# Economical Large Scale Advanced Membrane & Sorbent Strategies

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- Demand growth for chemical commodities, plus the high energy intensity of separations used in commodity production, present opportunities.

- Membranes and sorbents, offering up to 10X reductions in process energy intensity and CO_2 emissions, enable many opportunities.

- An approach is outlined to pursue these opportunities and to provide competitive advantages and environmental benefits.

- Numerous attractive targets exist :
  - high CO_2 & H_2S natural gas decontamination
  - olefin-paraffin debottlenecking
  - n-C_4/i C_4 debottlenecking
  - CO_2 capture from flue gas
  - shale gas "flow back" and natural gas liquids capture

Polymer-derived advanced materials in hollow fiber formats allow optimizing selectivity performance vs. manufacturing costs

Spin dope & bore fluid delivery

Spinneret

Thin skin for high flux + porous support for durability

200-300µm OD fibers

Fiber take-up

Water quench bath

Solvent exchange, drying & module formation

$20/m² and 10,000 m²/m³ module volume

most advanced materials

D

C

B

10x

A   simple polymers

5-10x   50x

Cost ($/m²)→

Performance →
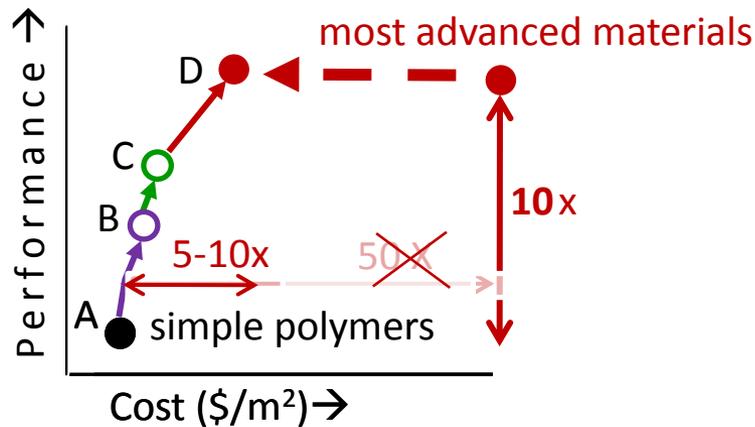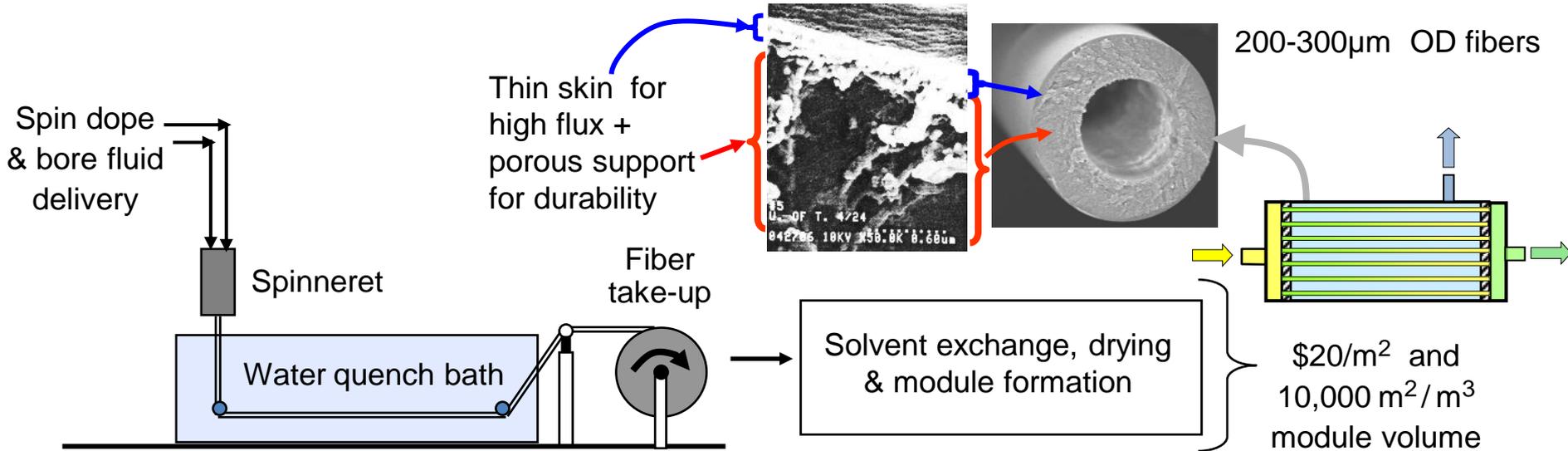
B = crosslinked polymers
C = hybrid polymer-inorganic mat'ls
D = carbon molecular sieve mat'ls

