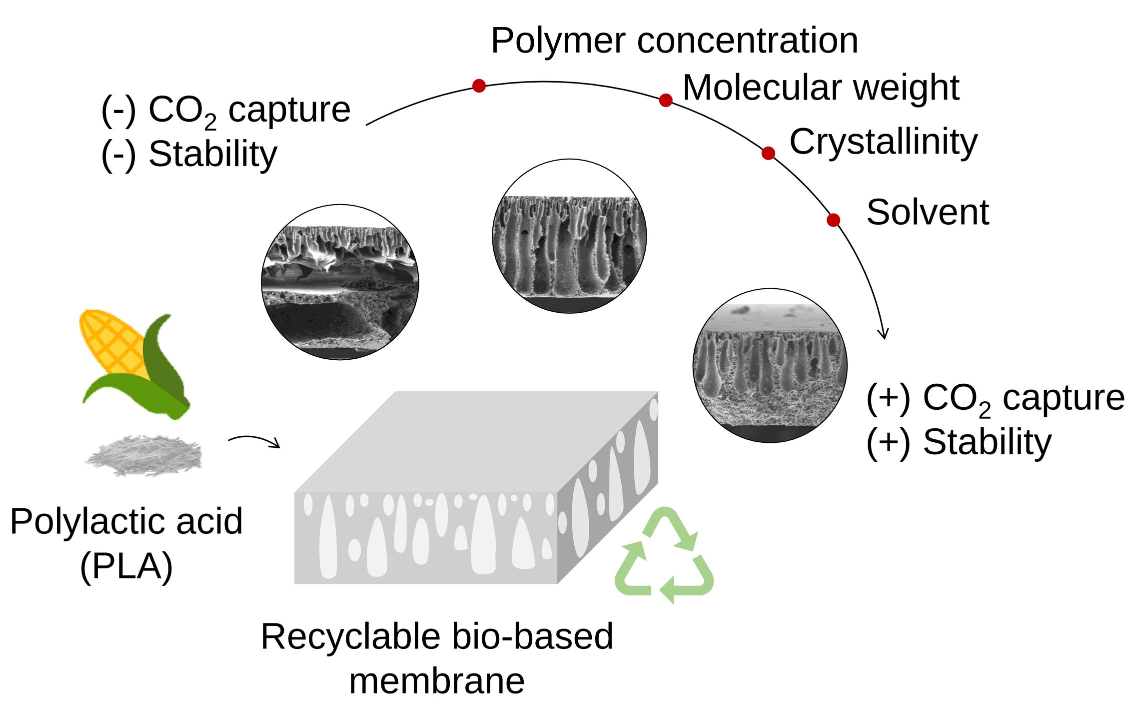


$$\frac{1}{K_{OV}^{G}} = \frac{1}{Hk_l E} + \frac{1}{k_{ml}} + \frac{1}{k_{mg}} = \frac{\Delta C_g}{J_g}$$

