Next Generation Fiber-Encapsulated Nanoscale Hybrid Materials for Direct Air Capture with Selective Water Rejection

Project Number DE-FE0031963

Ah-Hyung (Alissa) Park

Columbia University

U.S. Department of Energy

National Energy Technology Laboratory

Direct Air Capture Kickoff Meeting

February 24-25, 2021

Program Overview

a. Funding: $800,000 DOE + $200,000 Cost Share
b. Overall Project Performance Dates: 01/01/2021 – 06/30/2022
c. Project Participants:

    Columbia University (lead institution: Alissa Park (PI))

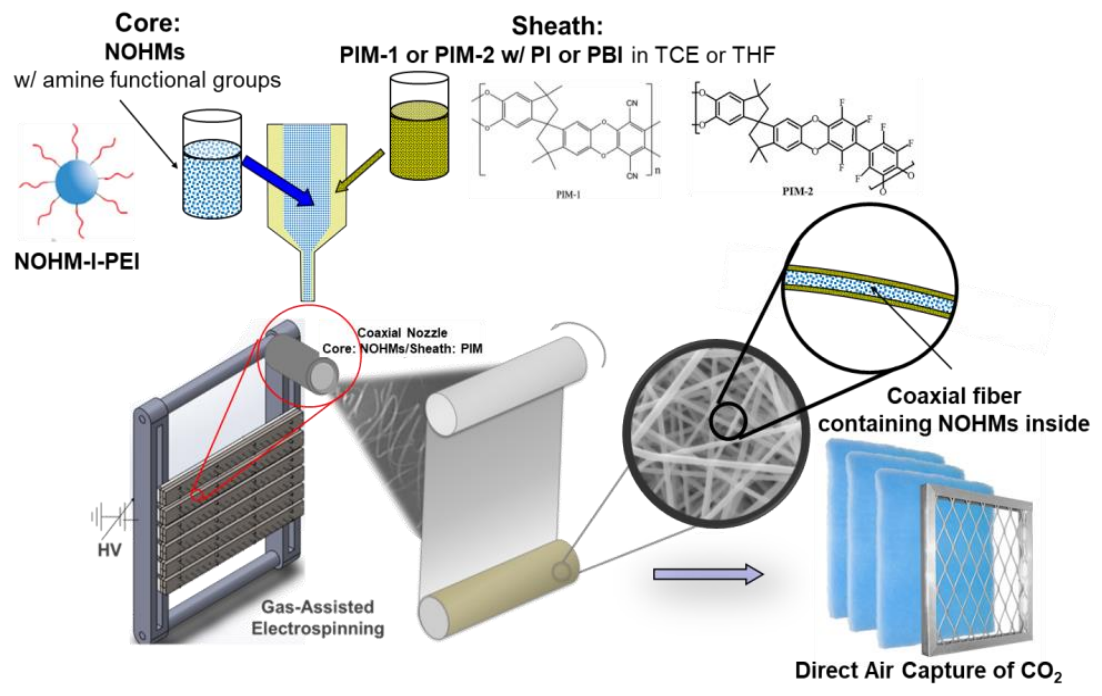
    Cornell University (Yong L. Joo)

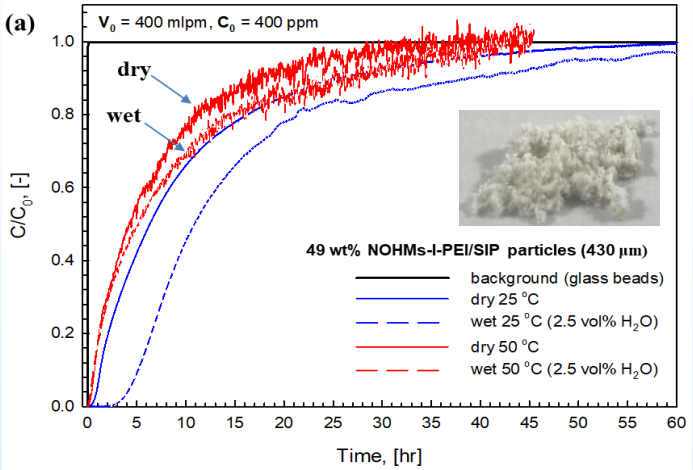
    Oak Ridge National Laboratory (Michelle Kidder)

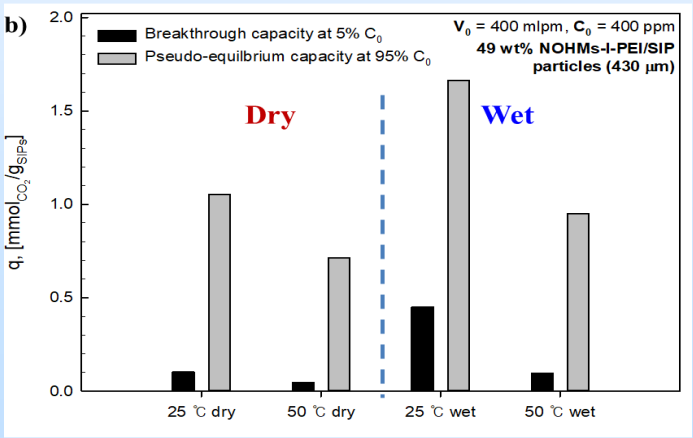
d. Overall Project Objectives

    We aim to address direct air capture (DAC) challenges by developing the **next generation fiber-encapsulated DAC sorbent** employing an electrospun, solid sorbent embedded with liquid-like Nanoparticle Organic Hybrid Materials (NOHMs) that will **selectively reject water while allowing facile CO_2 diffusion.**