$P_i / P_j = \alpha_{i/j}$

Advanced materials

$P_i = \dfrac{[\text{flux of } i]}{[\Delta p_i / L_{mem}]}$

Polymer upper bound

P_i (permeability of i)

Example high pay-off target: purification of high CO_2 content natural gas

Pre-treatment

CH_4 pipeline to land

Reinject CO_2– high α minimizes CH_4 loss

ocean

50:50 CO_2: CH_4 contaminated natural gas

Swelling-induced plasticization of cellulose acetate membranes increases CO_2 permeability, but CO_2/CH_4 selectivity <u>falls badly</u> in aggressive feeds

500
100
$\alpha \frac{_{CO2}}{_{CH4}}$
10
1

2001 polymer limit

Crosslinked (small change 10→800 psi total feed pressure)

Cellulose acetate large α loss loss between 10→800 psi total feed pressure)

0.01 0.1 1 10 10^2 10^3 10^4 10^5
CO_2 permeability (Barrers)

CO_2 Permeability

CO_2/CH_4 Selectivity

CO_2 partial pressure

Spin → Post-spin crosslink → Module formation

Hybrids & CMS have size discrimination abilities beyond those of polymers

Pure
poly

Hybrid material
spectrum

Low
loading

High
loading

ZIF's
Pure sieve

[CMS]

+ 0.1 Å tunable
pore sizes

Performance →

Cost ($/m²)→

"other"
>>10x

>10x

≤10x

A= simple polymers
B = X-linked
C = hybrids
D = carbons
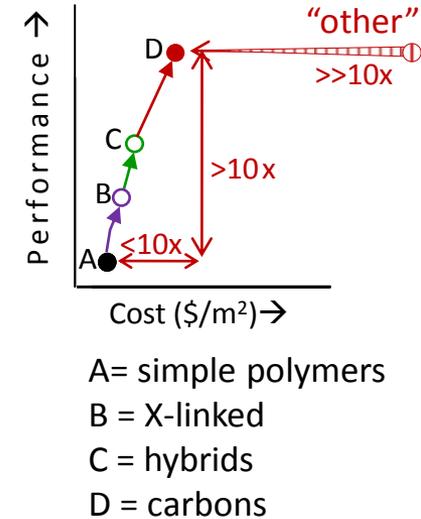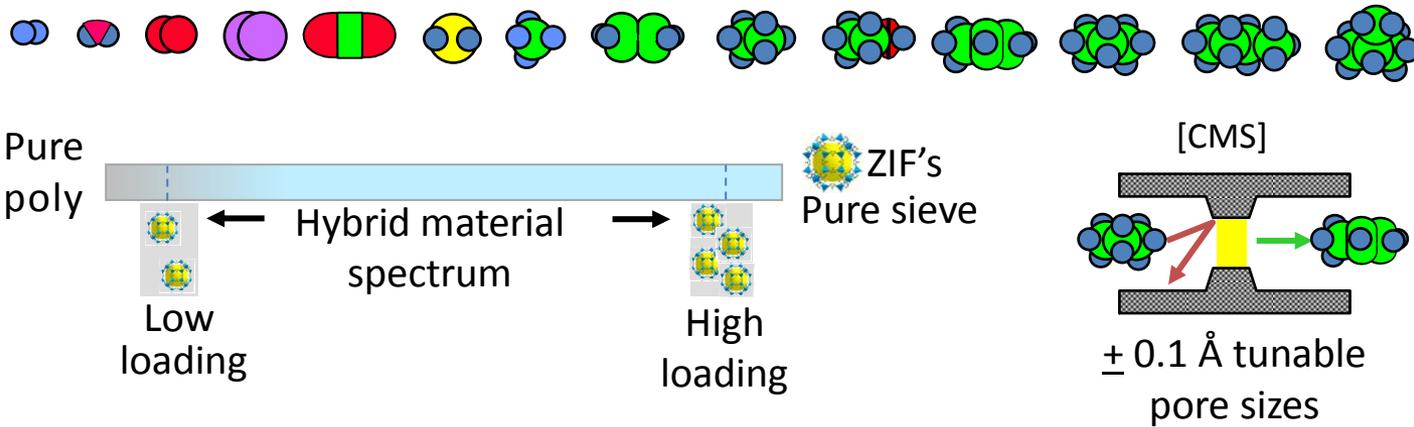
Technical **&** economic evolution occurs easily on the polymer fiber manufacturing platform

