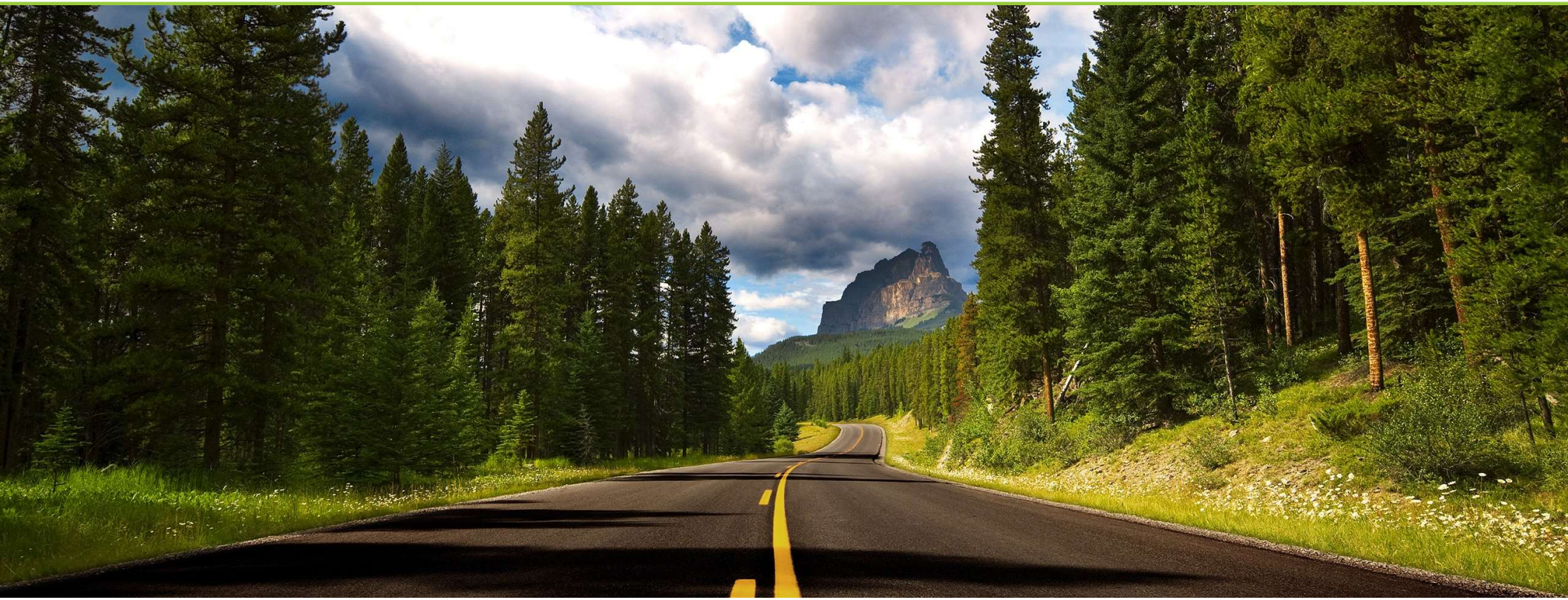
Reactive Capture Efforts at NETL

Enabling Technology - Lab Scale Activities to Advance Reactive Capture

Douglas Kauffman

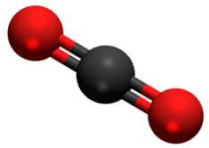


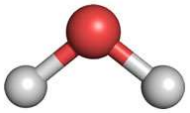
Catalytic CO_2 Conversion

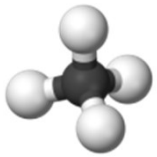
CO_2

H_2O

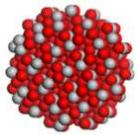
CH_4

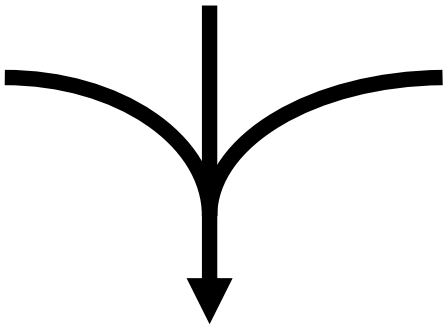






Catalyst



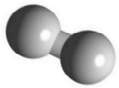


Decarbonized Electrons

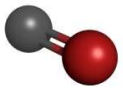
Electrochemistry

