Directly-Spun Epoxy-Crosslinked PEI Chemisorption Fiber Sorbents (CHEFS) for Direct Air Capture (DAC) of CO_2

Qiuming Wang

Chemical Engineer II, NETL Research & Innovation Center

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Disclaimer

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Authors and Contact Information

Qiuming Wang[1,2], Walter C. Wilfong[1,2], Shouliang Yi[1,2], Fan Shi[1], and McMahan L. Gray[1]

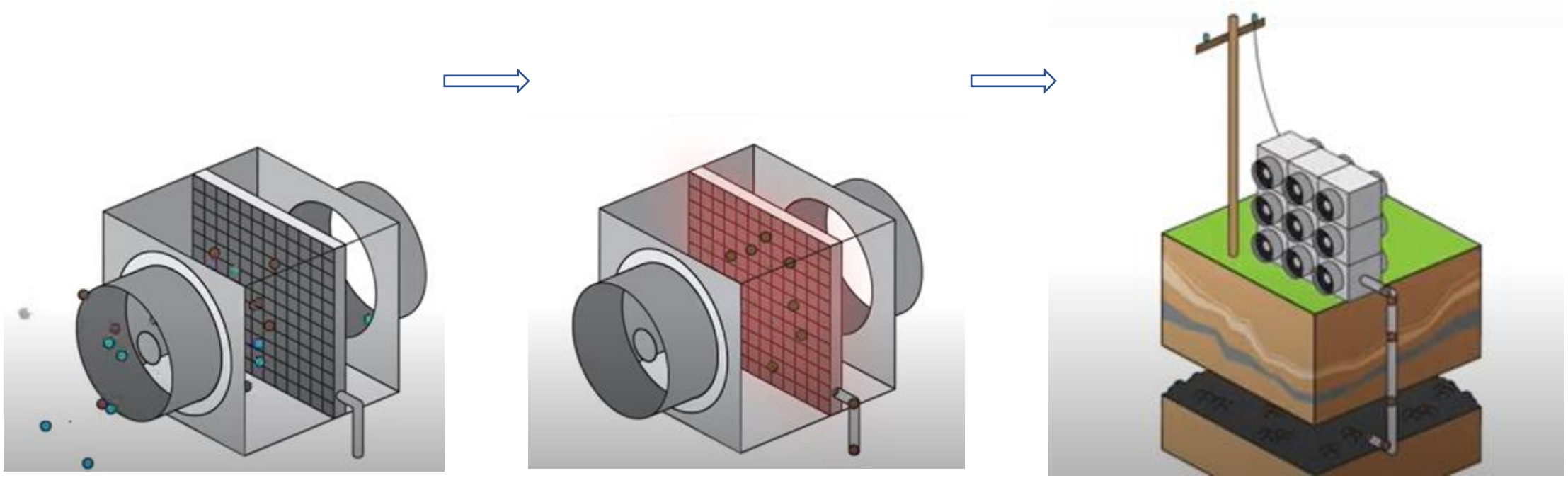
[1]National Energy Technology Laboratory, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA

[2]NETL Support Contractor, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA

Introduction: Direct Air Capture of CO_2 (DAC)

How DAC Works

CO_2 is captured from the air ⇒ **then unbounded by heat** ⇒ **and can be stored underground permanently**



DAC is currently categorized as “technology readiness level” 6 (on a scale of 1 to 9), meaning it is still in the large-scale and prototype phase, not yet ready for full commercial deployment. This also means there is ample opportunity to improve performance and reduce costs through learning from early iterations of the technology.

