

# Soft and Hybrid Nanoporous Materials for Membrane-based Separation and Catalysis

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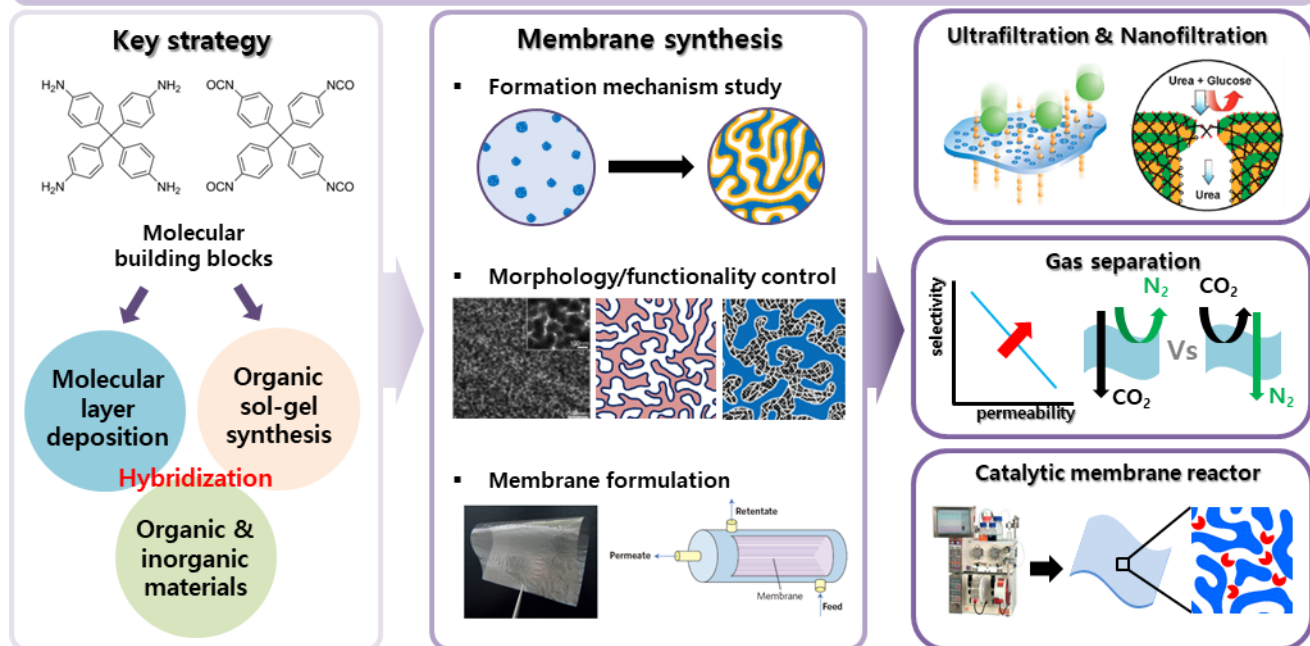
## Descriptions of Research Topics

- Synthesis of nanoporous membrane with molecular network
- Development of nanostructured organic/inorganic hybrid materials
- Development of catalytic membrane reactor
- Fundamental study on the chemistry with a membrane platform

Applications:

- Ultrafiltration and nanofiltration
- Gas separation & gas capture
- Catalytic membrane reactor

