Production of High-Purity O_2 via Membrane Contactor with Oxygen Carrier Solutions

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Key personnel

- **Not-for-profit** research company, providing energy and natural gas solutions to the industry since 1941
- **Facilities**: 18 acre campus near Chicago, 28 specialized labs

PI: Dr. Shiguang Li

Dr. James Zhou

Mr. Howard Meyer

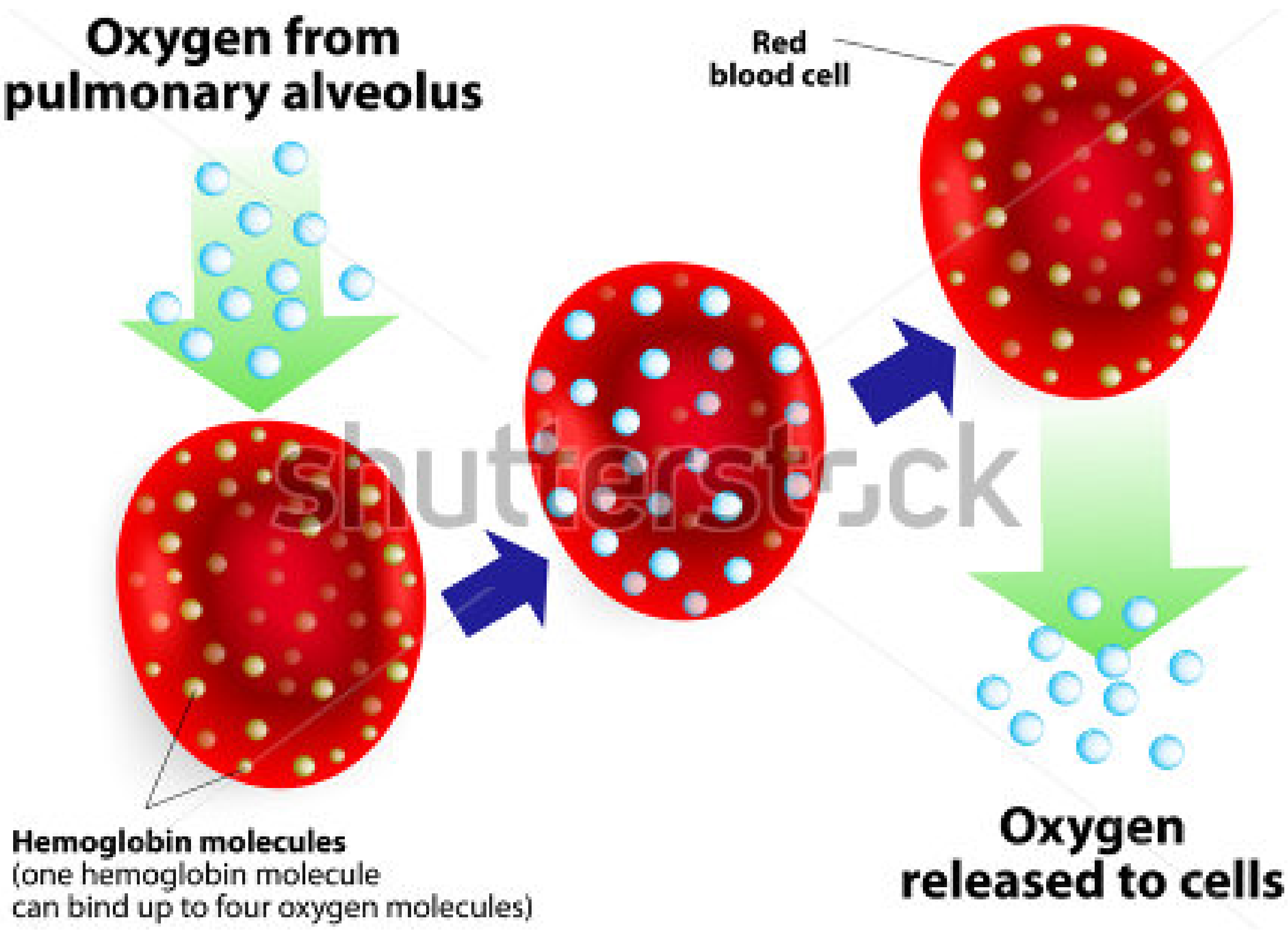
UNIVERSITY OF SOUTH CAROLINA

- **Co-educational research university** located in Columbia, South Carolina
- **Prof. Yu Group**: expertise in thin films, coatings, membranes, liquid absorption and transport mechanisms