wri.org/carbonremoval

Introduction: DAC

Status of the Leading DAC Companies

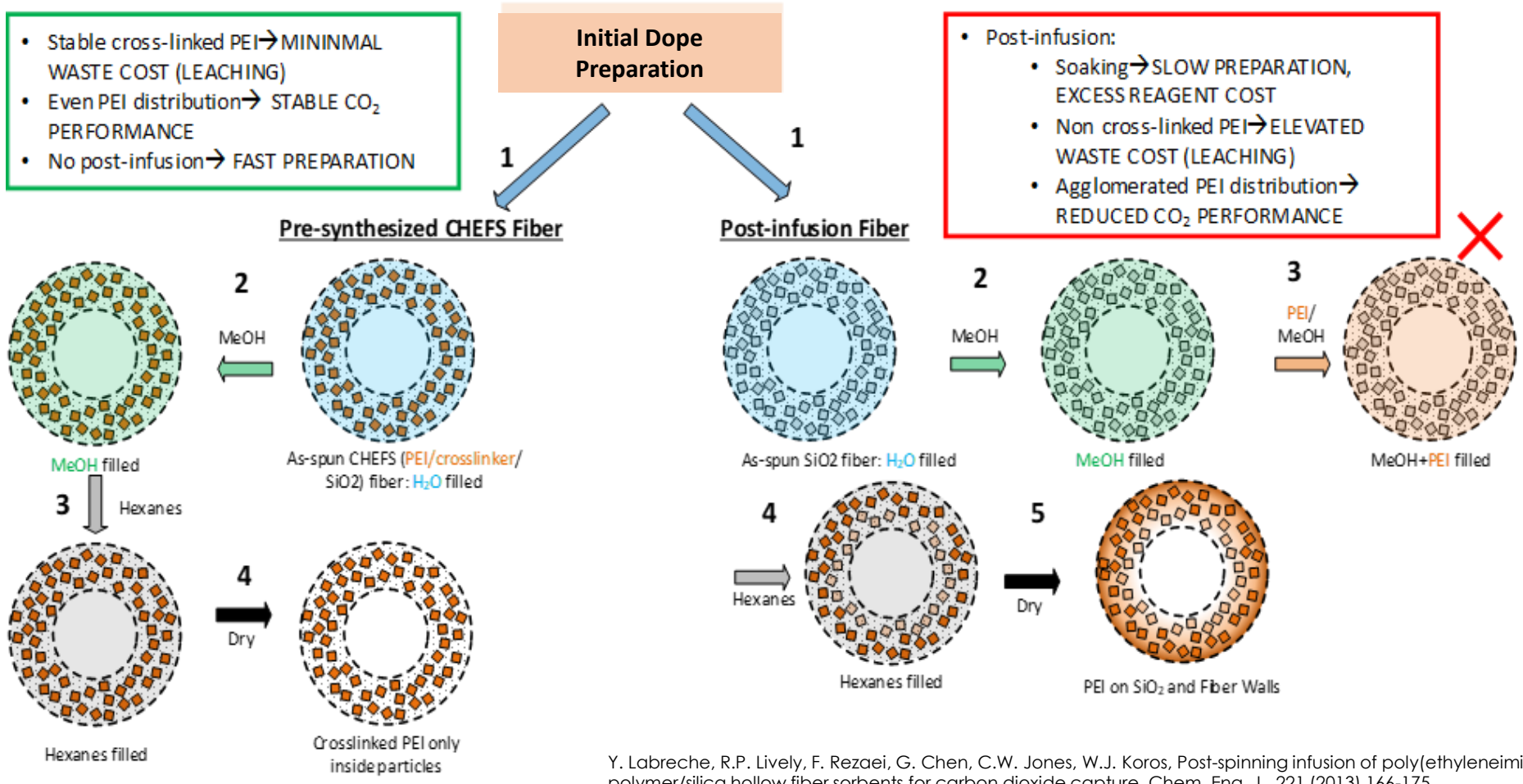
Companies	Cimeworks (Switzerland)	Carbon Engineering (Canada)	Global Thermostat (United States)
System Type	Solid sorbent	Liquid solvent	Solid sorbent
Thermal Energy Needs	80-120 °C	900 °C	105-120 °C
Thermal Energy Source	Non-fossil energy resources (geothermal, waste heat, etc.)	Natural gas with carbon capture and storage	Energy resource agnostic
Projects	15 plants throughout Europe with a collective capacity of just under 6,000 t CO_2/yr	Pilot plant in Canada; developing 1 $MtCO_2$/yr capacity plant in Southwest United States	2 plants in the United States with a collective capacity of 1,500 tCO_2/yr
Investments	Most recent round of funding, in March 2022, reached $560 million	Received $70 million in total investment from governments and corporations	Received investments of $68 million in most resent round of funding in 2019

