Dual Function Materials for DAC and Point-Source CO_2 Capture and Conversion to Fuels

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INTRODUCTION & BACKGROUND

The dual function material (DFM) components:

- Active metallic catalyst
- Alkaline sorbent
- Porous, high surface area carrier

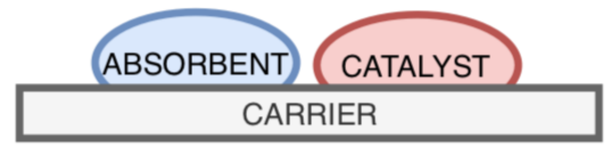

Figure 1: DFM structure.

DFM works in two steps at a single temperature:

1. Adsorbs CO_2 from gas stream
2. Catalytically converts CO_2 to CH_4 by the introduction of H_2 *OR* desorb CO_2 with N_2 purge

DFM mitigates CCUS problems such as:

- High energy requirements of temperature/pressure swing
- Use of corrosive materials
- Transportation needs

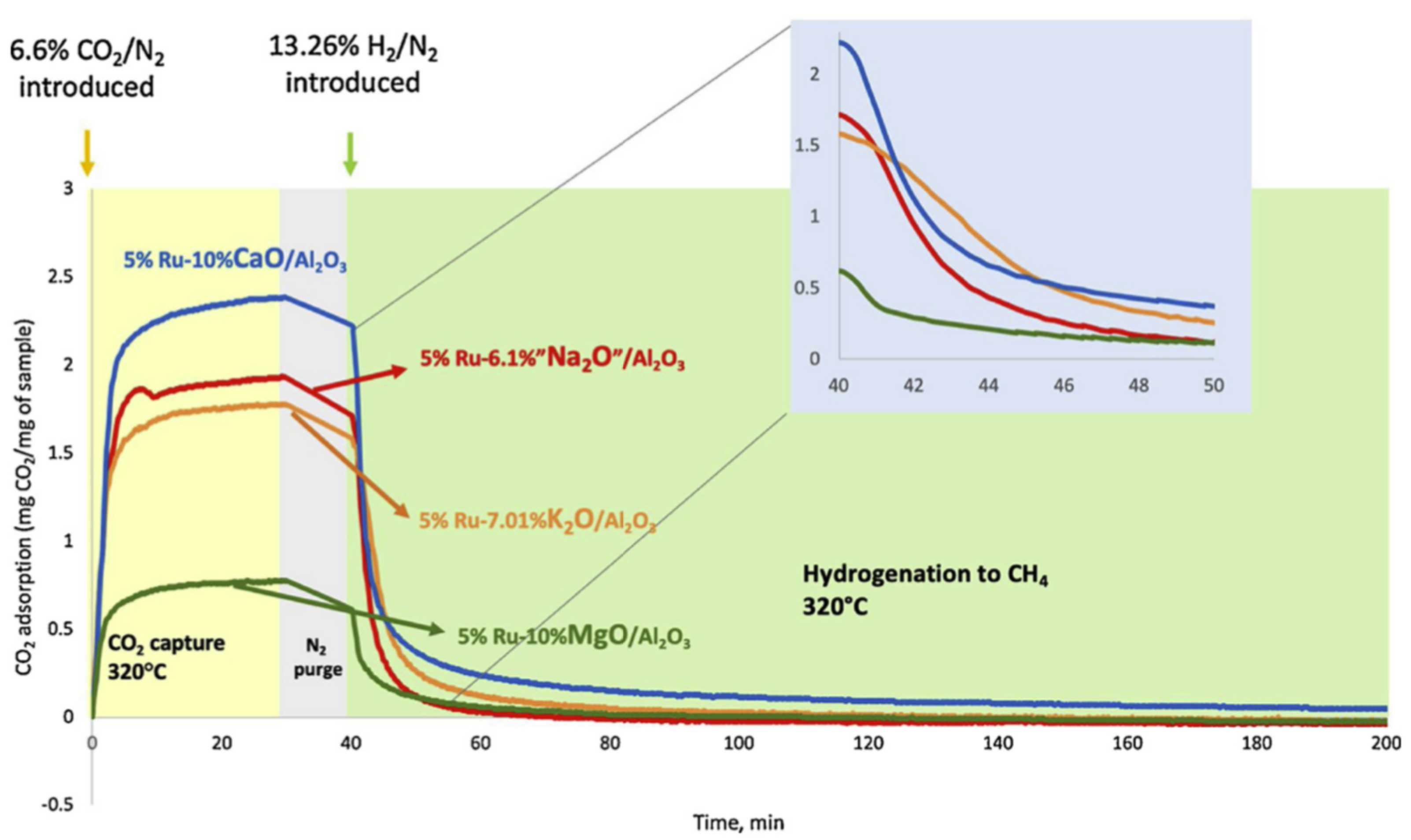

Figure 2: Results of TGA on DFM with 5% Ru in combination with various adsorbents (10% CaO, 6.1% "Na_2O", 7.1% "K_2O" and 10% MgO) dispersed on γ-Al_2O_3. All samples were pre-reduced in-situ at 320°C in 13.26% H_2/N_2 for 6 hours. The samples were exposed to 6.6% CO_2/N_2 for 30 minutes to test CO_2 adsorption capacity and exposed to 13.26% H_2/N_2 for 6 hours for catalytic hydrogenation. All steps are conducted at 320°C and 1 atm.

The adsorbent is optimized for:

- Adequate capture capacity
- Fast methanation kinetics
- Extent of hydrogenation

*** Our adsorbent is **Na_2O***

The catalyst is optimized for:

- High conversion at 320°C
- High selectivity towards methane

*** Our catalyst is **Ru***

ACKNOWLEDGEMENTS

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Point-Source Capture and Conversion

