Dual Function Materials for DAC and Point-Source CO₂ 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

DFM works in two steps at a single temperature:
1. Adsorbs CO₂ from gas stream
2. Catalytically converts CO₂ to CH₄ by the introduction of H₂

Off-does CO₂ with N₂ purge

DFM mitigates CCUS problems such as:
- High energy requirements of temperature/pressure swing
- Use of corrosive materials
- Transportation needs

DFM structure:

The catalyst is optimized for:
- Adequate conversion
- High selectivity towards methane
** Our adsorbent is Na₂O

The adsorbent is optimized for:
- Adequate capture capacity
- Fast methanation kinetics
- Extent of hydrogenation

Figure 1: DFM structure.

Figure 2: Results of TGA on DFM with 5% Ru in combination with various adsorbents (12% CaO, 6.1% Na₂O, 7.1% "NaD" and 10% MgO dispersed on γ-Al₂O₃. All samples were pre-reduced in situ at 320°C in 13.26% H₂/N₂, for 4 hours. The samples were exposed to 6.6% CO₂/N₂ for 30 minutes to test CO₂ adsorption capacity and exposed to 13.26% H₂/N₂ for 5 hours for catalytic hydrogenation. All steps are conducted at 320°C and 1 atm.

The DFM is optimized to:
- Adequate capture capacity
- Fast methanation kinetics
- Extent of hydrogenation
** Our adsorbent is Na₂O

The catalyst is optimized for:
- High conversion at 320°C
- High selectivity towards methane
** Our catalyst is Ru

Figure 3: Process flow diagram for CO₂ capture from power plants and synthetic natural gas (CH₄) generation using DFM.

DFM for DAC:
- Selective chemisorption of CO₂ from air (1000 – 400 ppm CO₂, high O₂ content)
- Desorb with N₂ purge at the same temperature
- Optional methanation possible with the introduction of H₂

Catalyzed DFM advantageous for:
- Promoting greater CO₂ capture capacity compared to non-catalyzed sorbent
- Providing option of producing methane from captured CO₂
- Methanation using catalyst allows for more rapid regeneration of material

Figure 4: Averaged results for every 10 cycles of 5% Ru, 6.1% Na₂O/Al₂O₃ tablets using simulated flue gas (7.5% CO₂, 4.5% O₂, 15% H₂O, balance N₂) CO₂ capture conditions.

DFM for point-source capture:
- Selective chemisorption of CO₂ from power plant flue gas, containing O₂ and steam
- Introduce H₂ 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 Na₂O

Figure 5: Thermal gravimetric analysis profiles of catalyzed DFM and non-catalyzed DFM during adsorption of CO₂ from a dilute steam and subsequent desorption upon introduction of N₂ and H₂ hydrogenation upon introduction of hydrogen. All steps (adsorption, desorption, hydrogenation) occur at 320°C and 1 atm.

FUTURE WORK

- 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

REFERENCES
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