co-PI: Dr. Miao Yu

Dr. Mahdi Fathizadeh

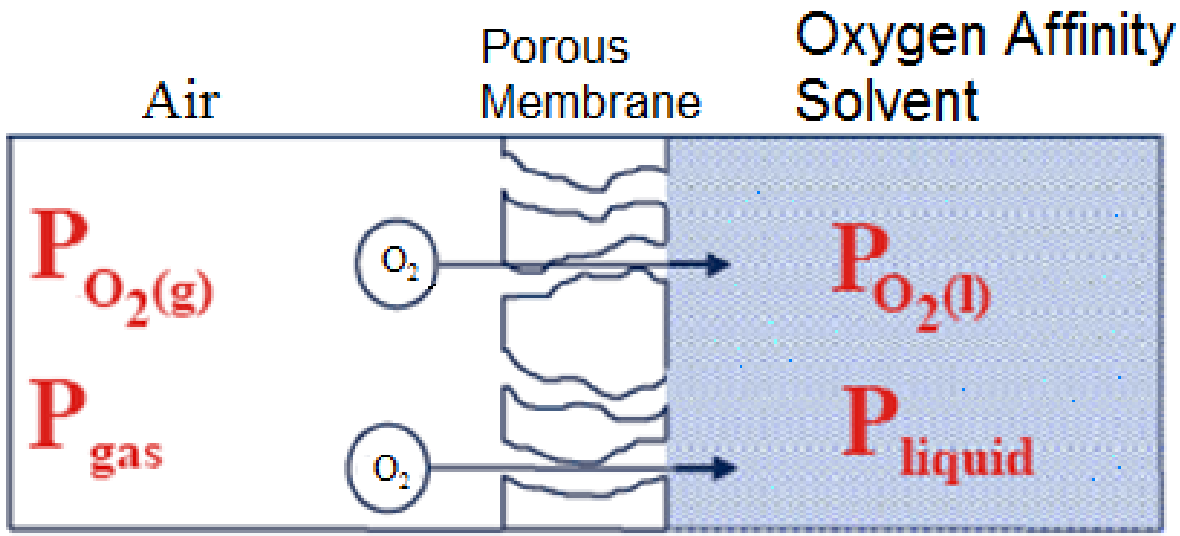
Our inspiration…Red Blood Cell



We use *membrane contactor* to realize our concept

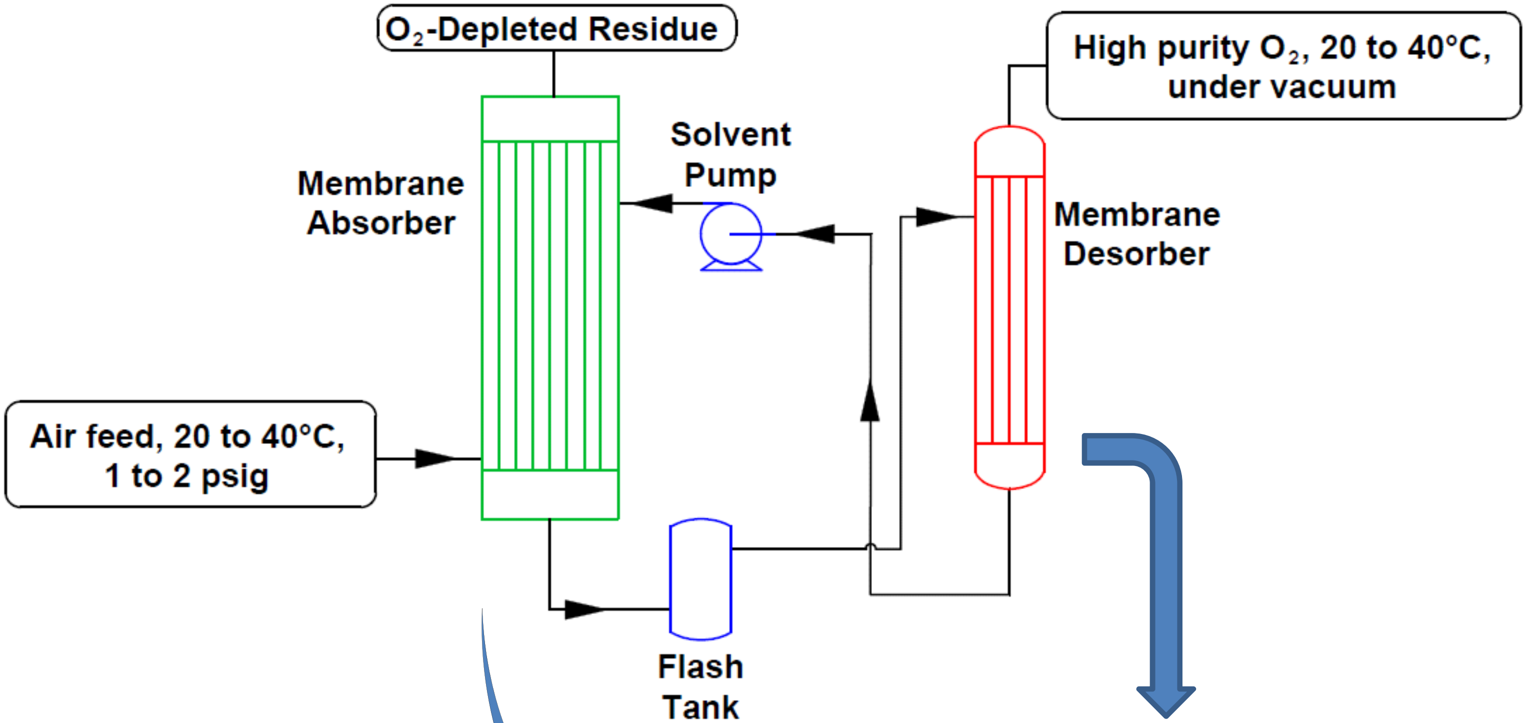