## Development and application of a new bottom-up membrane synthesis methods from molecular networks

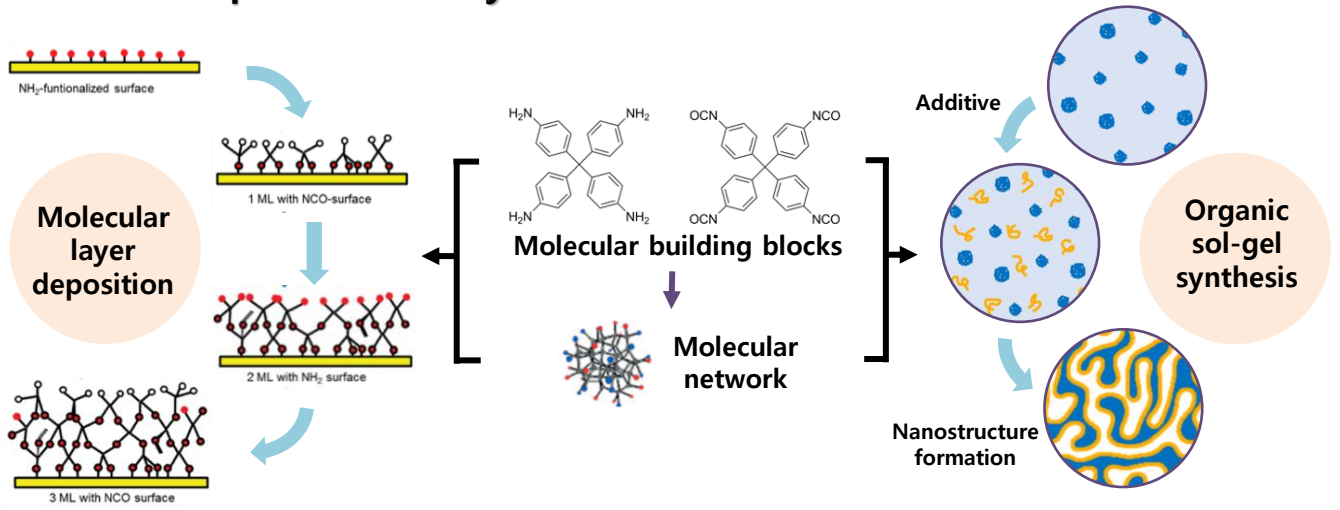


**Research Fields** 1 Material-Nano 2 Energy-Resource

**Keywords** Molecular network, Ultrafiltration, Nanofiltration, Continuous flow reactor, Catalyst immobilization, Gas separation, CO<sub>2</sub> capture, Organic sol-gel synthesis, Molecular layer deposition

# 1. Development of a new membrane synthesis strategy

## Bottom-up membrane synthesis from molecular network

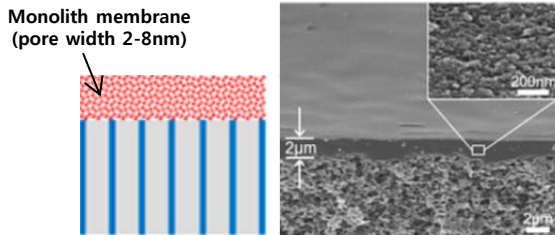


*Angew. Chem. Int. Ed.* **2010**, 49, 9504-9508

- Development of membrane synthesis using molecular building blocks
- Fundamental understanding of membrane formation mechanism

## Development of various types of membrane from molecular network

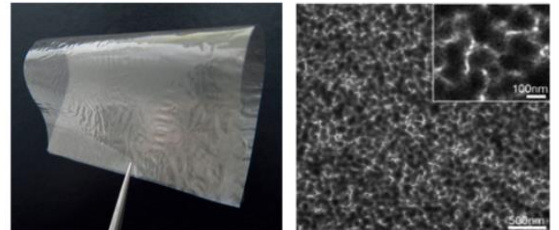
### < Thin film composite membrane >



- ✓ One-pot membrane formation by filtration
- ✓ Controllable membrane thickness

*ACS Macro Lett.* **2015**, 4, 991-995

### < Homogeneous nanoporous membrane >

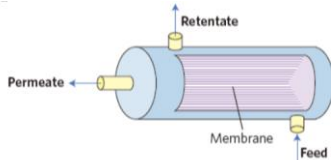


- ✓ Solution-processability
- ✓ Functional mesopore surface

*Angew. Chem. Int. Ed.* **2016**, 55, 11495-11498.

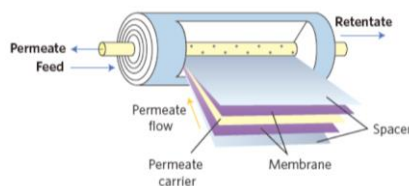
### < Membrane module formulation >

- Hollow fiber format



Koros *et al.* *Nat. Mater.* (2017)

- Spiral wound format



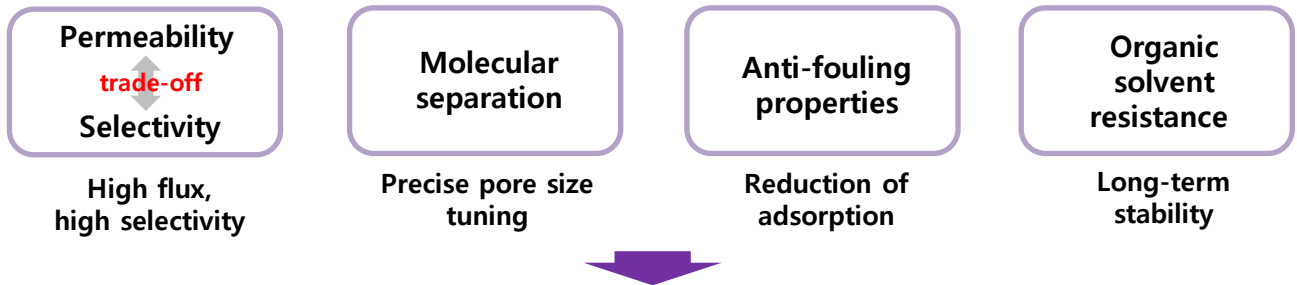
- ✓ Processing of nanostructured molecular network into a practical module format
  - flat sheet
  - spiral wound
  - hollow fiber

