Carbon Dioxide Emission Reduction and Utilization: Process Development and Pilot Scale

SOUTHWEST RESEARCH INSTITUTE®

CHEMICAL ENGINEERING DEPARTMENT
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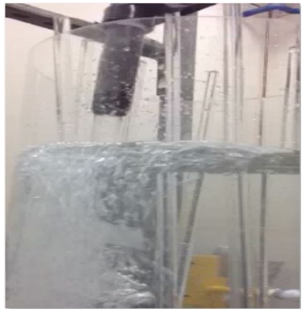
Carbon Dioxide Emission Reduction and Utilization: Process Development and Pilot Scale

Alternative Feedstocks and Fuels

- Enhance the carbon cycle with more fuels and chemicals from renewable and recyclable sources



Capture

- Inorganic bases, MOFs, amines, other novel solvents, and membranes.

- Hydrogen, Ammonia fuels, Chemical Looping, Gasification, Electrification, Plasma, Advanced chemical recycling

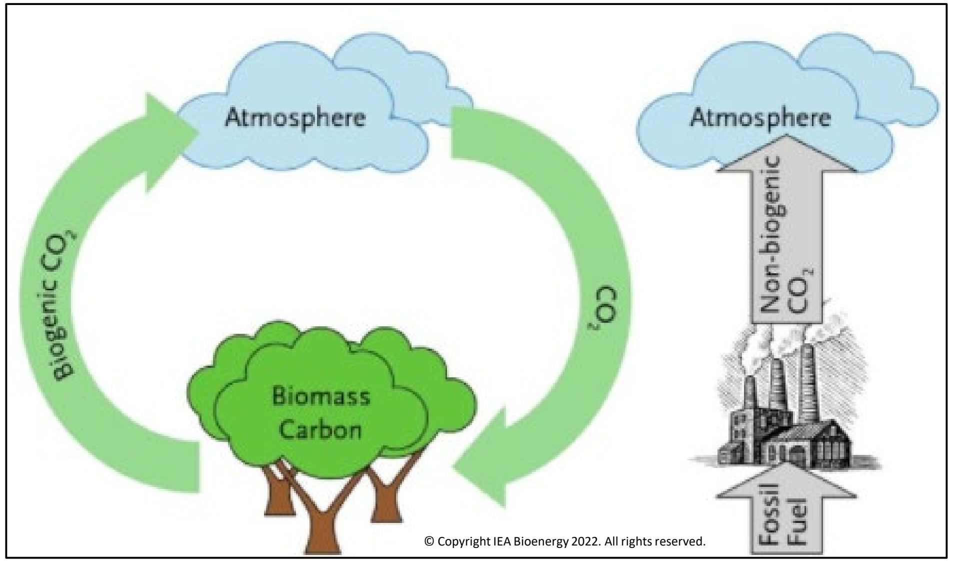
Lower Emission Processes

- Develop CO_2 derived chemicals, fuels, plastics or other consumables.

Utilization

Advanced BioFuels Production from Waste and Recyclable Sources

- Turn biomass, animal fat, municipal wastes, plastics, algae, and crops into "green" fuels and products: renewable diesel, green gasoline, sustainable aviation fuel (jet).
- SwRI produces specification-grade gasoline, diesel, and jet fuels and other specialty products or chemicals
- Advanced biofuels can produce up to 70% reduction in GHG emissions according to Argonne GREET models