What is a membrane contactor?

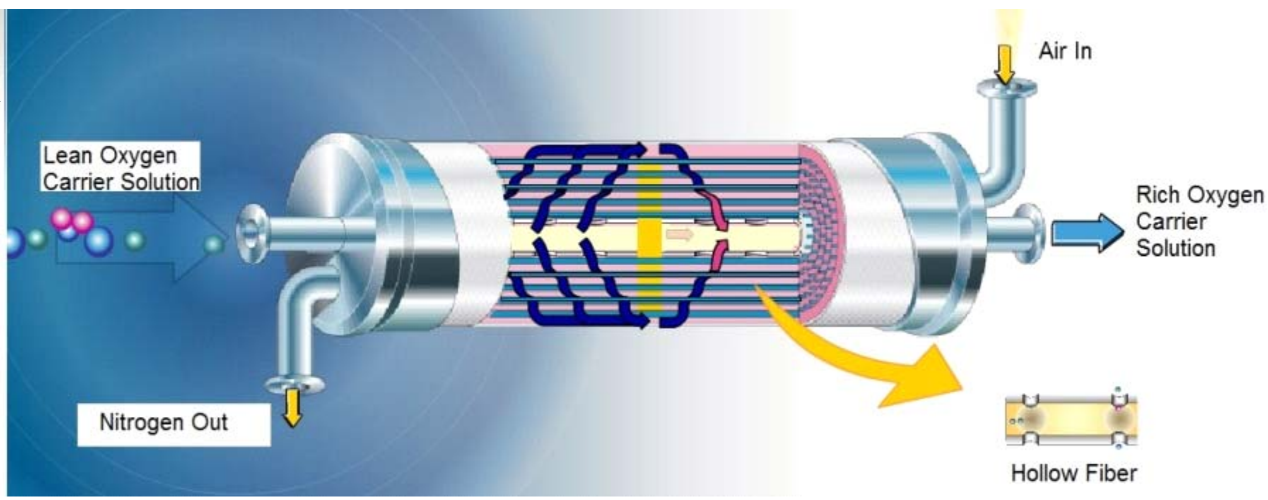
- <u>High</u> surface area membrane device that <u>facilitates</u> mass transfer
- Gas on one side, liquid on other side