6 things to know about direct air capture | Greenbiz

Climeworks 2022, IEA 2022, McQueen et al. 2021, NASEM 2019, Carbon Engineering 2019, Bipartisan Policy Center 2022

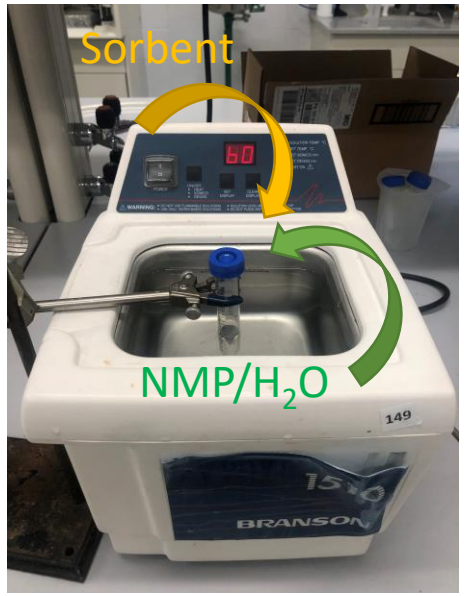
Introduction: DAC

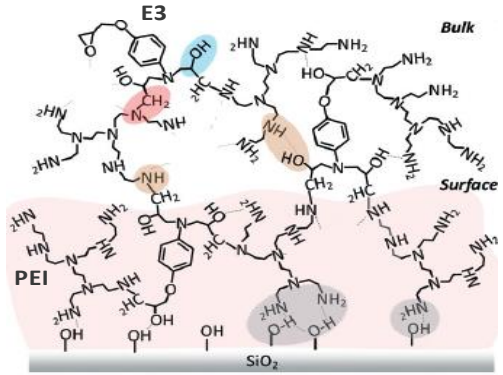
Directly-Spun CHEFS Fiber vs. Post-Infusion Fiber