Hydrotreating and Hydrocracking


Pyrolysis and Gasification

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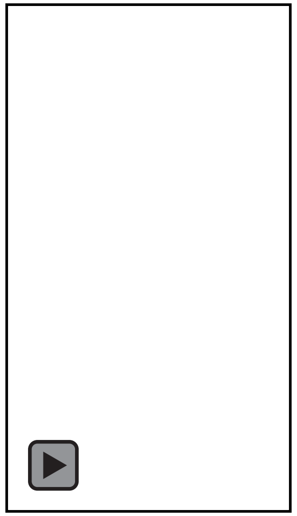
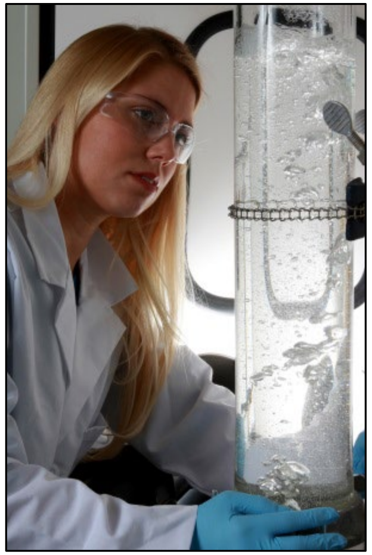
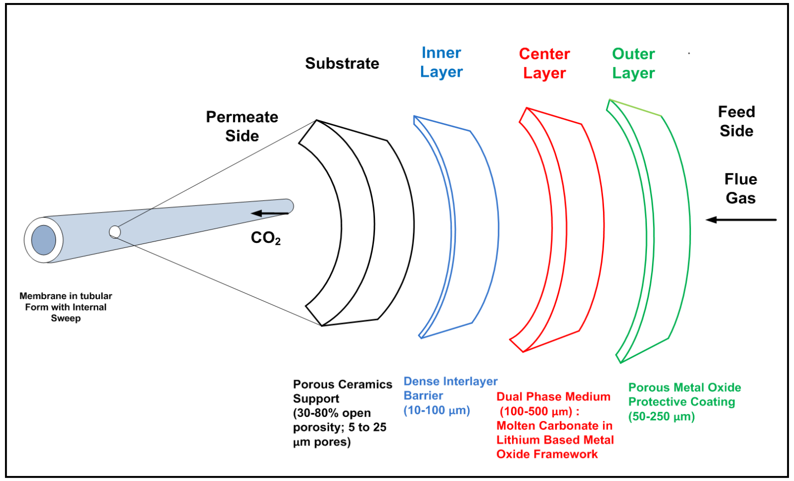
swri.org

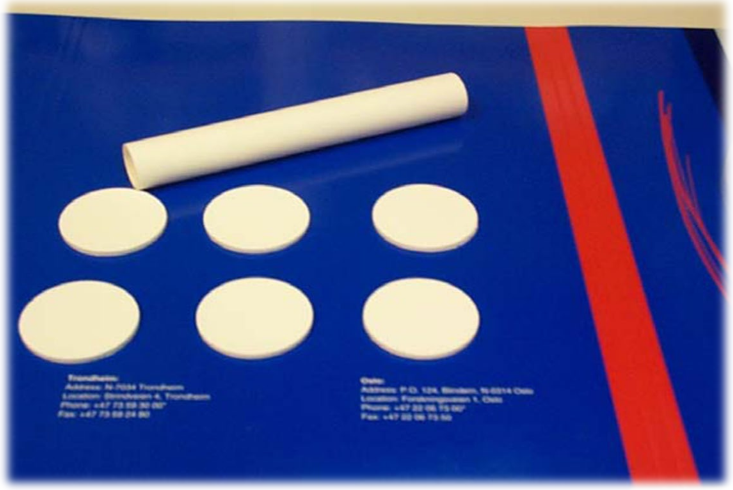
Carbon Dioxide Capture

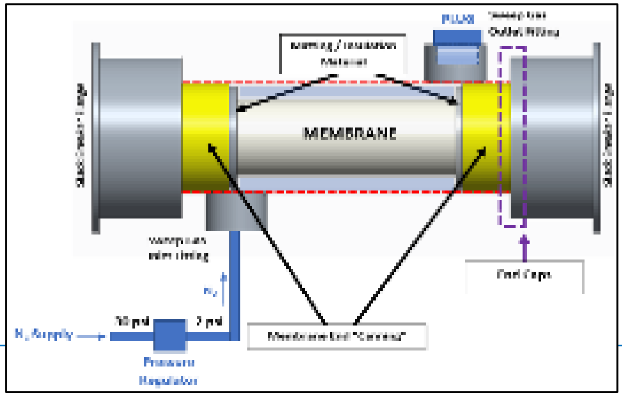
- Designer solvents
- Mineralization
  - $NaHCO_3$
- Ceramic membranes
  - High temperature
  - Molten metal
- Adsorption, MOFs