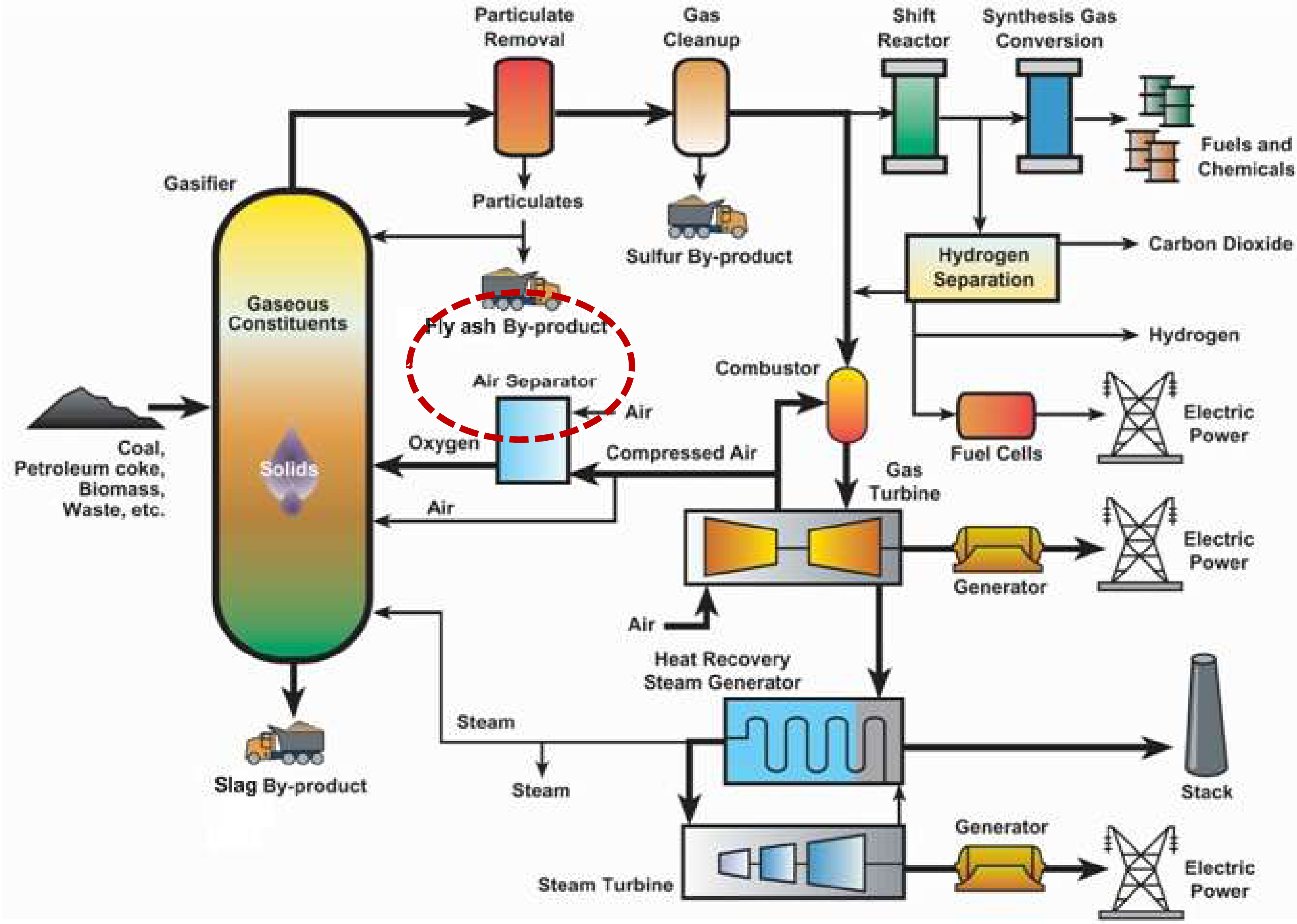
- Membrane does not wet out in contact with liquid
- **<u>Separation mechanism</u>**: O_2 permeates through membrane, reacts with the solvent; N_2 does not react and has low solubility in solvent

Process description





Application in the Integrated Gasification Combined Cycles (IGCC)



Project objective and goal

Objective: achieve proof of concept using hollow fiber membrane contactor (HFMC) with an O_2 carrier solution as solvent and air as feed to produce greater than 95% purity of O_2