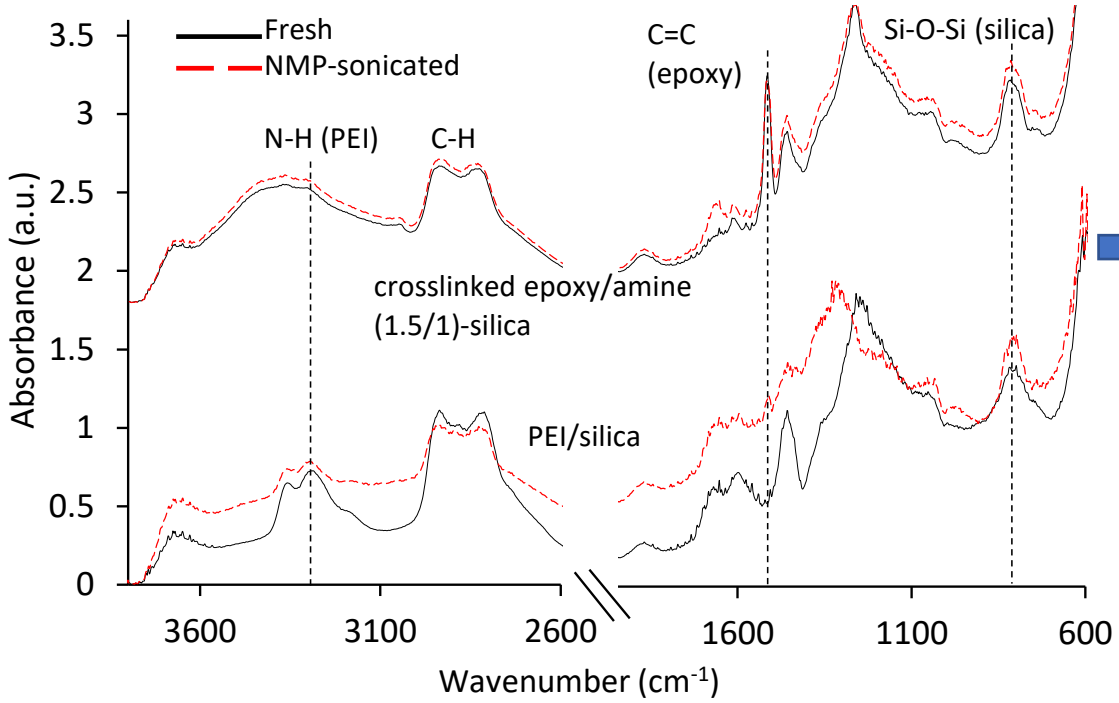


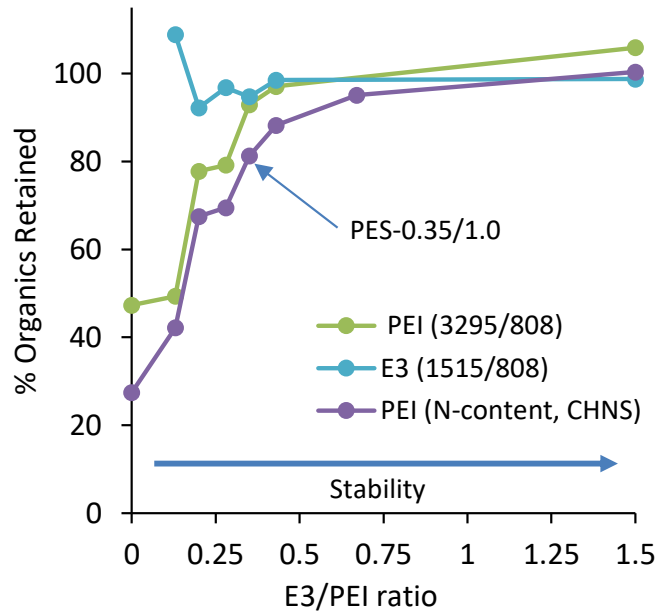
Y. Labreche, R.P. Lively, F. Rezaei, G. Chen, C.W. Jones, W.J. Koros, Post-spinning infusion of poly(ethyleneimine) into polymer/silica hollow fiber sorbents for carbon dioxide capture, Chem. Eng. J., 221 (2013) 166-175.