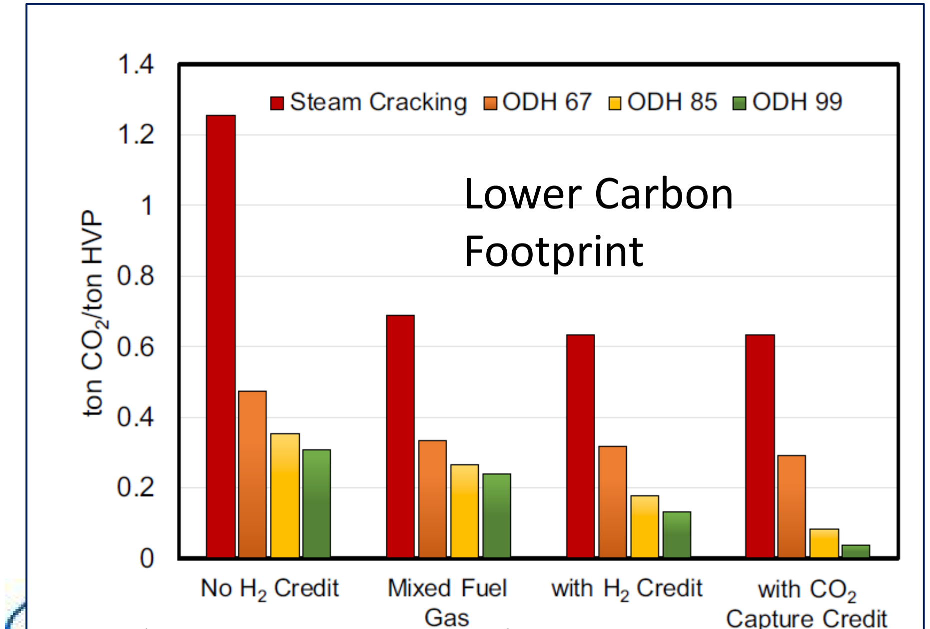




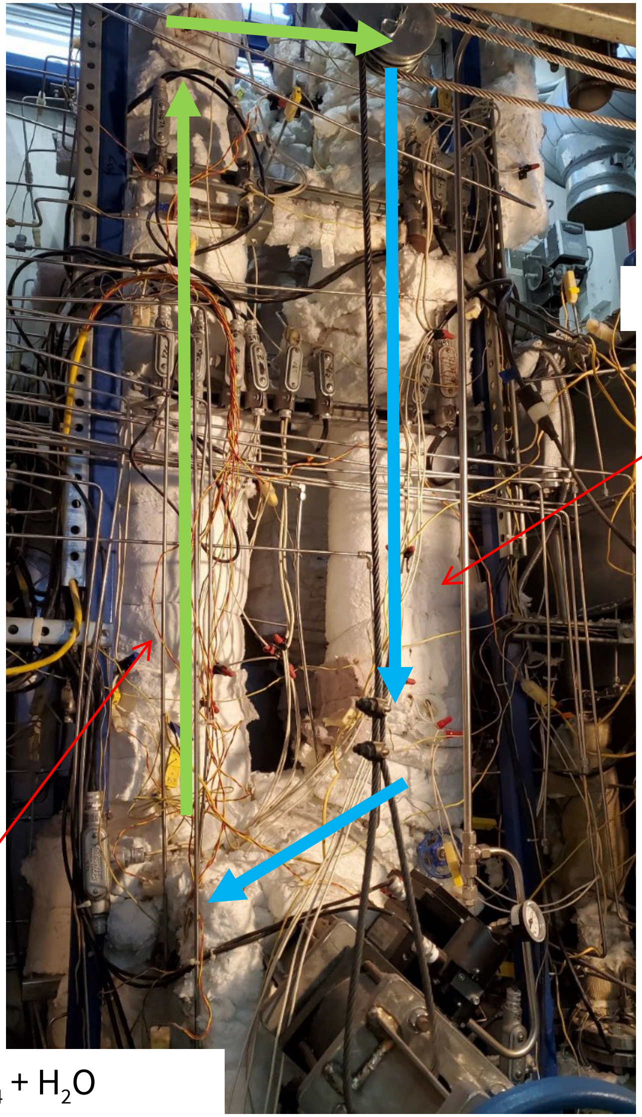


Process Improvements

- Process modularization / intensification (existing)
- Electrification
- Heat integration
  - Electrification
- Example: Chemical Looping, Oxidative Dehydrogenation of Ethane to produce Ethylene.