Microwave chemistry

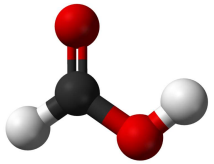
Polymers & Plastics



Hydrogen



Carbon Monoxide



Formic Acid

Alcohols / Fuels

Efforts span several TRLs

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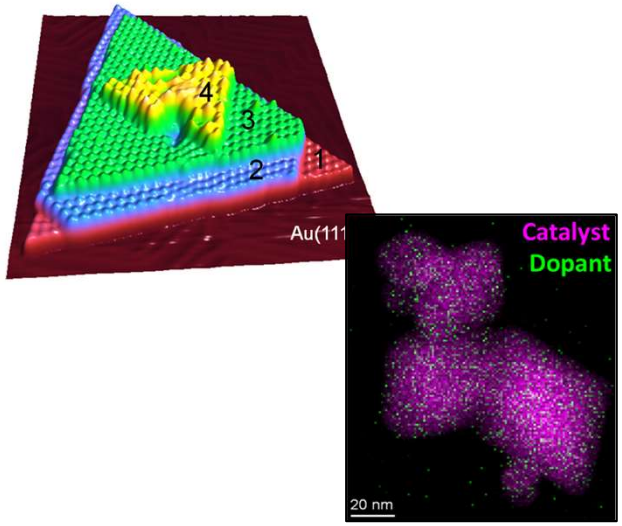
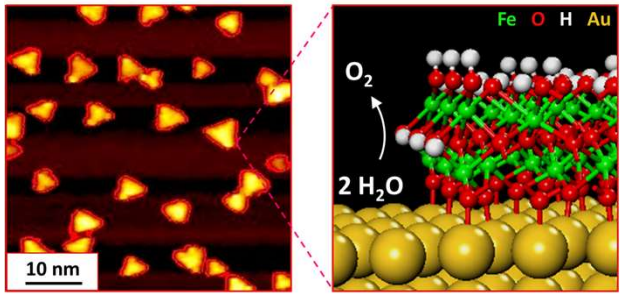
Materials Design and Advanced Characterization

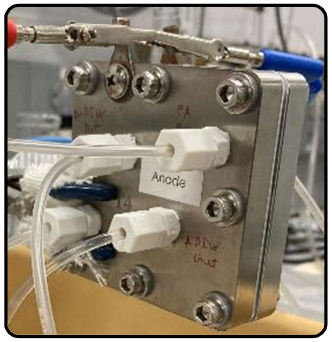


Experiment and Theory to Understand and Control Chemistry



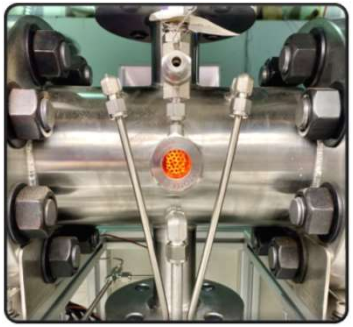
Identify which parts make the catalyst "work" to optimize performance

