Chemical Looping Splitting of CO_2 and H_2O for Syngas Production and Oxidative Coupling of Methane for Producing Ethylene at Intermediate Temperatures

FE0032496

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Project Overview

– Funding (Federal Share: $250,000. Cost Share: $62,500)

– Overall Project Performance Dates
08/01/2024-07/31/2025

– Project Participants

- University of Utah
- University of Oklahoma

Project Objectives

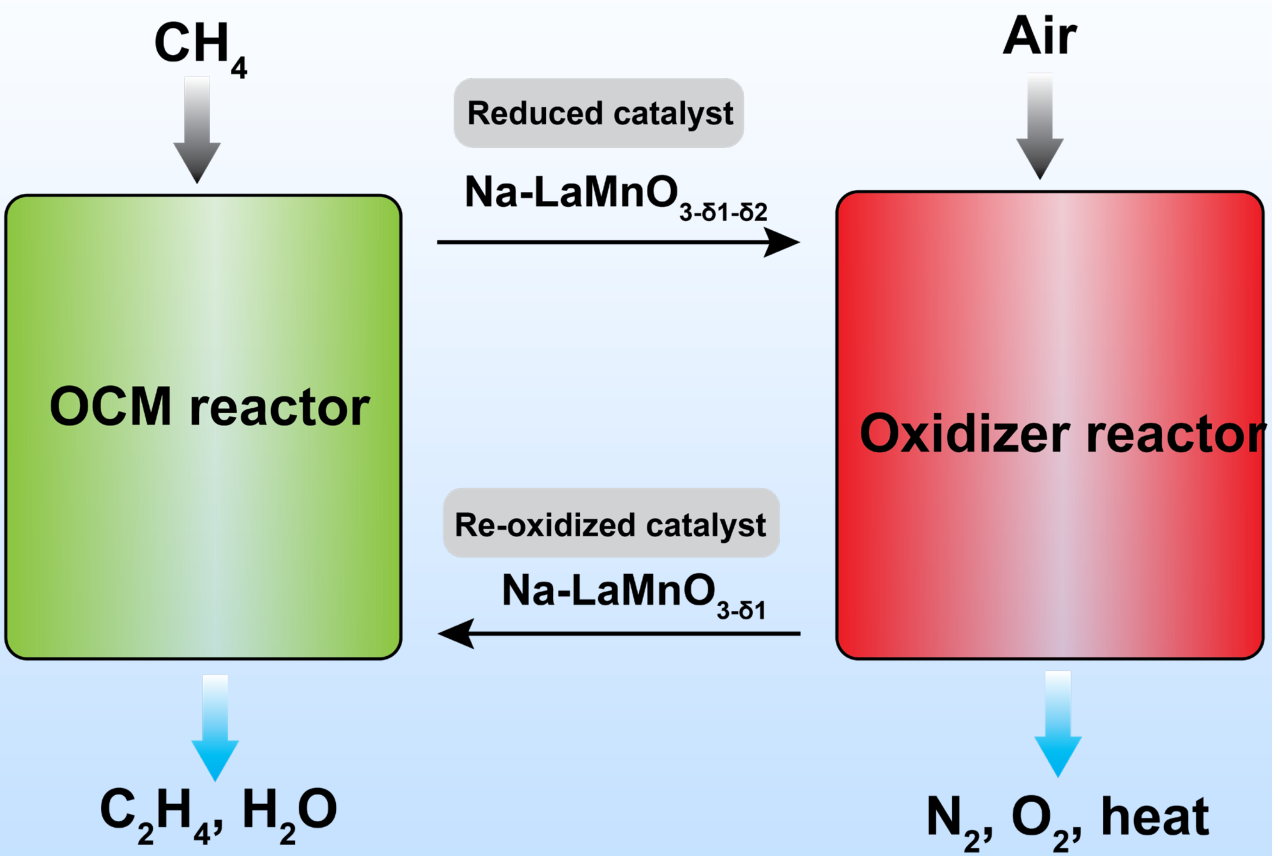
The team envisions to design, analyze, and validate a novel **bifunctional chemical looping concept** that utilizes the **perovskite-based oxide** (Na-doped $LaMnO_{3-\delta}$) as an oxygen carrier, which can be employed to produce chemicals and mitigate CO_2 emissions in both reduction and oxidation steps.