iScience volume 19 , 27 Sept. 2019 Pages 894-904. Fanxing Li et. al.



$MeO_x + 1/2O_2 \rightarrow MeO_x$

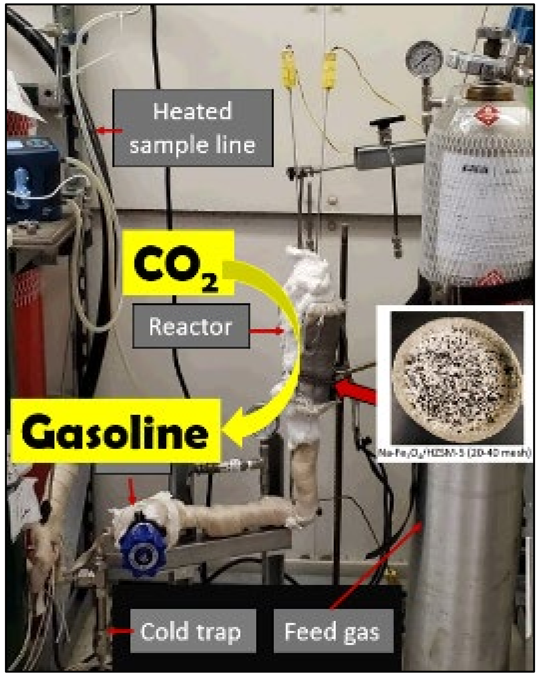
Regeneration

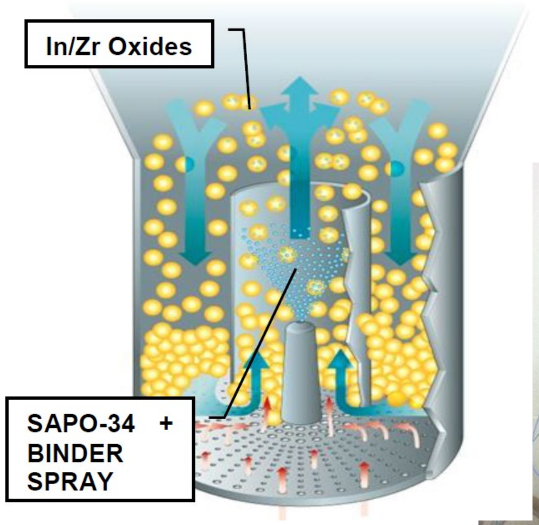
Reduction

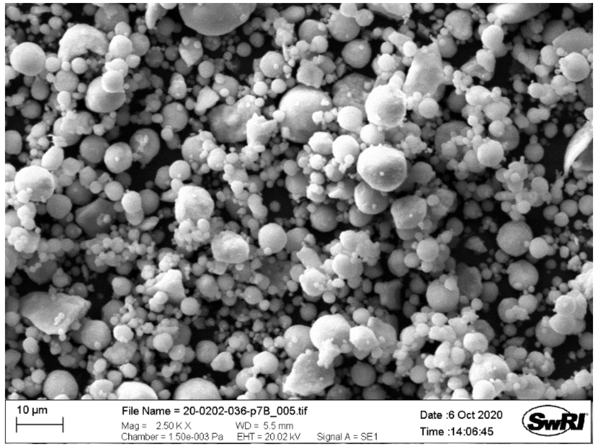
$C_2H_6 + MeO_x \rightarrow MeO_{x-1} + C_2H_4 + H_2O$