NETL Basic Immobilized Amine Sorbent (BIAS) Solvent Stability





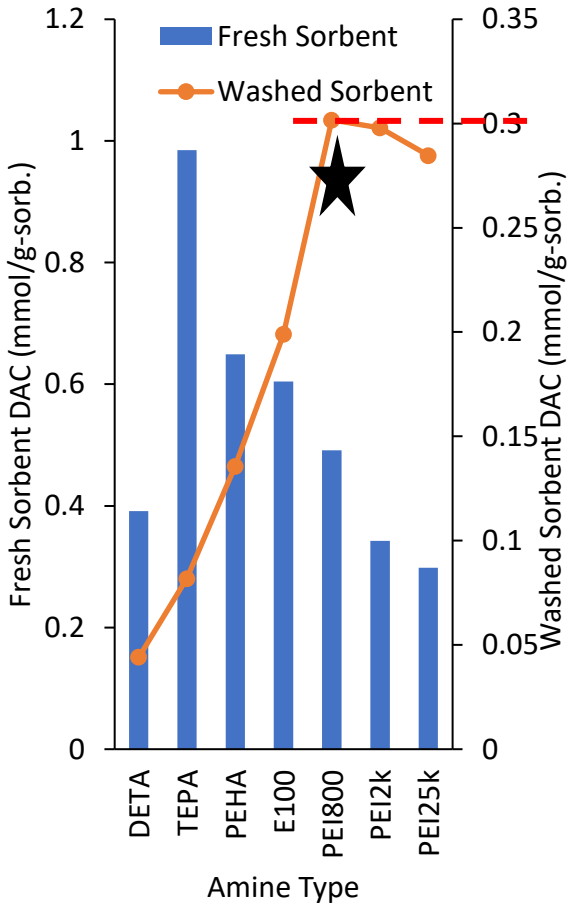




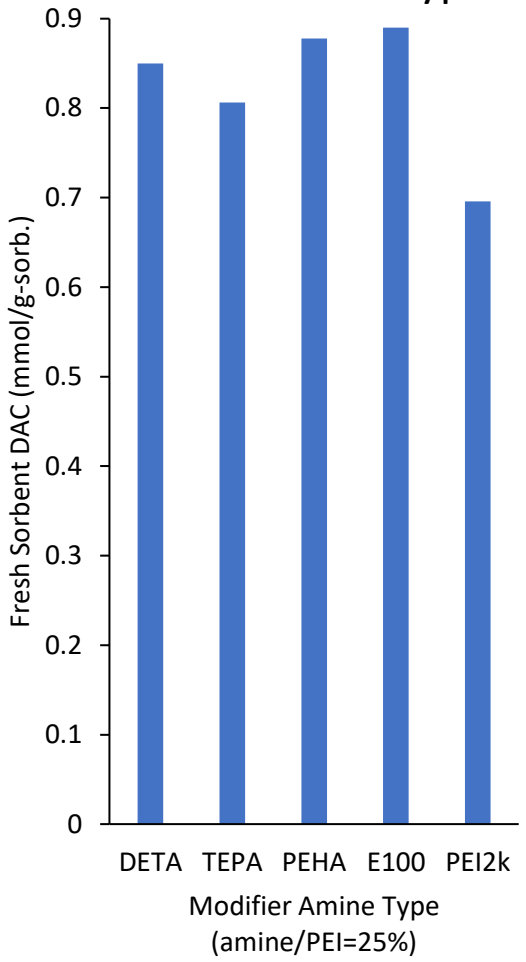
Epoxy-amine crosslinking creates a 3D polymer CO_2 capture network that is highly resistant to leaching by the fiber dope solvent.