- Different aspects of the chemical looping design, perovskite oxide manufacturing, and testing have already validated under various operating conditions, with a technology readiness level of TRL 3 has been achieved.

- The proposed work will bring the TRL from TRL 3 to TRL 4.

- By the end of this Phase I project, the team will fully accomplish the chemical looping concept design and analysis, and the laboratory validation, aiming to provide sufficient results to demonstrate a TRL 4 to TRL 5 system in Phase II. The objectives of this project are to achieve highly efficient chemicals synthesis by valorizing CH_4, CO_2, and H_2O, mitigating emissions.

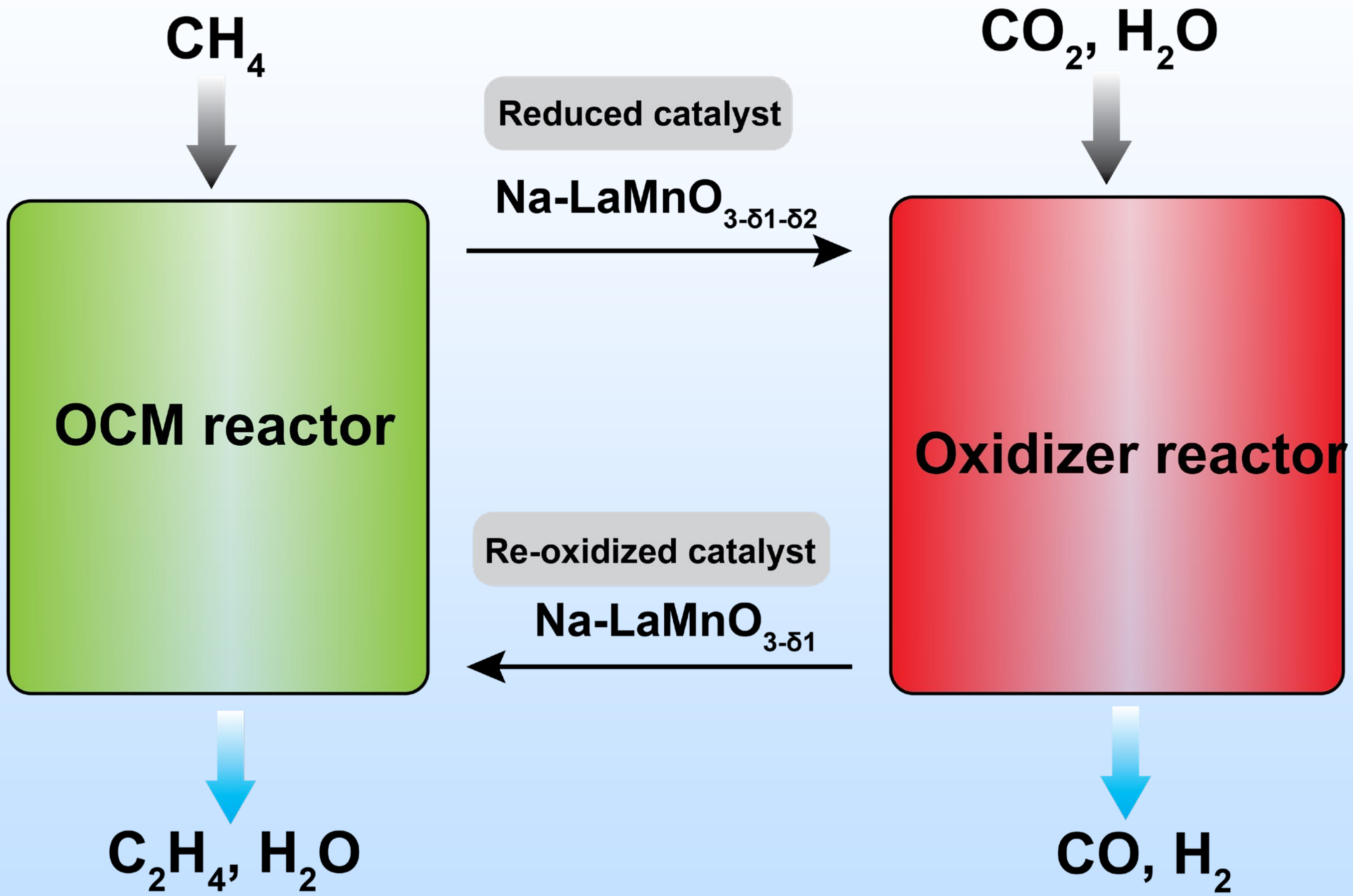
Technology Background



OCM Reactor (Reduction Reactor):

$$2/\delta_2 \text{ Na-doped } LaMnO_{3\text{-}\delta 1} + 2CH_4 \rightarrow C_2H_4 + 2H_2O + 2/\delta_2 \text{ Na-doped } LaMnO_{3\text{-}\delta 1\text{-}\delta 2}$$

Technology Background



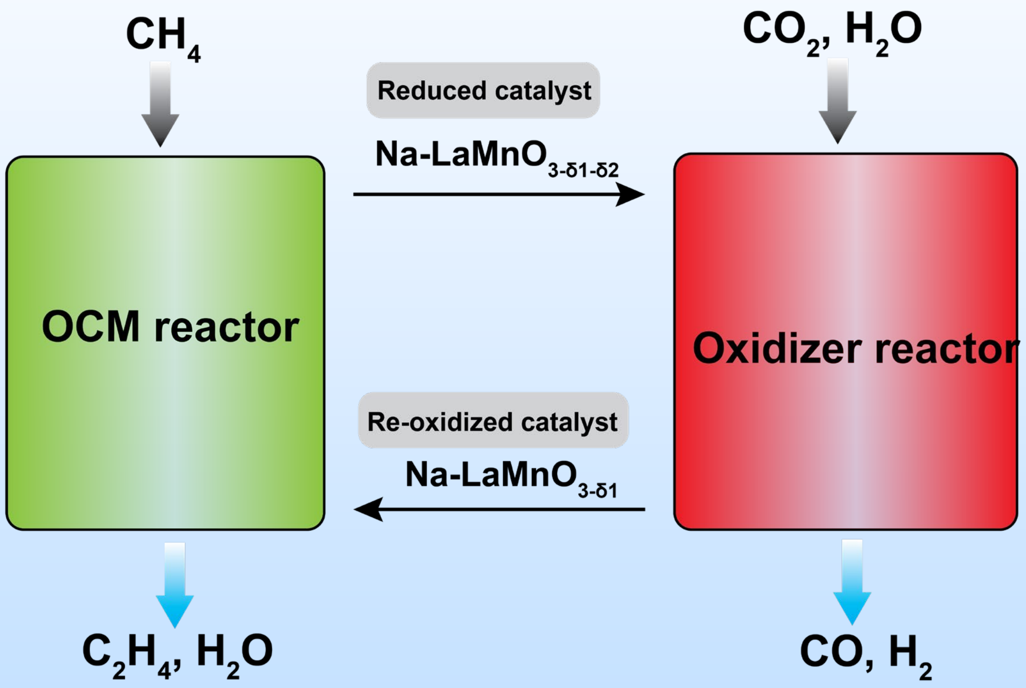
Oxidation Reactor:

$$1/\delta_2 \text{ Na-doped LaMnO}_{3\text{-}\delta1\text{-}\delta2} + CO_2 \rightarrow CO + 1/\delta_2 \text{ Na-doped LaMnO}_{3\text{-}\delta1}$$

$$1/\delta_2 \text{ Na-doped LaMnO}_{3\text{-}\delta1\text{-}\delta2} + H_2O \rightarrow H_2 + 1/\delta_2 \text{ Na-doped LaMnO}_{3\text{-}\delta1}$$