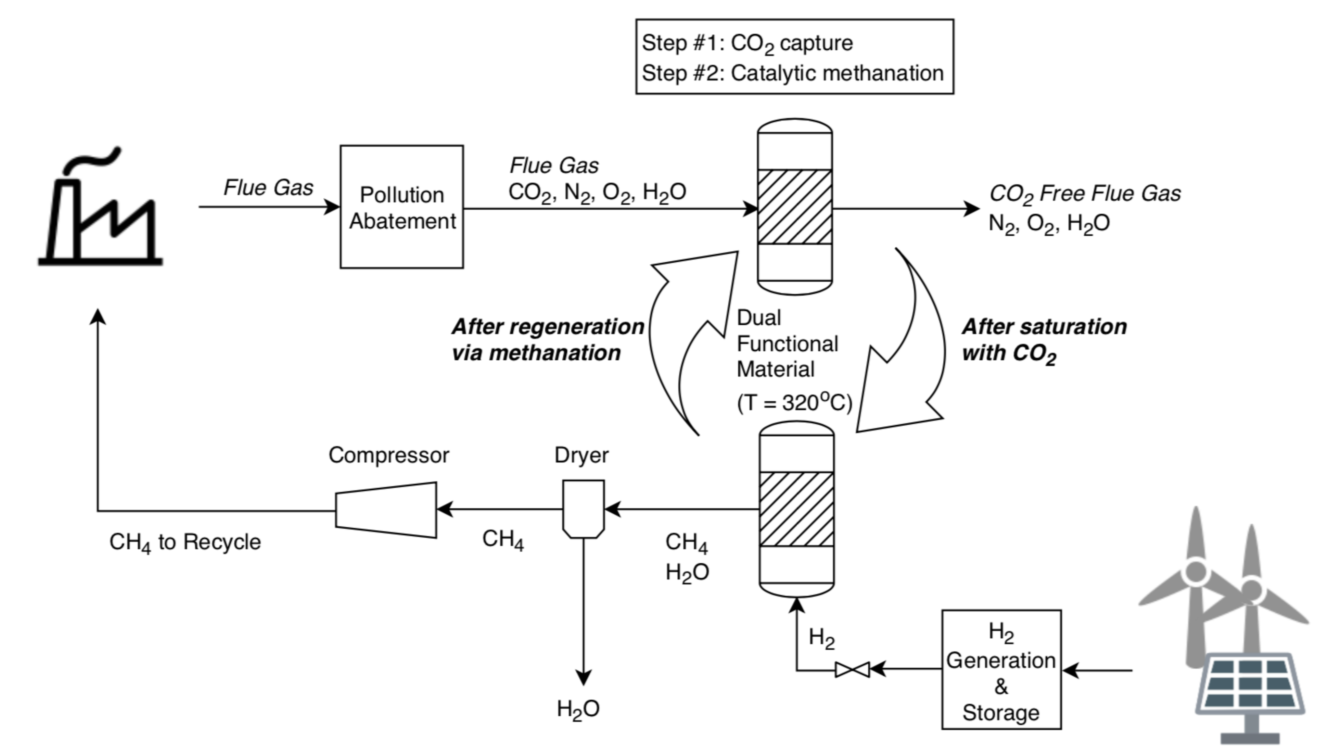

Figure 3: Process flow diagram for CO_2 capture from power plants and synthetic natural gas (CH_4) generation using DFM.

DFM for point-source capture process:

- Selective chemisorption of CO_2 from power plant flue gas, containing O_2 and steam
- Introduce H_2 after saturation
- Produce methane for recycle or injection into pipelines