Performance of the membranes depend on morphology



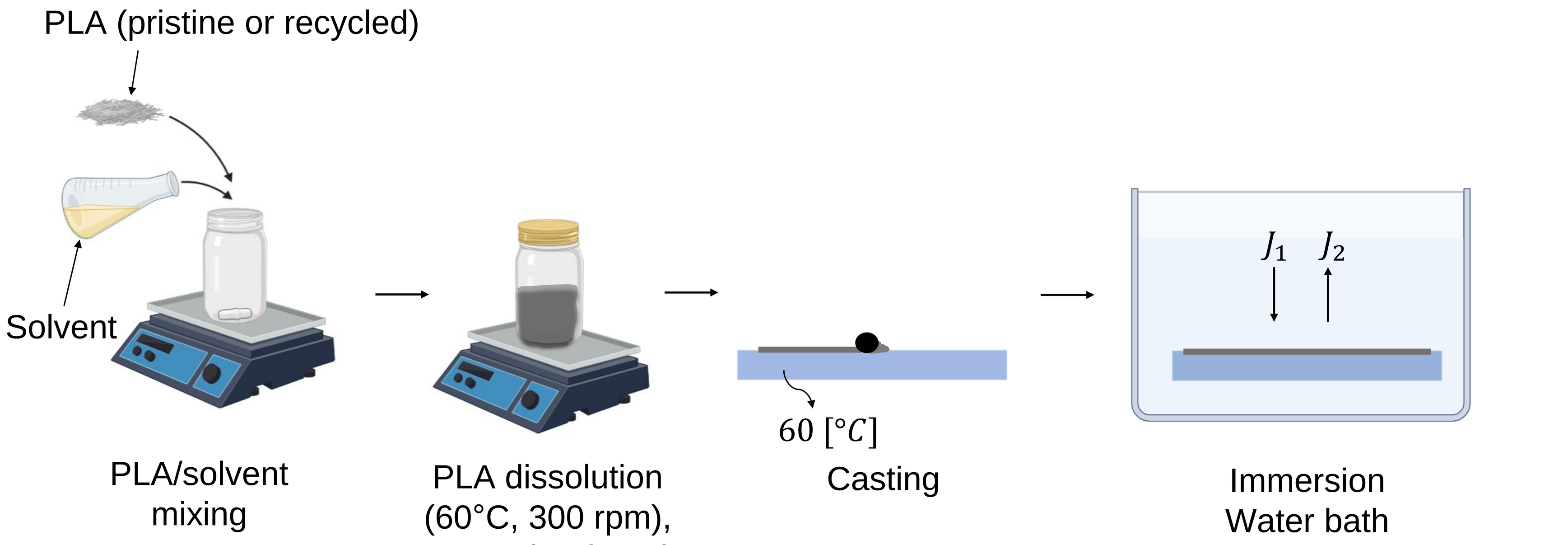
PLA is bio-based, renewable thermoplastic: good candidate



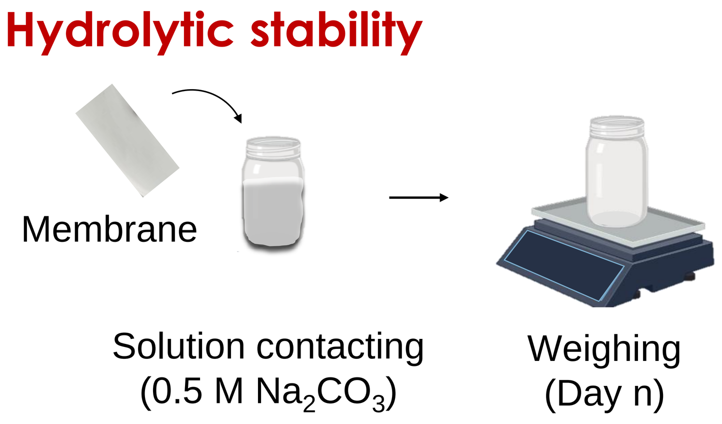
The objective is to synthesize a sustainable bio-based membrane for CO_2 capture, by studying the effect of different synthesis parameters on CO_2 capture performance and hydrolytic stability.

Methodology

Synthesis of (recycled) PLA membranes



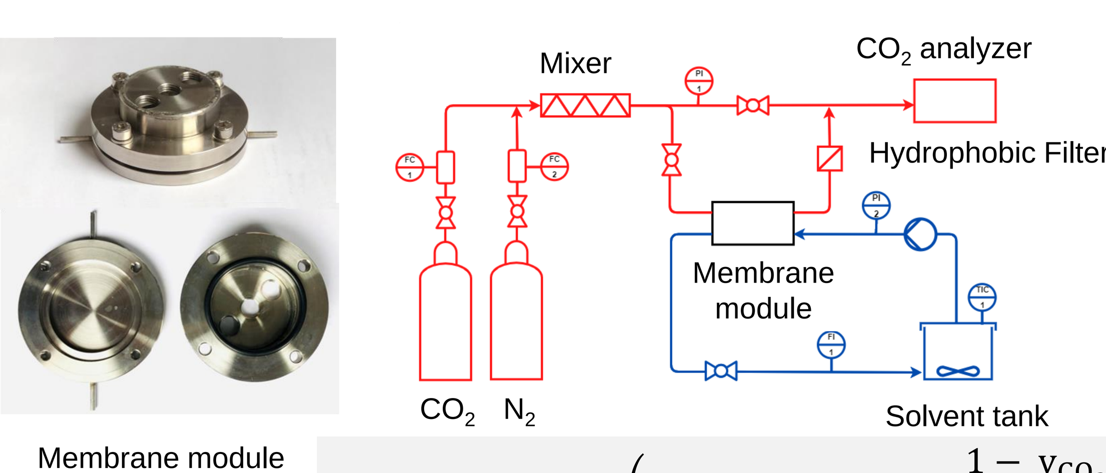
Hydrolytic stability



$$\text{Mass retention (\%)} = 100 - \frac{m_0 - m_n}{m_0} \times 100$$

$$\text{Porosity (\%)} = \frac{V_m - V_p}{V_m} \times 100 = \left(1 - \frac{W_m}{D \times A \times \rho_p}\right) \times 100$$