Technology Background

1. **Shared Oxygen Carrier**
2. **Process Integration**
3. **Energy Efficiency**
4. **Greenhouse Gas Utilization**
5. **Product Yield Optimization**
6. **Lower Emissions**
7. **Simplified System Design**
8. **Economic Viability**

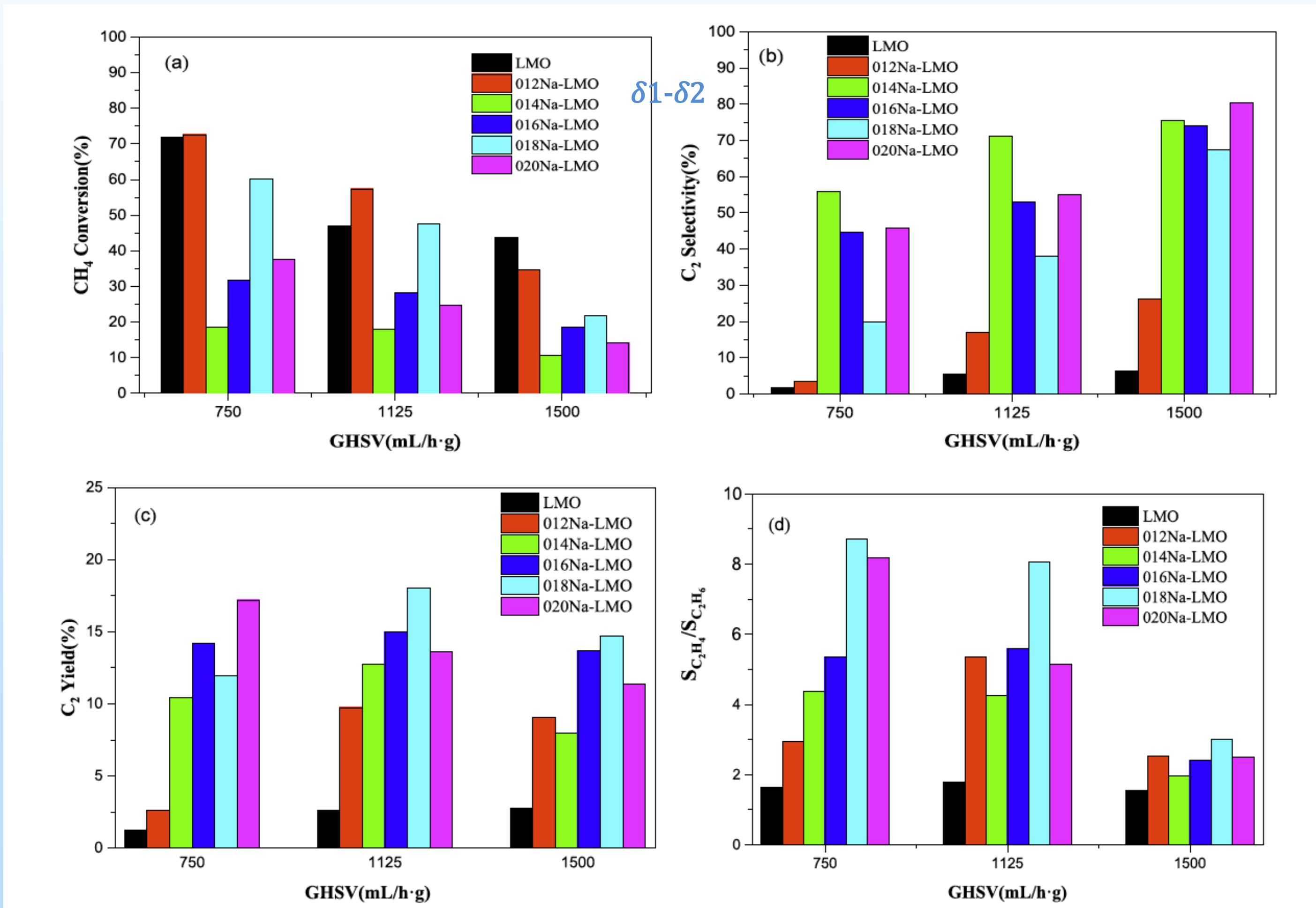


Technology Background

OCM Reactor (Reduction Reactor):

Fuel, 299:120932.

$2/\delta_2$ **Na-doped LaMnO$_{3\text{-}\delta 1}$** $+ 2CH_4 \rightarrow C_2H_4 + 2H_2O + 2/\delta_2$ **Na-doped LaMnO$_{3\text{-}}$**