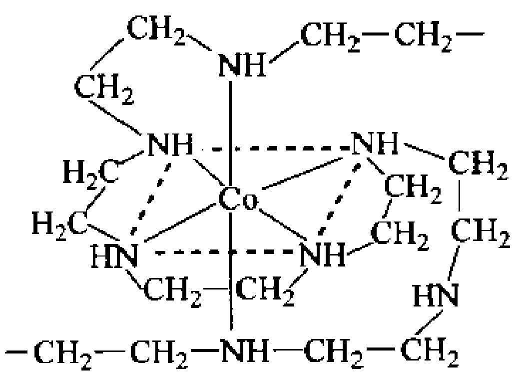
Goal: achieve O_2 production rate with a mass transfer coefficient ≥ 1.0 $(sec)^{-1}$ and O_2 purity ≥ 95%

Membrane contactor vs. conventional contactors

Gas-liquid contactor	Volumetric mass transfer Coefficient ($(sec)^{-1}$)
Packed column (Countercurrent)	0.0004 – 0.07
Bubble column (Agitated)	0.003 – 0.04
Spray column	0.0007 – 0.075
Our goal for membrane contactor	**1.0**

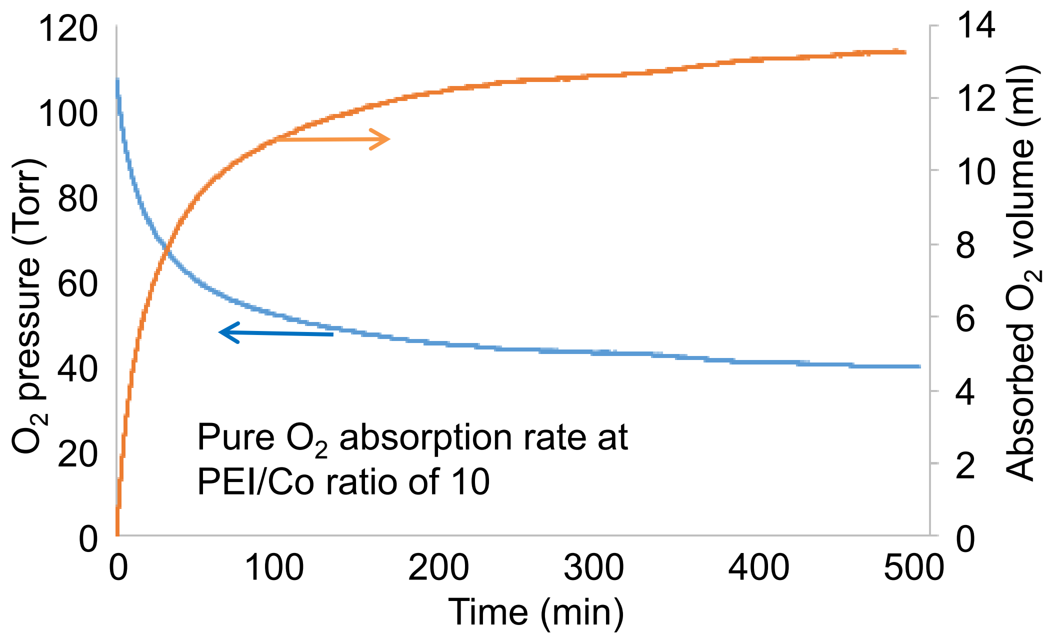
Our current progress

PEI-Co = poly(ethyleneimine)-cobalt



Loading on oxygen carrier, ml (STP)/L solution		Solubility in water, ml (STP)/L solution		Total capacity, ml (STP)/L solution		Product O_2 purity, %
O_2	N_2	O_2	N_2	O_2	N_2	
1,000	0	2.9	5.3	1,003	5.3	**99.5**