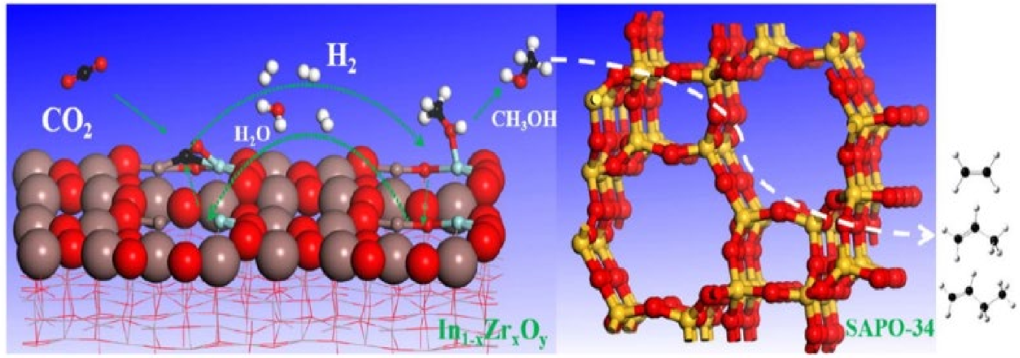
Carbon Dioxide Utilization

- CO_2 to fuels
  - Automobile applications
- CO_2 to chemicals
  - Circulating fluid bed catalyst
  - Micropore zeolite
- Nonbiological approaches
- Needs low CO_2 energy









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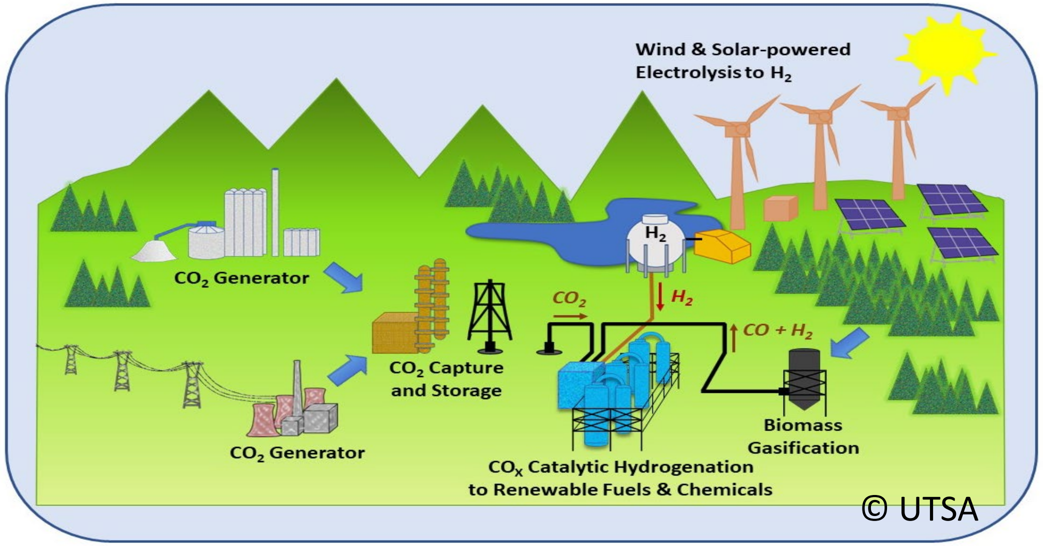
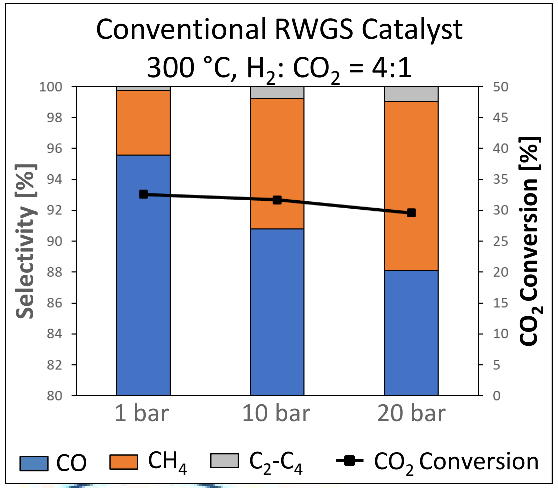
UTSA-SwRI Connect Program: CO_2 to Fuel