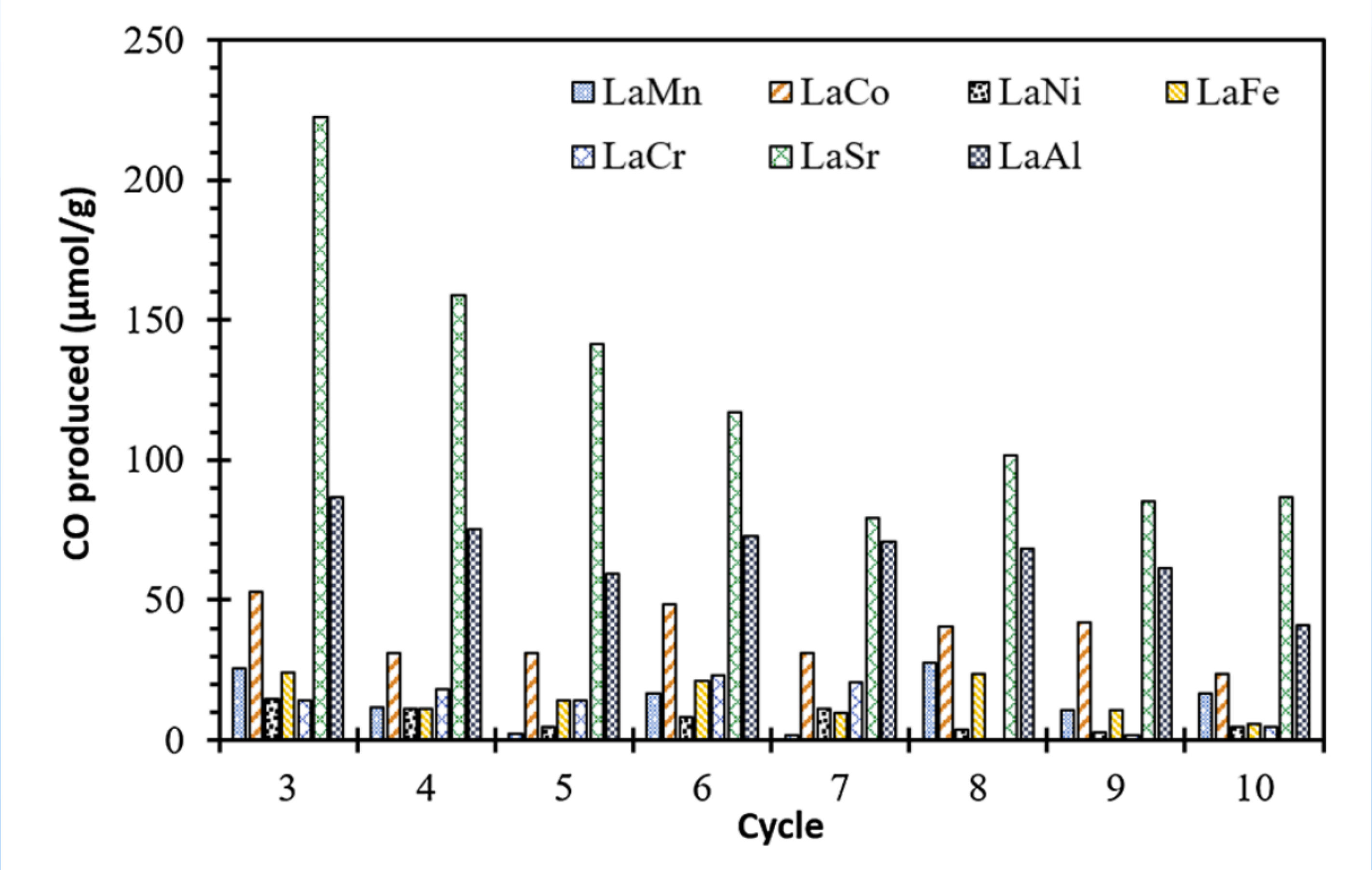


Technology Background

Oxidation Reactor:

Applied Surface Science, 509:144908.

$1/\delta_2$ **Na-doped LaMnO$_{3-\delta1-\delta2}$** + CO_2 → CO + $1/\delta_2$ **Na-doped LaMnO$_{3-\delta1}$**



Technical Approach/Project Scope

Task 1: Project Management and Planning

Subtask 1.1 – Project Management Plan (PMP).
Subtask 1.2 – Technology Maturation Plan (TMP).
Subtask 1.3 – Community Benefits Plan (CBP).
Subtask 1.4 – Phase 2 Application

Task 2: Establishing desired end states and identifying most suitable path from initial to end.

Task 3. Develop and validate a computational model to support chemical looping system development.

Task 4: Experimental validation of the proposed chemical looping system.

Task 5: Technology Assessments.
Subtask 5.1 - Create a performance model and data table.
Subtask 5.2 – Preliminary Techno-Economic Analysis (TEA).
Subtask 5.3 – Preliminary Life Cycle Analysis (LCA).
Subtask 5.4 – Technology Environmental Health and Safety (EH&S) Analysis.
Subtask 5.5 – Technology Gap Analysis.

Technical Approach/Project Scope

Objective/Goal	Target	Approaches to achieve those targets