Aging study on DFM with simulated flue gas showed:

- Material is stable for 50 cycles on stream
- Slight improvement in performance attributed to re-dispersion of both Ru and Na_2O

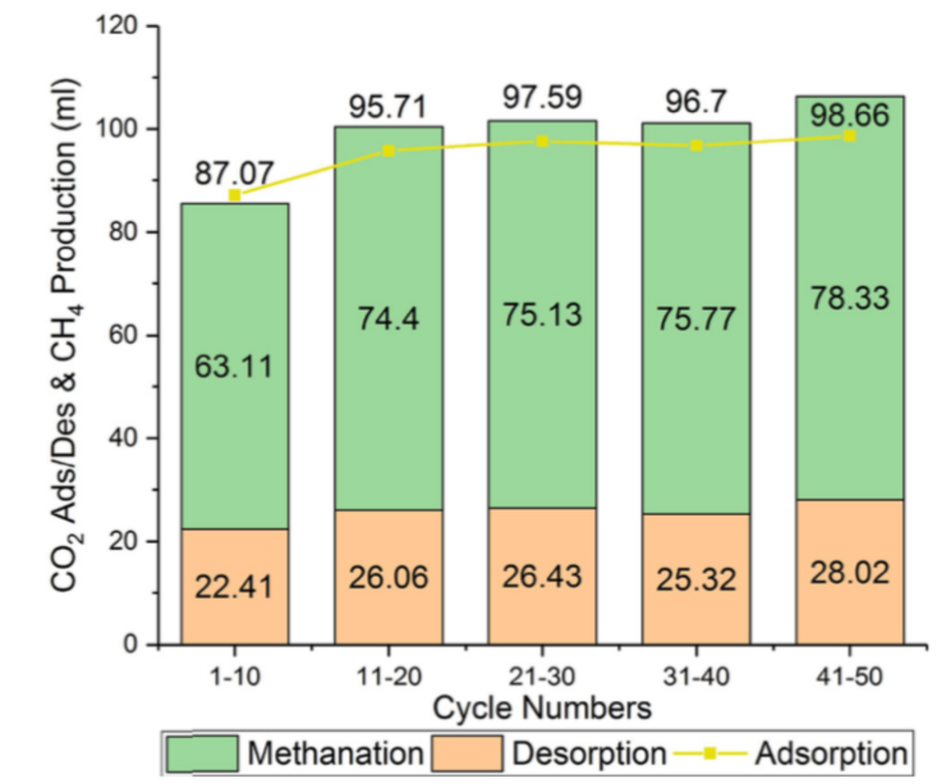

Figure 4: Averaged results for every 10 cycles of 50 cycle aging study on 5% Ru, 6.1% "Na_2O"/Al_2O_3 tablets using simulated flue gas (7.5% CO_2, 4.5% O_2, 15% H_2O, balance N_2) CO_2 capture conditions.