- Synthesis of nanoporous membrane for specific applications
- Solution processing of molecular network toward a practical module development

## 2. Ultrafiltration and nanofiltration membrane

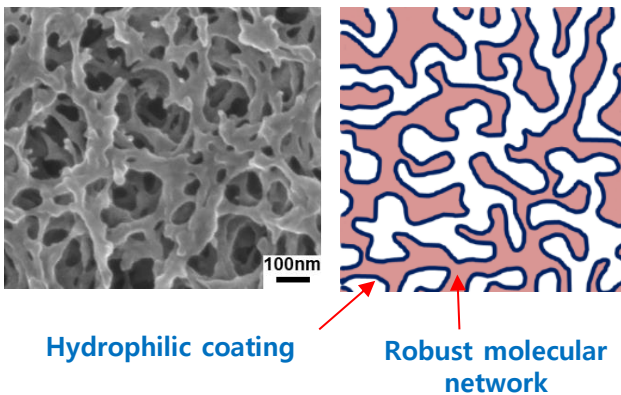
### □ Key issues in membrane-based ultrafiltration and nanofiltration

- **Ultrafiltration** : filtration of colloidal particles and macromolecules such as proteins
- **Nanofiltration** : retention of molecules(200~300 Da), divalent and higher valent ions



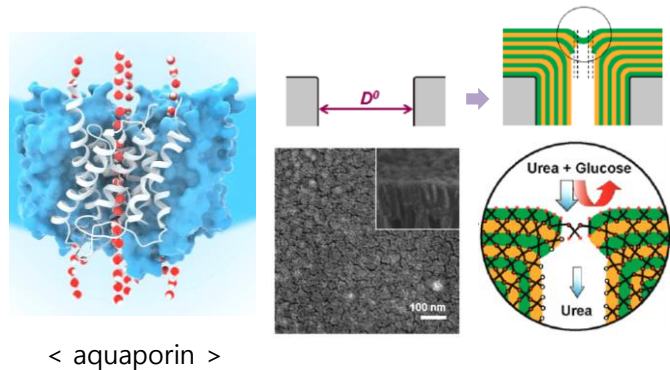
### □ Strategies to tackle the key issues in ultrafiltration and nanofiltration

< *In situ* hydrophilic grafting >



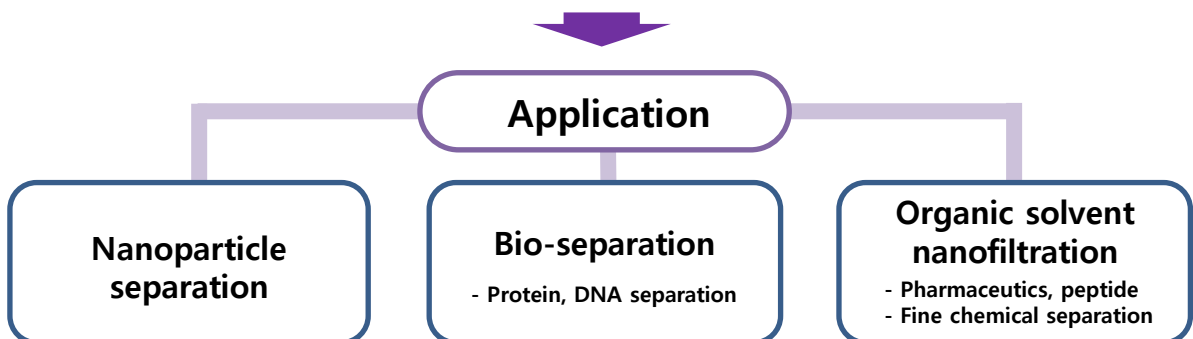
- ✓ Facile method for robust membrane synthesis
- ✓ Hydrophilic coating for high water flux

< Biomimetic membrane by MLD >



*Macromolecules* **2011**, 44, 7092-7095.  
*Chem. Mater.* **2016**, 28, 8044-8050.