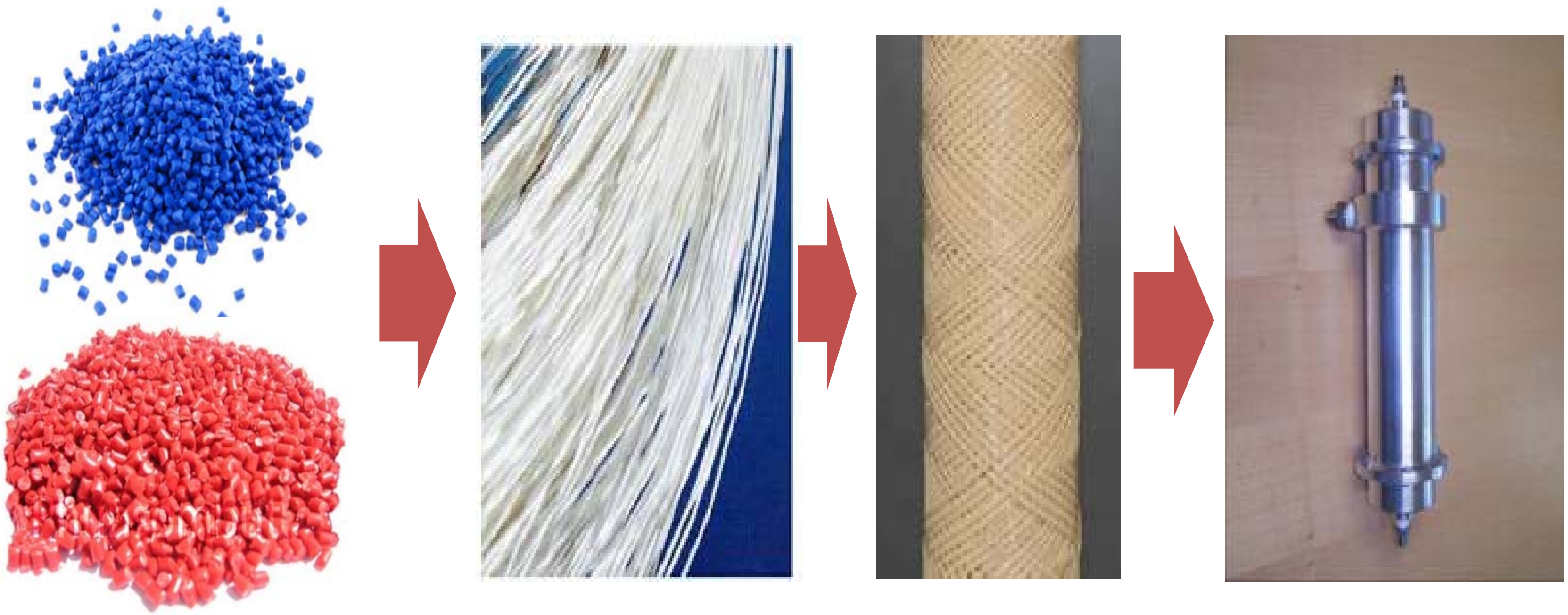
PEI/Co ratio	mL O_2/L solution
20	590
15	780
10	1,100
7.5	1,300
5	1,500



Stage of the current project and beyond the project

- Current project
  - We are developing a promising O_2 production process using HFMC with O_2 carrier solution
  - O_2 carrier solution developed and showed high O_2 absorption capacity
  - >95% purity of O_2 production proof of concept in progress
  - Techno-economic analysis (TEA) based on experimental data
- Beyond the project
  - PEI-Co solution optimization: *longer lifetime, fast bonding and desorption kinetics, desired physical properties, etc.*
  - HFMC operation condition optimization towards high production rate
  - Continuous >95% O_2 production in HFMC

PEEK membrane under development



Membrane geometry	Packing density (m^2/m^3)	O_2 permeance (GPU)
Hollow fiber	2,200	1,000

Mature air separation technologies and comparison

Technology	O_2 purity limit (vol.%)	Largest O_2 flow rate (Ton O_2/day)
Cryogenic distillation	99+	>3,000
Pressure swing adsorption (PSA)	95	<350
Conventional gas separation membranes	40	<20

Advantages of our technology compared to cryogenic distillation

Capital Equipment Savings	Operating Cost Savings
• **Simple materials of construction** • **Reduction in compression and heat exchange equipment** • **Near atmospheric pressure operations**	• Compression to operating conditions only for O_2 fraction of air • Near ambient temperature and pressure • Low binding energy for O_2 solvent

- Estimated O_2 purity >95%
- Projected cost including capital, operating, and energy use is ~ \$19.97/ton O_2, lower than cryogenic distillation (~ \$35.80/ton O_2)
- Can be easily scaled

Acknowledgements

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- **DOE NETL Darryl T. Shockley**