CO_2 absorption test



Membrane module

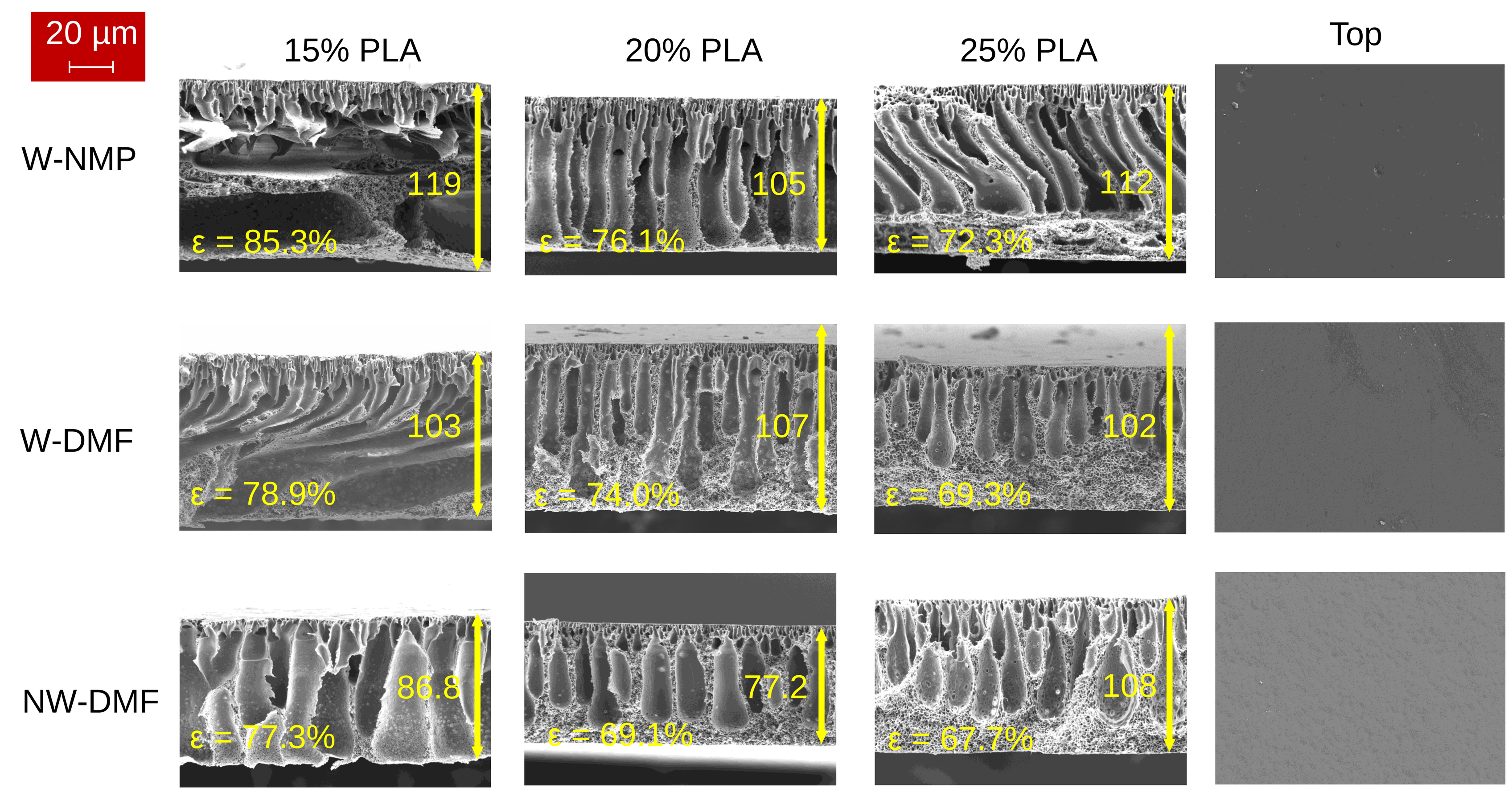
Absorption conditions:

- Gas flow-rate: 0.4 Ln/min (15% CO_2, 85% N_2)
- Liquid flow-rate: 0.6 L/min (0.5 M Na_2CO_3)
- 25°C, 1 h

$$K_{ov} = \frac{J}{\Delta C} = \frac{2Q_{t,in}}{A} \frac{\left(y_{CO_2,in} - y_{CO_2,out} \cdot \frac{1 - y_{CO_2,in}}{1 - y_{CO_2,out}}\right)}{\left(C_{CO_2,in} + C_{CO_2,out}\right)_{gas}}$$

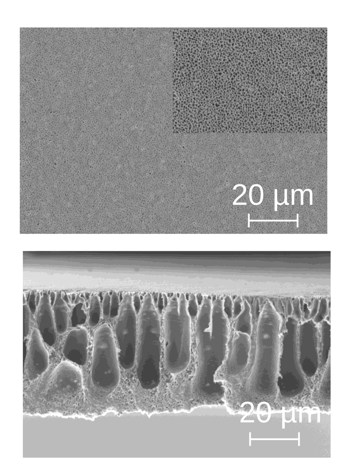
Results and Discussion

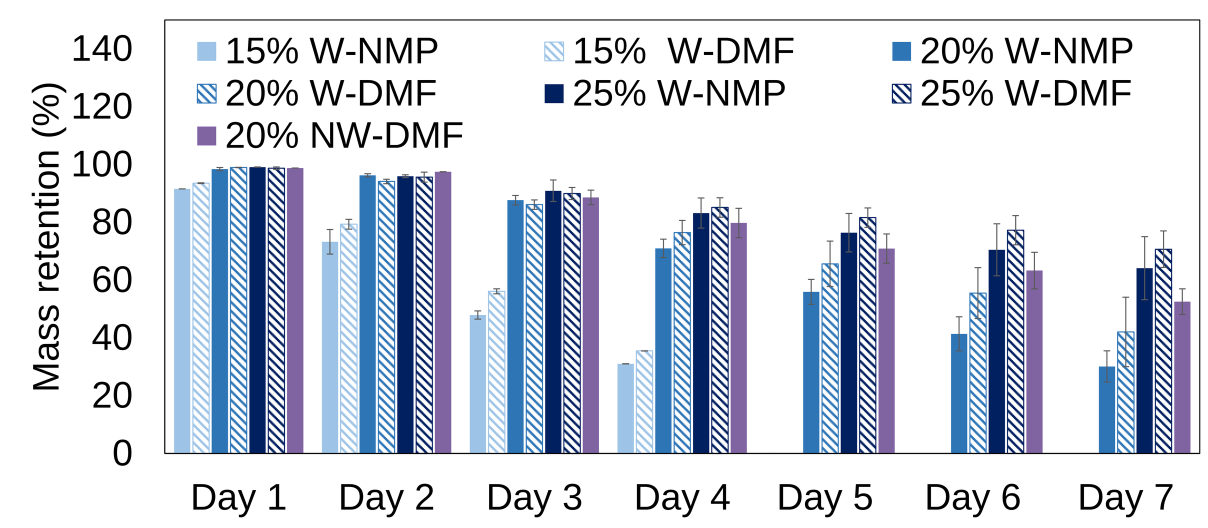
Polymer concentration and solvent



Higher polymer concentration and **molecular weight** favored the formation of **strong skin layer**, whereas **lower solubility** increased solution viscosity, hindering the polymer-solvent exchange rate resulting in **sponge morphology**.

