Membrane Adsorbents Comprising Self-Assembled Inorganic Nanocages (SINCs) for Super-fast Direct Air Capture Enabled by Passive Cooling

DE-FE0031960

Haiqing Lin
University at Buffalo, The State University of New York

U.S. Department of Energy
National Energy Technology Laboratory
Direct Air Capture Kickoff Meeting
February 24-25, 2021
Program Overview

a. Funding (DOE: $800,000; Cost Share: $206,330)
b. Overall Project Performance Dates: 10/1/20 – 3/31/22
c. Project Participants: University at Buffalo (UB) and Trimeric Corporation (Trimeric)
d. Overall Project Objectives

- Year 1: design and prepare membrane adsorbent based on CO$_2$-philic polymers and SINC$_s$, and design operation cycles with solar heating and radiative cooling for CO$_2$ capture from air.
- M13-M18: construct and characterize a DAC prototype, demonstrate the 100-h continuous operation for DAC, and complete the TEA.
Technical Approach/Project Scope

First 12 months (Year 1)

- Develop test membrane adsorbents comprising SINCs for CO₂ capture from air; integrate sorption/desorption cycles with solar power and radiative cooling

Project Management Plan
- Project Kick-off Meeting
- Technology Maturation Plan

6 months

- Construct and characterize adsorbents; continuous operation; and TEA
- Membrane adsorbents; Operation cycles
- 100-h continuous operation of DAC

Success criteria

- Lab-scale tests demonstrate CO₂ sorption of >2.0 mmol/g and excellent stability less for 100-h continuous operation.

- TEA shows that the process is economically competitive with the state-of-the-art sorbent technologies ($600/ton CO₂)
Technology Background

Each cycle
1. Sorption
2. Desorption by heating provided by solar cell
3. Radiative cooling

- Porous membrane adsorbents
- Nanocages
- electricity-free radiative cooling
- solar heating and desorption
Our Technology: Membrane Adsorbents

Flat-sheet membrane adsorbents with porosity 60–95% comprising CO$_2$-philic SINCs and polymers

$CO_2 + 2RNH_2 \leftrightarrow RNH_3^+ + RNHCOO^-$

$CO_2 + 2R_1R_2NH \leftrightarrow R_1R_2NH_2^+ + R_1R_2NCOO^-$

$CO_2 + R_1R_2NH + H_2O \leftrightarrow R_1R_2NH_2^+ HCO_3^-$

$CO_2 + R_1R_2R_3N + H_2O \leftrightarrow R_1R_2R_3NH^+ HCO_3^-$

Larger ligands expand the cavity to $\sim 3.4$ nm, providing room for alkyl amines
Radiative Cooling

Outdoor continuous measurement of proposed radiative cooling architecture.

*Nature Sustainability* 2, 718 (2019)
Team and Facilities

Haiqing Lin
Novel membrane materials for CO₂ capture

Tim Cook
Self-assembly of discrete inorganic metallacycles & cages

Qiaoqiang Gan
Thermal management

Andrew Sexton
TEA
Opportunities for Collaboration

a. Collaboration in our project
   ➢ New CO2 adsorbents: porous membranes; SINCs
   ➢ Electricity-free thermal management and TSA
   ➢ Materials and TEA

b. Potential areas of complementary work
   ➢ High performance adsorbents
   ➢ System analysis: life cycle analysis
   ➢ Design of rapid sorption/desorption systems