Reversible Direct Air Capture and Conversion

DFM for DAC:

- Selective chemisorption of CO_2 from air (1000 – 400 ppm CO_2, high O_2 content)
- Desorb with N_2 purge at the same temperature
- Optional methanation possible with the introduction of H_2

Catalyzed DFM advantageous for:

- Promoting greater CO_2 capture capacity compared to non-catalyzed sorbent
- Providing option of producing methane from captured CO_2
- Methanation using catalyst allows for more rapid regeneration of material

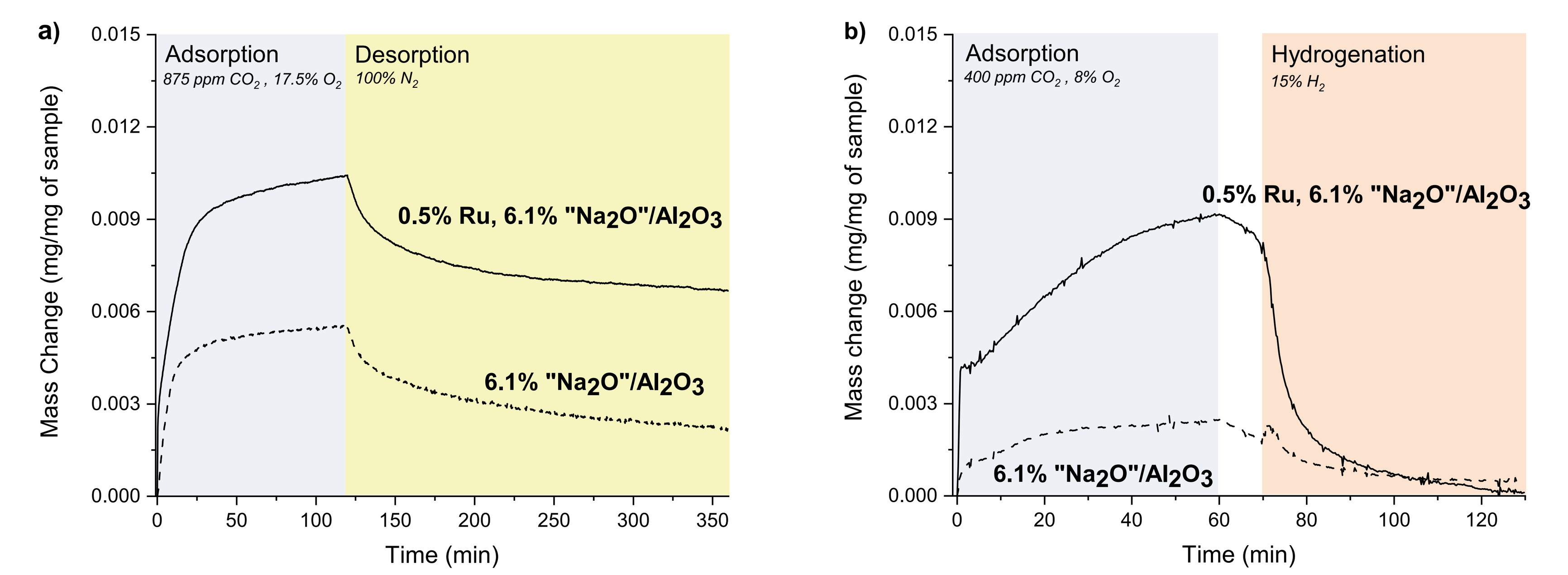

Figure 5: Thermal gravimetric analysis profiles of catalyzed DFM and non-catalyzed DFM during adsorption of CO_2 from a dilute stream and subsequent **(a)** desorption upon introduction of N_2 and **(b)** hydrogenation upon introduction of hydrogen. All steps (adsorption, desorption, hydrogenation) occur at 320°C and 1 atm

FUTURE WORK

DFM for point-source capture:

- Scaled up aging study of low Ru loading and Ru-Ni DFM, followed by surface characterization of fresh and aged samples
- Pilot plant studies and exposure to real power plant flue gas
- Techno-economic assessment and life cycle assessment of DFM

DFM for DAC:

- Parametric studies to optimize temperature and flow rate for maximum capture, desorption, and methanation
- Kinetic studies to establish rates for adsorption, desorption, and catalytic conversion of CO_2
- Cyclic aging studies of DAC and desorption/methanation

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