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Cooperative Research and Development Agreement Final Report,

CRADA TC02407

February 14, 2024

Patrick Campbell, Duel Phase Membrane for CO2 Separation (Phase 1)

Innovations and Partnerships Office

Prepared by LLNL under Contract DE-AC52-07NA27344.

Dual Phase Membrane for CO2 Separation (Phase 1)

Cooperative Research and Development Agreement Final Report
CRADA No. TC02407
Date Technical Work Ended: May 9, 2023

February 14, 2024

A. Parties

This project was a relationship between Lawrence Livermore National Security, LLC and Saint Gobain Ceramic & Plastic, Inc.

Lawrence Livermore National Security, LLC
Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, CA 94550
Patrick Campbell
Tel: (925) 423-6935
Email: campbell82@llnl.gov

Saint-Gobain Ceramics & Plastics, Inc.
9 Goddard Road
Northboro, MA 01532
Mark Hampden-Smith, Project Manager
Tel: (508) 351-7600
Email: mark.hampden-smith@saint-gobain.com

B. Project Scope

This was a collaborative effort between Lawrence Livermore National Security, LLC (LLNS), as manager and operator of Lawrence Livermore National Laboratory (LLNL) and Saint-Gobain Ceramics & Plastics, Inc. (Participant/SG), to develop porous solid support materials for dual-phase carbon dioxide (CO2) separation membranes.

The project was originally designated as a nine (9) month project. LLNL received a two-month no-cost project extension to complete the scheduled long-term material evaluation. All goals and objectives of this CRADA were met.

The project consisted of three (3) major tasks and the following three (3) major deliverables:

Task1 (LLNL and SG; Month 1-Month 7)
Deliverable 1.1 (Month 7): SG to deliver six (6) batches of materials (including materials from Task 3) for evaluation by LLNL (ongoing)

Task 2 (LLNL and SG; Month 2-Month 8)
Deliverable 2.1 (Month 3): LLNL to provide report (PowerPoint presentation) summarizing materials compatibility testing for batch 1, presented at regular standing meeting

Deliverable 2.2 (Month 4): LLNL to provide report (PowerPoint presentation) summarizing materials compatibility testing for batch 2, presented at regular standing meeting

Deliverable 2.3 (Month 5): LLNL to provide report (PowerPoint presentation) summarizing materials compatibility testing for batch 3, presented at regular standing meeting

Deliverable 2.4 (Month 6): LLNL to provide report (PowerPoint presentation) summarizing materials compatibility testing for batch 4, presented at regular standing meeting

Deliverable 2.5 (Month 7): LLNL to provide report (PowerPoint presentation) summarizing materials compatibility testing for batch 5, presented at regular standing meeting

Deliverable 2.6 (Month 8): LLNL to provide report (PowerPoint presentation) summarizing materials compatibility testing for batch 6, presented at regular standing meeting

Task 3 (LLNL and SG; Month 4-Month 9)
Deliverable 3.1 (Month 5): LLNL and SG to develop report (PowerPoint presentation) summarizing materials improvement strategies.

Deliverable 3.2 (Month 7): LLNL and SG to develop report (PowerPoint presentation) summarizing evaluations needed to assess material/structural improvements to membrane design.

Deliverable 3.3 (Month 9): SG to deliver prototype structured materials for evaluation (as batches)

Task 4 (LLNL and SG; Month 8-Month 9)
Deliverable 4.1 (Month 9): LLNL and SG to develop report (PowerPoint presentation) summarizing materials test plan and requirements for Phase II.

Deliverable 4.2 (Month 9): SG to deliver Go-no-Go decision to proceed with amendment to CRADA to move to Phase II.

Deliverable 4.3 (Month 9): Final Report and Abstract due upon the completion or termination date of this CRADA, as required under Article X of the CRADA.
(LLNL/Participant) All of the deliverables for this project were successfully completed on time.

A No-Cost Time Extension was executed on March 9, 2023, to extend the term for an additional two (2) months. The reason for the extension was to allow enough time to complete tasks and experiments that were pending and plan for Phase II of the CRADA.

C. Technical Accomplishments

The purpose of this project was to evaluate the suitability of Saint-Gobain (SG) ceramic support materials for use in hydroxide/ceramic dual-phase HCDP membranes for CO2 separation and develop advanced support designs to improve membrane performance. Program objectives included: 1) demonstrating chemical and thermal compatibility of candidate materials with molten hydroxide, 2) designing, constructing, and testing modified support materials incorporating advanced features for improved performance and to facilitate integration into expected operating environments, and 3) establishing testing protocols and sample requirements to evaluate membrane performance.

The specific technical accomplishments were:

1) Identification of suitable SG materials that are compatible with the required temperature and chemical environment.
2) Development and testing of advanced membrane designs, including dual-layer materials.
3) Testing protocols and post-test analyses were established between the partners to determine that candidate materials were compatible and provided desired performance characteristics.

D. Expected Economic Impact

Conventional sorbent-based technologies can be utilized to capture CO2 from large point sources, but the $50 – 100 per ton CO2 costs are much higher than the $30 per ton CO2 target of the Department of Energy. Therefore, the domestic market needs technologies specifically designed for natural gas power plants. The novel separation membrane technology developed in this project is uniquely designed to efficiently capture CO2, even from low concentration sources, and meat DOE cost and performance targets.

The proposed design and scale up of this carbon dioxide separation membrane has the potential to facilitate a reduction in the United States' carbon dioxide emissions by 10-20% by avoiding tens of billions of US dollars per year in separation costs. A significant reduction in carbon dioxide emissions is expected to have a positive effect on the environment, carbon dioxide separation methods in fossil fuel power plants, and the overall carbon economy.

D.1 Specific Benefits

<u>Benefits to DOE</u>

DOE is interested in technologies that can contribute to the capture of CO2 large point sorces (e.g., fossil fuel power plants). This collaboration has successfully matured an LLNL technology towards commercialization. Ongoing work at LLNL is focused on further developments in solid phase materials for optimal pore structure, mechanical stability and CO2 separation, and efforts to produce dense and porous ceramic materials through additive manufacturing. Specifically, the project has:

1. Identified SG materials and processes compatible with membrane chemistry and operating environment.
2. Produced next-generation ceramic support materials with layered design and hierarchical pore morphology for improved performance
3. Laid the groundwork for continued collaboration between SG and LLNL to produce, evaluate, scale, and ultimately commercialize HCDP membrane technology.

Benefits to Industry

In general, the development of a new technology that can be applied to the capture of CO2 increases the opportunities available to industry. The technical achievements of this CRADA that are important steps to commercialization, and of interest to industry are:

1. New materials and production techniques to produce materials at scale and at lower cost.
2. Advanced designs to improve performance.

E. Participant Contribution

SG prepared porous ceramic membranes from a variety of ceramic feedstocks and with various pore sizes. These materials were evaluated by LLNL to determine thermal/chemical compatibility and appropriate pore morphology for good CO2 separation performance and long-term stability. Candidate materials that met the selection criteria were then refined by SG to minimize membrane thickness for improved performance. Ceramic support materials consisting of two layers with distinct pore structures were also produced by SG, which enable the active transport layer to be made considerably thinner while maintaining mechanical stability.

F. Documents/Reference List

None

Reports

None

Copyright Activity

None

Subject Inventions

None