Lab-scale validation in prototype reactors, LCA/TEA



Electrochemical Devices

Microwave Reactors

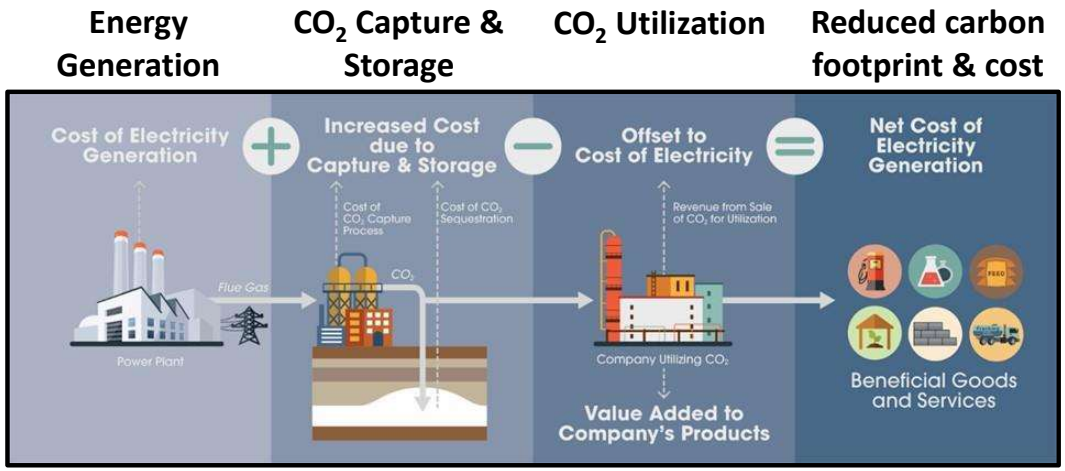


Fundamental Understanding → **Lab-Scale Validation**

Motivation

Traditional carbon capture, separation, compression, and sorbent regeneration incur energy penalties and increase cost.

- Hypothesis: Combining these separate steps into an "all-in-one" process could reduce the energy requirements, complexity, and cost of CO_2 utilization strategies.
- TEA shows that expensive CO_2 sources make the most sense.



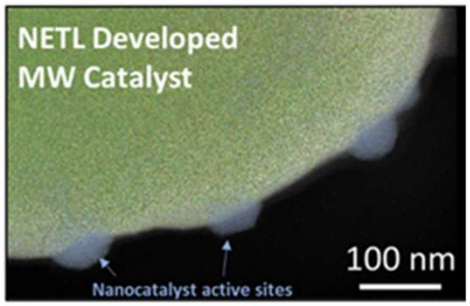
Projects

- **NETL's Carbon Conversion Program (FWP-1022426)**
  - Microwave Reactive CO_2 Capture and Conversion -- CO
  - Thermal Reactive CO_2 Capture and Conversion -- C_{2+} olefins

- **FECM Lab-call: Electrochemical Reactive Capture (FWP-1022482)**
  - Integrating CO_2 selective separation membranes with low-temperature, electrochemical CO_2 conversion -- formic acid
  - Wednesday's presentation.

Microwave-Assisted Catalysis

- **Develop materials and systems that absorb microwaves, generate heat, and promote desired chemistry.**
- **Efficiently promote *thermal* catalysis.**
- **Experience with microwave-assisted CO_2 + CH_4 reforming.**
  - Produce tunable CO:H_2 (syngas) ratios.
  - CO_2 + CH_4 + H_2O "mixed reforming" can produce syngas ratios suitable for CO_2-derived methanol production approaching cost-parity w/ SOTA.
  - Catalyst & reactor scaling; pre-pilot scale demo planned with industrial partner.



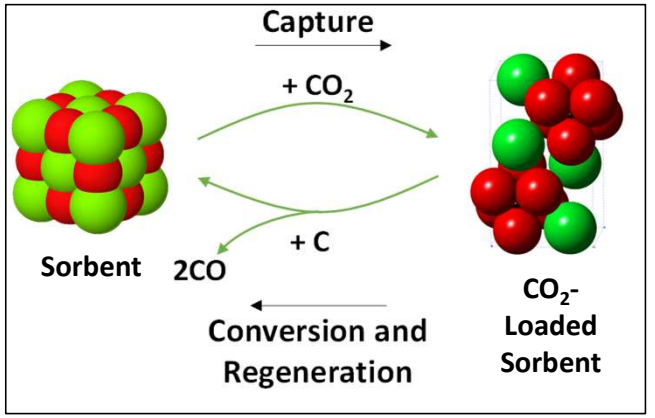
10-kg batch of NETL-developed microwave catalyst.