Technology Background







Technical and economic advantages and challenges

- Great oxidative thermal stability & negligible vapor pressure
- Low pressure drop design of air filter system
- Selective rejection of water to minimize the parasitic energy consumption
- Challenges: mass transfer limitation, materials selection and design, potential challenges associated with the sorbent regeneration

Technical Approach/Project Scope

Experimental design and work plan

- Q1-Q2: Design and synthesis of NOHMs for DAC
- Q2-Q5: Fabrication of NOHMs/PIM coaxial fibers
- Q2-Q5: Fabrication of NOHMs(core)/ceramic(sheath) nanofibers
- Q3-Q6: Fabrication of air filters based on deposition of NOHMs/PIM nanofibers
- Q4-Q6: Process modeling and TEA/LCA

Decision Points	Success Criteria
Can NOHMs be synthesized for DAC?	At least **three** of the synthesized NOHMs can effectively capture CO_2 at the same levels as conventional DAC sorbents.
Can the fiber-encapsulated NOHMs capture CO_2 faster?	The developed fiber-encapsulated NOHMs should be able to capture CO_2 at a rate **50% faster** than that of NOHMs.
Can the fiber-encapsulated NOHMs sorbent selectively reject water?	The developed fiber-encapsulated NOHMs should reject at least **30% of water** in the system.
Are fibers impregnated with NOHMs stable for multiple cycles?	The first generation of fiber-encapsulated NOHMs generated from this project should be stable at least **10 DAC cycles**.

Team and Facilities

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

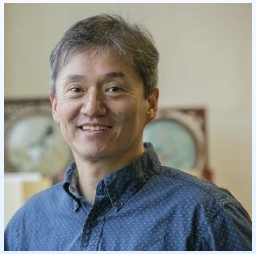
Cornell University

OAK RIDGE National Laboratory


Alissa Park (PI)


Annie Lee (GRA)


Kyle Kersey (GRA)

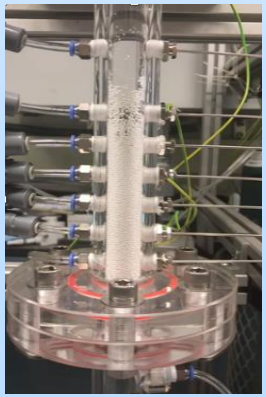

Yong Joo (co-PI)

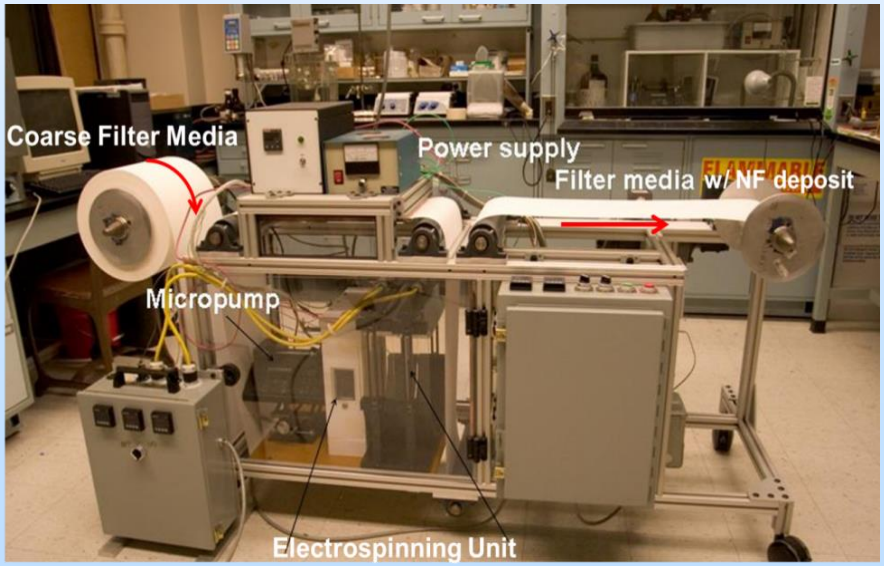

Min Nie (postdoc)


Michelle Kidder (co-PI)


Full materials characterization lab and facilities (ORNL)

CO_2 capture column equipped with pressure transducers, hygrometer, gas sensors (Columbia)