Ability to achieve high methane conversion and high C2 yield in the OCM reactor, and high syngas yield in the oxidation reactor	Achieve a C2 yield of >30% in the OCM reactor. Achieve a syngas yield of >20% in the oxidation reactor	Using the 018Na-doped $LaMnO_{3-\delta 1}$ as the oxygen carrier. Optimizing the operating conditions of both COM reactor and oxidation reactor.
A complete system design and analysis of the chemical looping systems	Deliver a comprehensive model of the proposed system and report the TEA and LCA results of the proposed system	Establish computational modeling. Perform TEA and LCA.

Summary of Community Benefits / Societal Considerations (CB/SCI) and Impacts

CBP milestone #	Due date	Milestone Description
CBP milestone 1 (DEIA)	Budget Period 1 (Q4)	Two students and three senior personnels across the two collaborating institutions, and meet or exceed 50% diversity participation.
CBP milestone 2 (Energy Equity)	Budget Period 1 (Q4)	Organize at least one meeting with the disadvantaged communities
CBP milestone 3 (Workforce)	Budget Period 1 (Q4)	Train two graduate students, and develop the next-generation sustainable energy workforce

Thanks for your attention

U.S. DEPARTMENT OF ENERGY | Fossil Energy and Carbon Management

NATIONAL ENERGY TECHNOLOGY LABORATORY

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