Optimization of NETL BIAS Sorbent

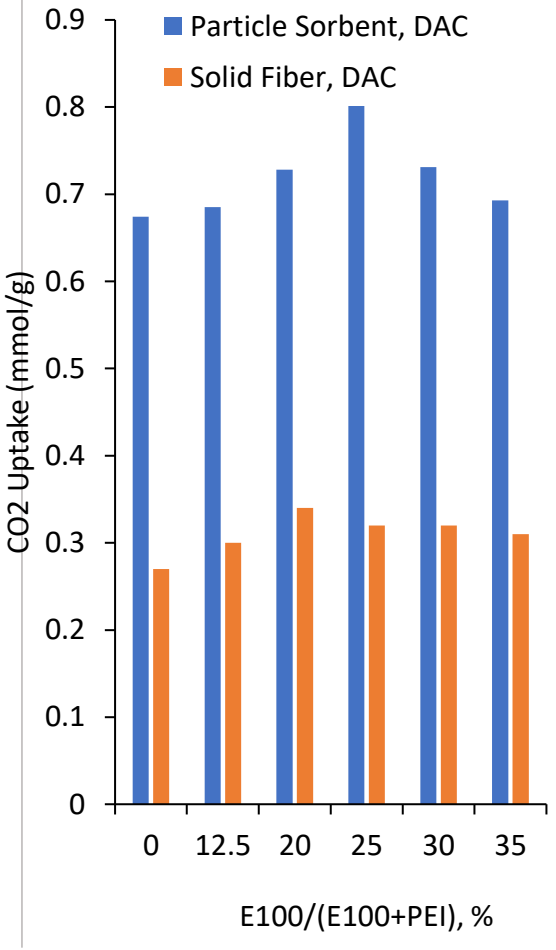
Amine Molecule Weight



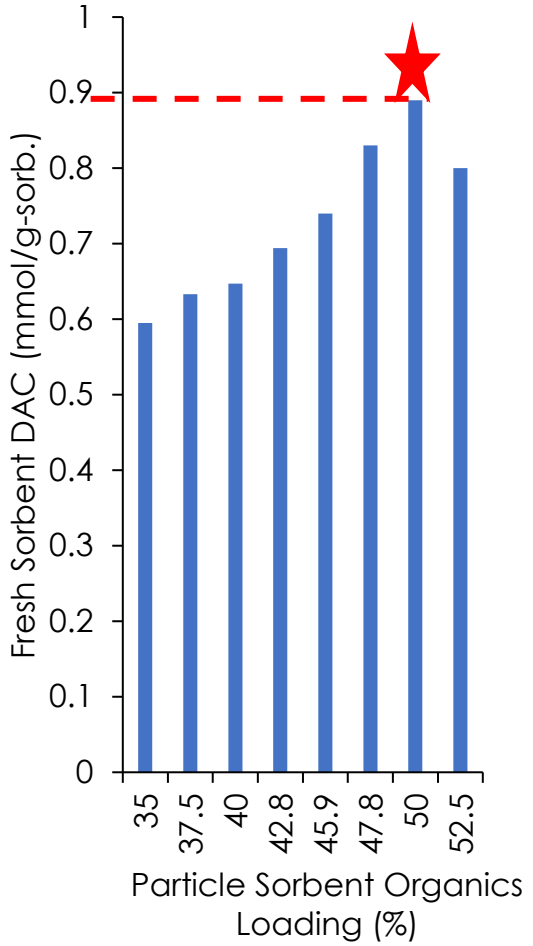
Modifier Amine Type



Modifier Amine Ratio

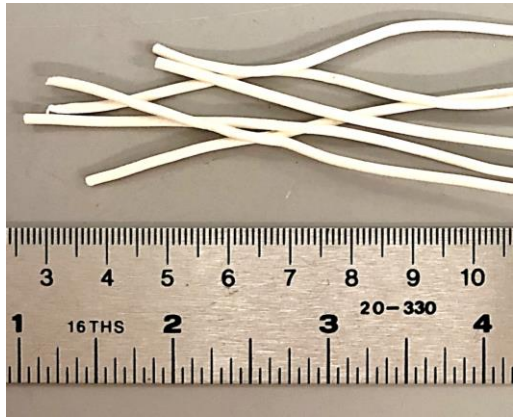


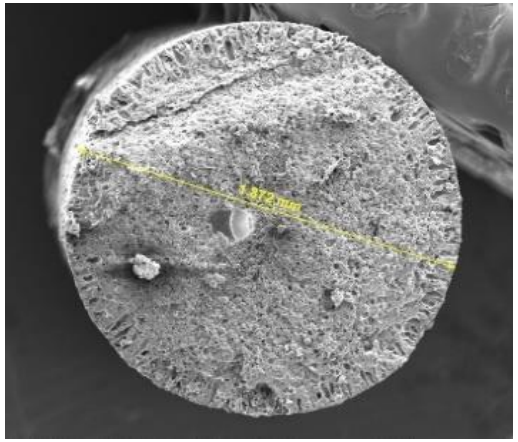
Organics Loading



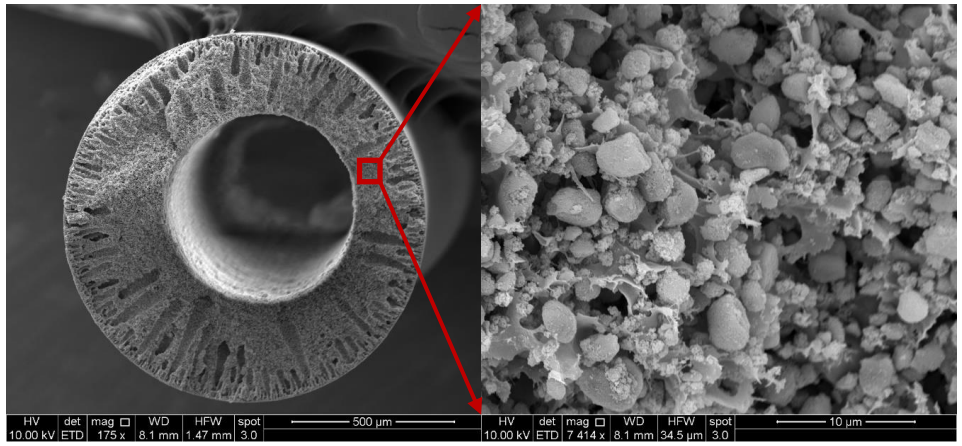
NETL Solid/Hollow Fiber and Fiber Module