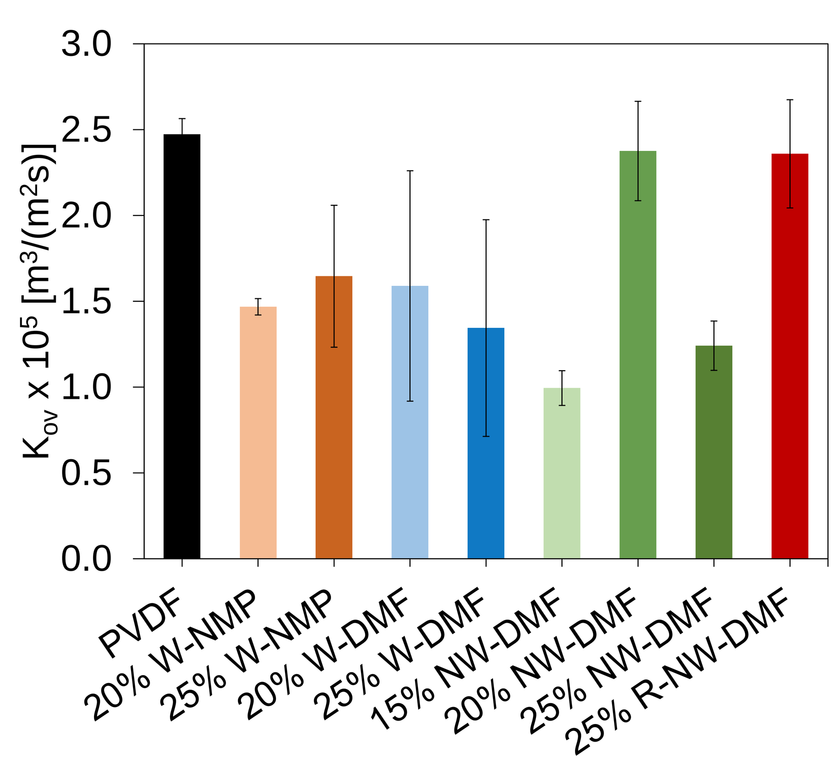
Hydrolytic stability

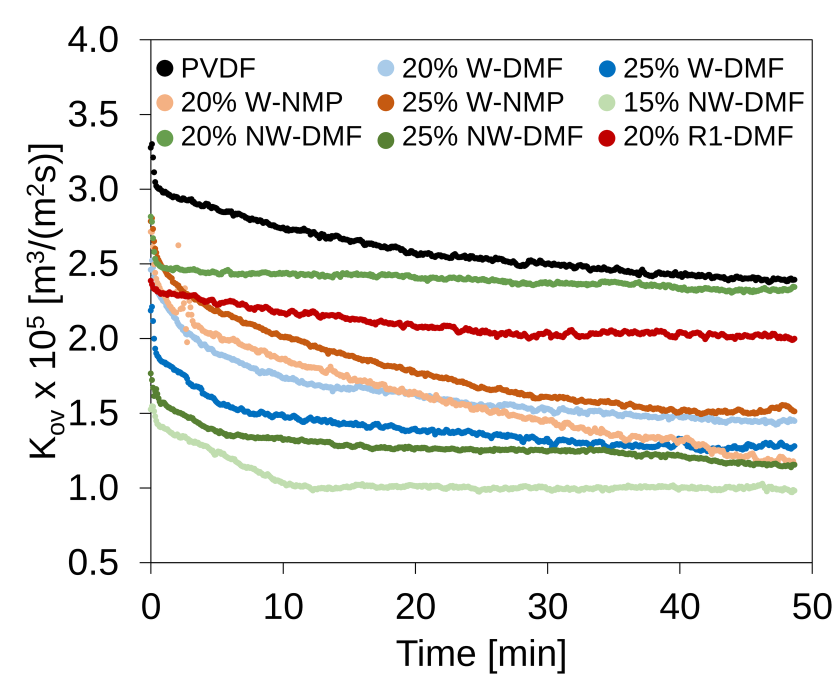




PLA degradation followed **surface erosion** (left), where membranes exhibiting **sponge morphology** with **higher molecular weight** and **lower crystallinity** (NW) resulted in **higher stability** (right)