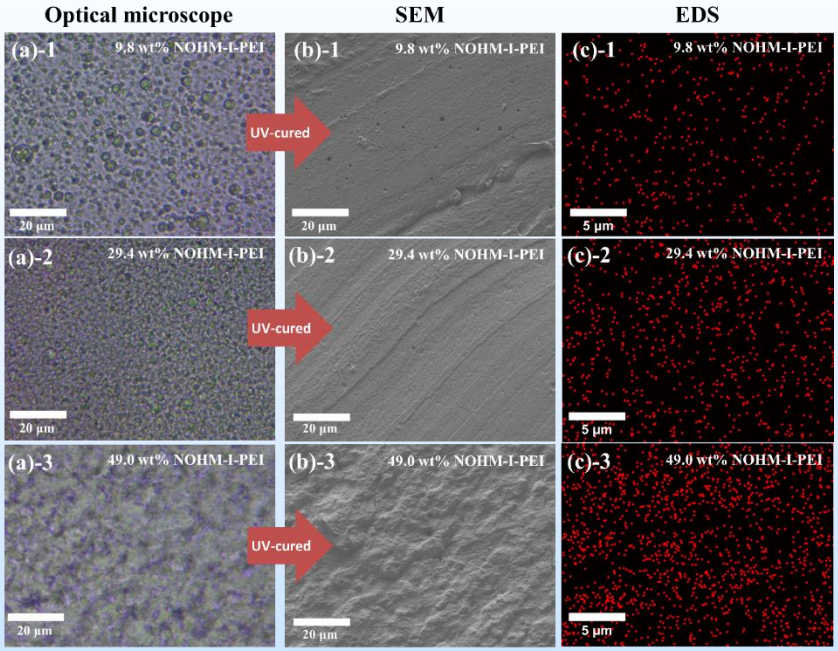
Electrospinning unit that can operate under different gaseous environment (Cornell)

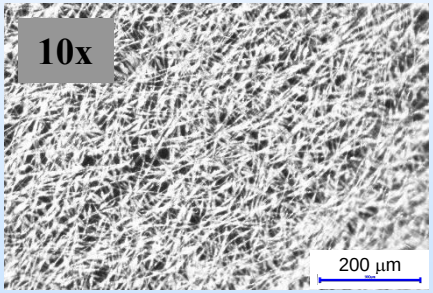
Progress and Current Status of Project

Air-controlled electrospray of PIM-1 polymer solution in THF showing excellent fiber morphology across wide range of spinning voltages and flow rates

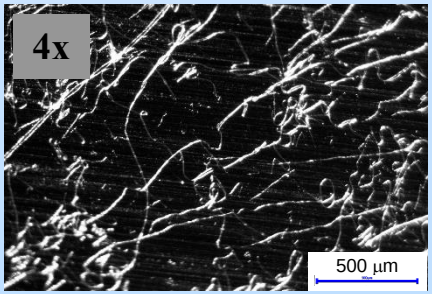
Experimental conditions: 5 wt% PIM-1, 5 psi air, 20 cm distance, 25°C

NOHM-I-PEI encapsulated in TEGO Rad 2650 via UV-curing

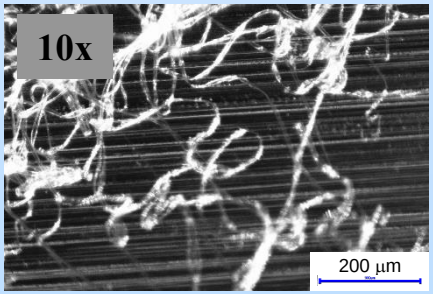




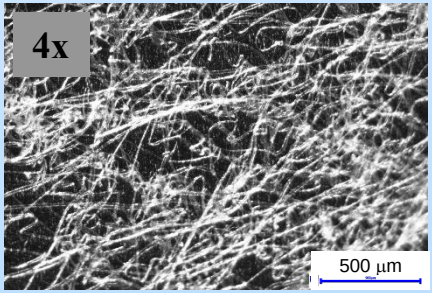
15 kV, **0.1 mL/min**



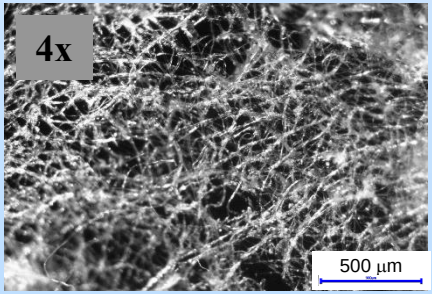
30 kV, **0.05 mL/min**



30 kV, **0.1 mL/min**



30 kV, **0.2 mL/min**



30 kV, **0.5 mL/min**

Opportunities for Collaboration

Collaboration among team members: PIs have distinct expertise (Park: CO_2 capture materials and mechanistic studies, Kidder: Material development in capture and conversion, Joo: electrospinning and device fabrication) and have a long history of strong collaborations. The proposed hybrid DAC materials require the expertise from all three areas.

List potential areas of complementary work that others may contribute to this technology

- **Scale-up:** DAC companies (e.g., Climeworks, Global Thermostat), Energy companies (e.g., Shell, TOTAL, Saudi Aramco)
- **Engineering design and fabrication:** HVAC technology companies
- **The utilization of captured CO_2**: Conversion R&D groups