Solid Fiber





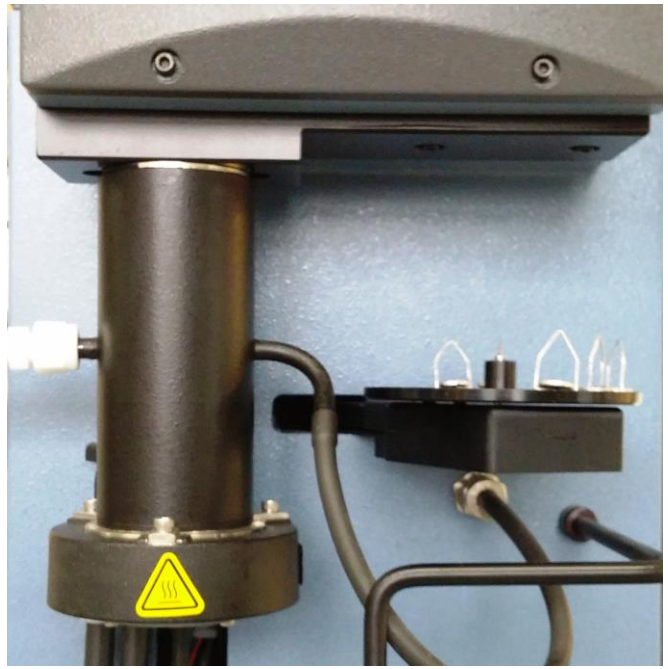
Hollow Fiber



Bench-Scale Multiple Fiber Module

CO_2 Cyclic Adsorption under DAC Conditions

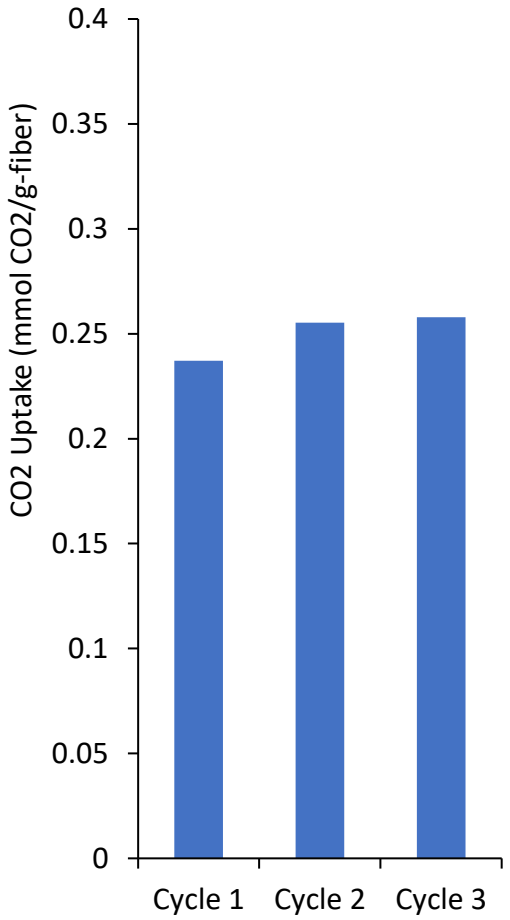
Adsorption,
35 °C, 5 h



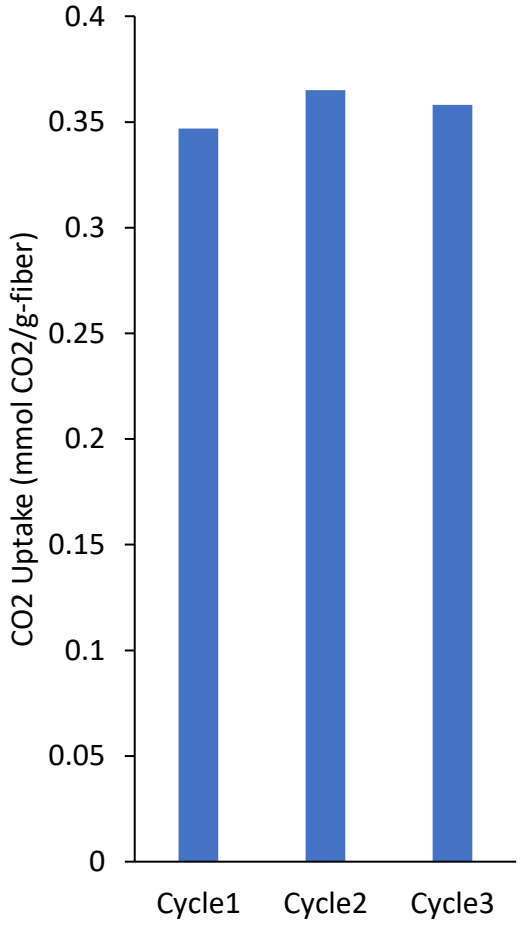
Desorption,
105°C, 1 h

Gas Purge

Hollow Fiber

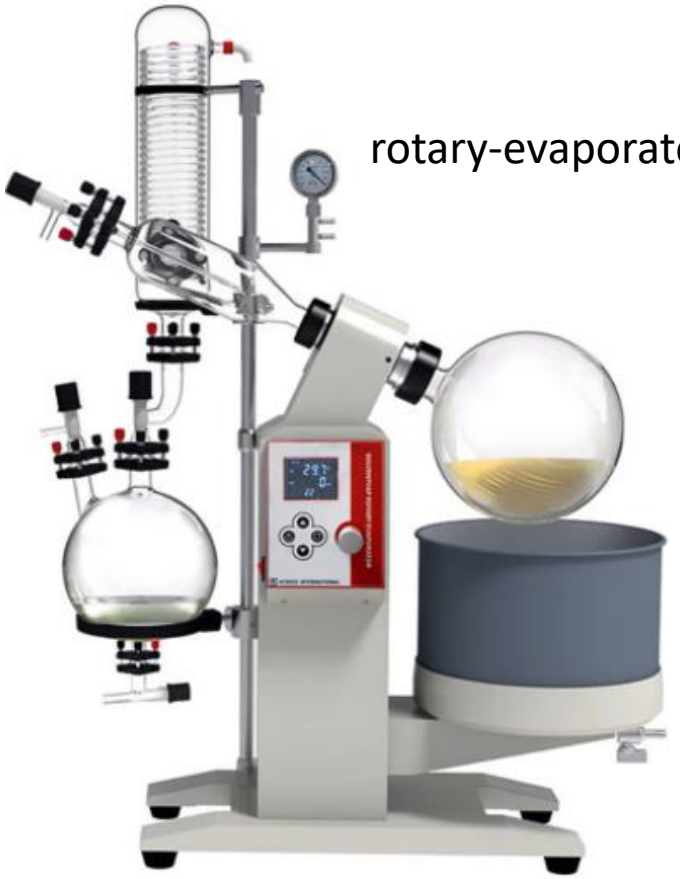


Solid Fiber



2022 Fiber Scaling-Utilizing GIT Partnership

NETL sorbent synthesis (350 g/batch)



rotary-evaporator

GIT hollow fiber spinner

- Sorbent scaling:
  50 g/batch → 300 g/batch
- Hollow CHEFS scaling:
  50 g total → 500 g total
- Module evaluation of scaled fiber

Conclusions

- A E3/PEI ratio of 0.35 retained appreciable cross-linked E3-PEI network to balance the solvent stability-CO_2 uptake performance.
- The optimized PEI-modifieramine-E3-silica network greatly improved the CO_2 uptake from 0.3 mmol/g-sorbent to 0.8 mmol/g-sorbent.
- The directly extruded solid fiber sorbent or directly spun hollow fiber sorbent offers: 1) superior stability imparted by the crosslinked amine-epoxy network within the sorbent pores to avoid amine leaching by the fiber dope solvent; 2) the single-step spinning approach avoids a post-amine infusion impregnation step; 3) the high scalability for large-scale production; and 4) low energy cost and low waste production for material manufacture and operation.

Publication: W. Wilfong, Q. Wang, T. Ji, J. Baker, F. Shi, S. Yi, M. Gray, Directly-Spun Epoxy-Crosslinked PEI Fiber Sorbents for Direct Air Capture and Post-Combustion Capture of CO_2. Energy Technology, 2022, accepted.

Patent: M. Gray, F. Shi, S. Yi, W. Wilfong, Q. Wang, Single-Step Synthesis of CHEmisorption Fiber Sorbents (CHEFS) for the Capture of CO_2 and Removal of Water Contaminants. U.S Non-provisional patent filed.

Partners: PQ Corporation, Georgia Institute of Technology

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Contact:
Qiuming Wang, Ph.D.
Qiuming.wang@netl.doe.gov
Office: 412-386-4922