Applied Catalysis B **2021**, *284*, 119711 (article link) & US Patent Application #17/079,924 – just allowed.

Microwave-Assisted Reactive Capture

- **Metal oxide sorbent for direct air capture.**
  - DAC is a high cost CO_2 source.

- **Microwaves generate heat: CO_2-loaded sorbent reacts with carbon powder to produce CO.**
  - Upgrade CO with H_2 (via electrolysis) or other pathways to produce sustainable chemicals.



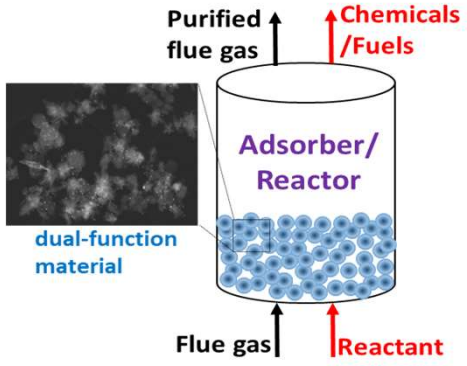
- **Microwaves provide efficient heating for chemical reaction and sorbent regeneration.**
  - Bench-scale experiments (10s milligram) have confirmed cyclability, screened several carbon sources, and we are currently conducting DFT calculations to understand atomic-level reaction pathway.
  - Lab-scale tests (grams) in larger reactor for better energy estimates and eventual TEA.

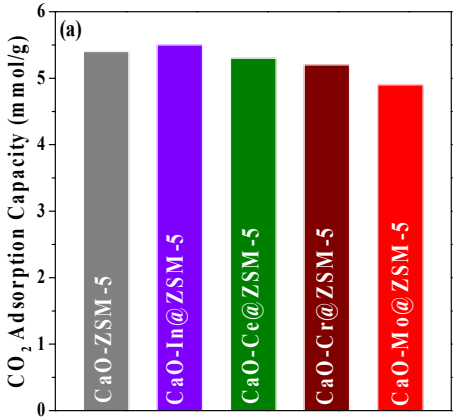
Manuscript and patent application in preparation

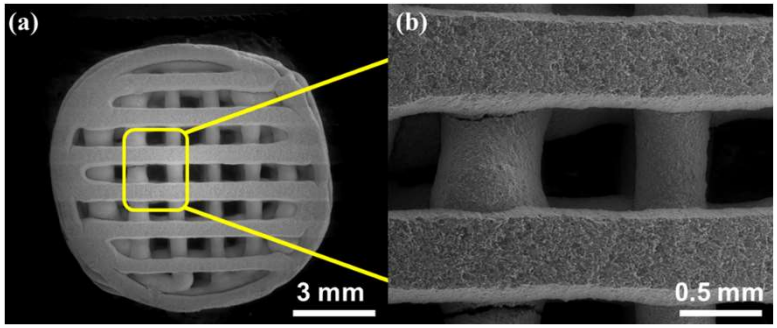
Thermal Reactive Capture

- **Bifunctional materials for CO_2 capture and natural gas conversion.**
  - Catalyst loaded CaO.
  - CO_2 oxidative dehydrogenation of ethane and propane into ethylene and propylene.

- **Bench-scale studies are focused on optimizing composition, achieving relevant form factors, understanding deactivation, and scaling.**







PI: Ali Rownaghi. *ACS Catalysis*, 12, 22 (2022), 14264–14279 (article link).

Questions or Comments?

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Thank you for your attention!

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