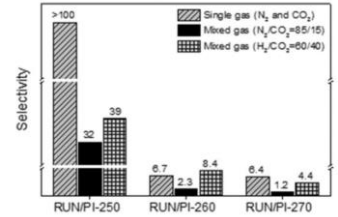
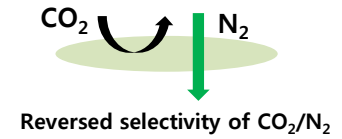
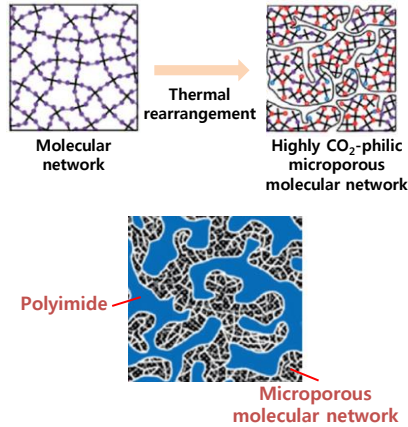
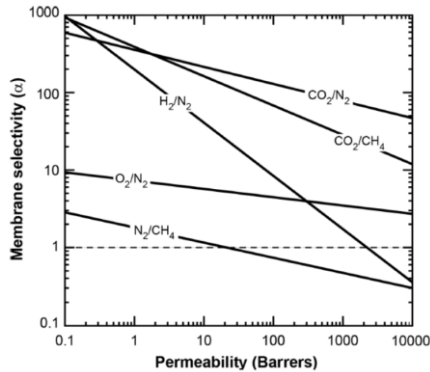
- ✓ Aquaporin-mimetic artificial nanochannel
- ✓ Precise control in pore size and thickness through molecular layer deposition



- Robust ultrafiltration membrane with diverse surface functionalities
- Molecular layer deposition approach for biomimetic nanofiltration membrane

### 3. Gas separation membrane

#### □ Microporous polymer composite membrane for CO<sub>2</sub> separation



✓ Overcoming permeability-selectivity trade-off is a critical issue.

How to control gas affinity and diffusion?

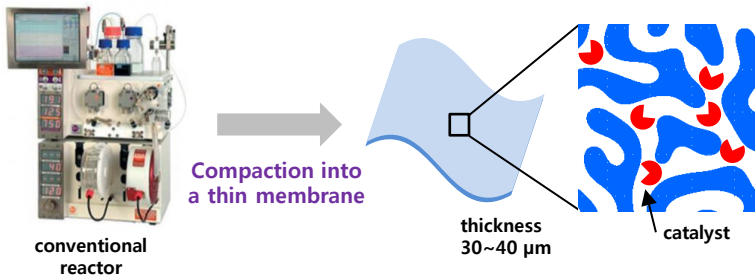
✓ Combination of highly CO<sub>2</sub>-philic microporous molecular network and commercial polymer for gas separation

*Angew. Chem. Int. Ed.* **2016**, *55*, 1318-1323.

➤ Composite membrane of commercial polymer and CO<sub>2</sub>-philic rigid molecular network for high performance CO<sub>2</sub> separation

### 4. Catalytic membrane reactor

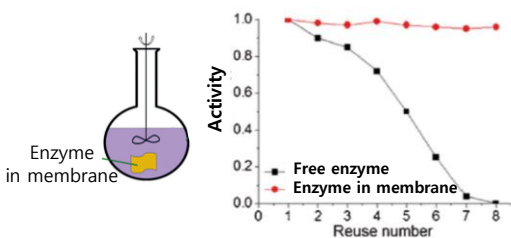
#### □ Continuous nanopores in membrane for catalytic reaction



- ✓ Various membrane catalyst system (enzyme, nanoparticle, organic catalyst)
- ✓ Enhanced stability, recyclability
- ✓ Application to batch and flow reaction

Image : Jensen *et al.* Lab Chip (2014)

#### Highly stable enzymatic membrane catalyst



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#### Biocatalytic/catalytic membrane reactor

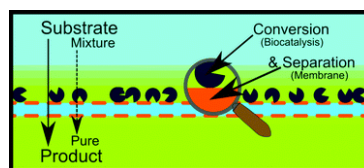
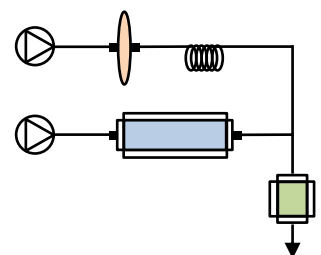


Image : Jochems *et al.* Green Chem. (2011)

#### Hybridization with other flow reactor system



- Compact catalytic membrane reactor for efficient enzymatic and chemical reaction
- Development of a membrane-based reactor system