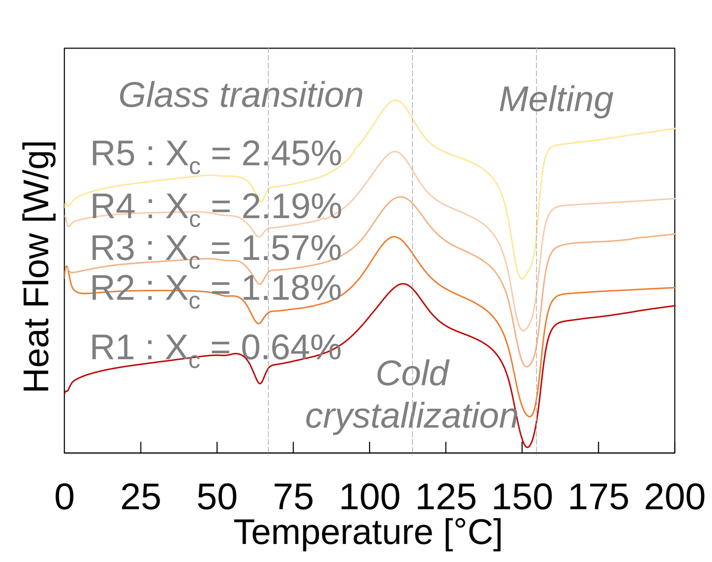
CO_2 absorption test

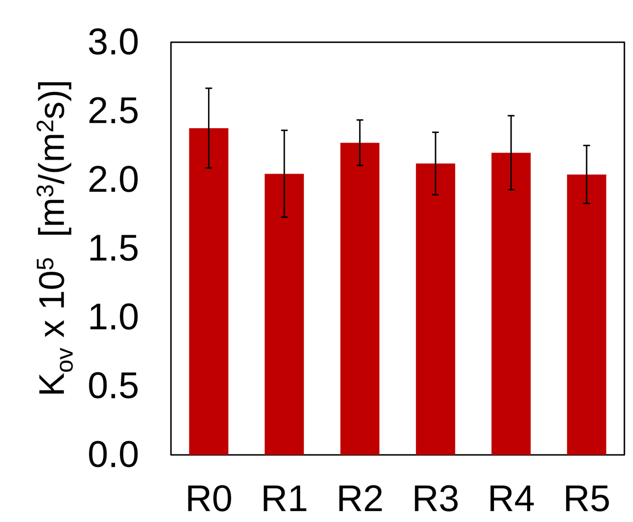


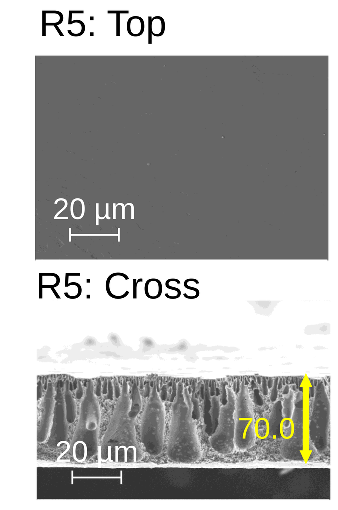


Finger morphology resulted in **higher initial mass transfer rate** but suffered **pore wetting** heavily.

Recyclability







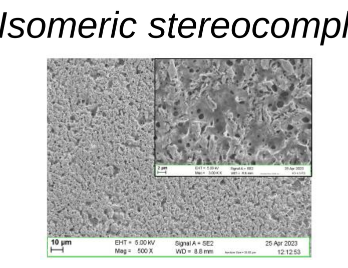
Recycling did not significantly affected PLA properties and mass transfer performance

Conclusion

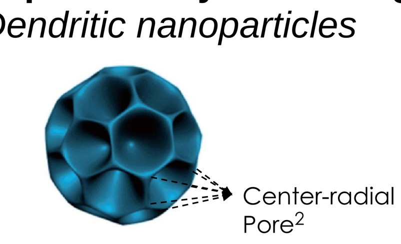
- Membrane morphology is determined by kinetics and thermodynamics of separation, where **slower kinetics and unfavorable thermodynamics** leads to **sponge-like morphology**.
- The most stable PLA membrane was obtained with **25% NW-DMF**, exhibiting the highest molecular weight, lowest crystallinity, and least porosity.
- Pore wetting is a serious issue with PLA membranes and can be minimized by synthesizing sponge-like membranes, but porosity should be sufficient to support transfer (*i.e.*, 20% NW-DMF)
- PLA polymer shows **high recyclability** with **no significant loss in performance**

Future work

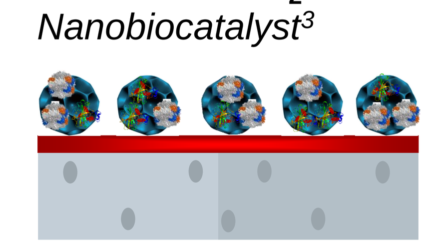
Stable PLA membrane: *Isomeric stereocomplexation[1]*



Improve enzyme loading: *Dendritic nanoparticles*



Intensified CO_2 conversion: *Nanobiocatalyst[3]*



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Acknowledgements

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