| Spin | → | solvent exchange | → | Dry | → | Module formation |

A = simple polymers

| Spin | → | solvent exchange | → | Dry + crosslink | → | Module formation |

B = X-linked

| Sheath-core spin | → | solvent exchange | → | Dry | → | Module formation |

C = hybrids

| Spin | → | solvent exchange | → | Dry | → | Pyrolyze | → | Module formation |

D = carbons
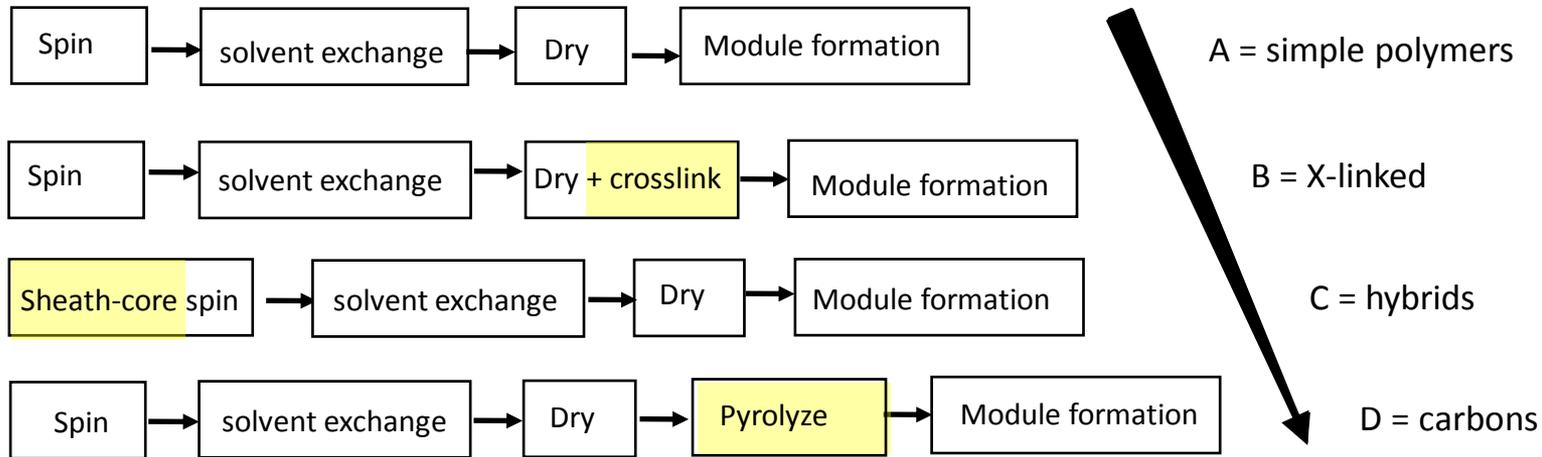
Finding ways for "other" advanced materials (e.g., ceramics and zeolites) to be added to the fiber manufacturing platform would enable their use when materials A-D (above) are inadequate!

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