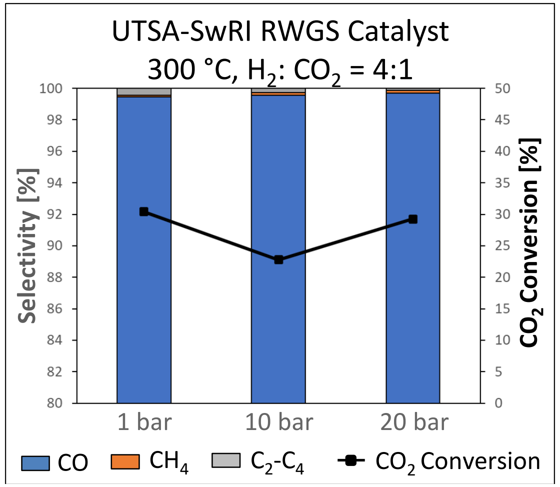
SwRI- Dr. Grant Seuser, UTSA- Dr. Gary Jacobs

Sustainable production of hydrocarbons through carbon recycling



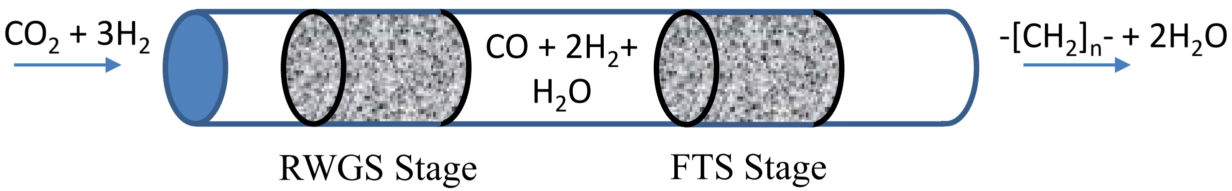
RWGS Stage





Superior CO selectivity!

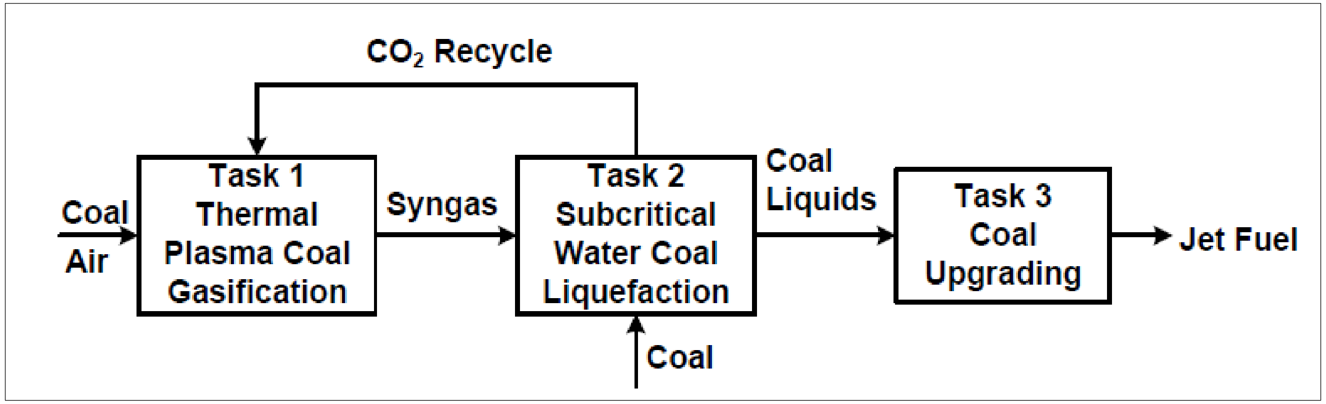
Single Reactor Concept for Converting CO_2 to Fuel

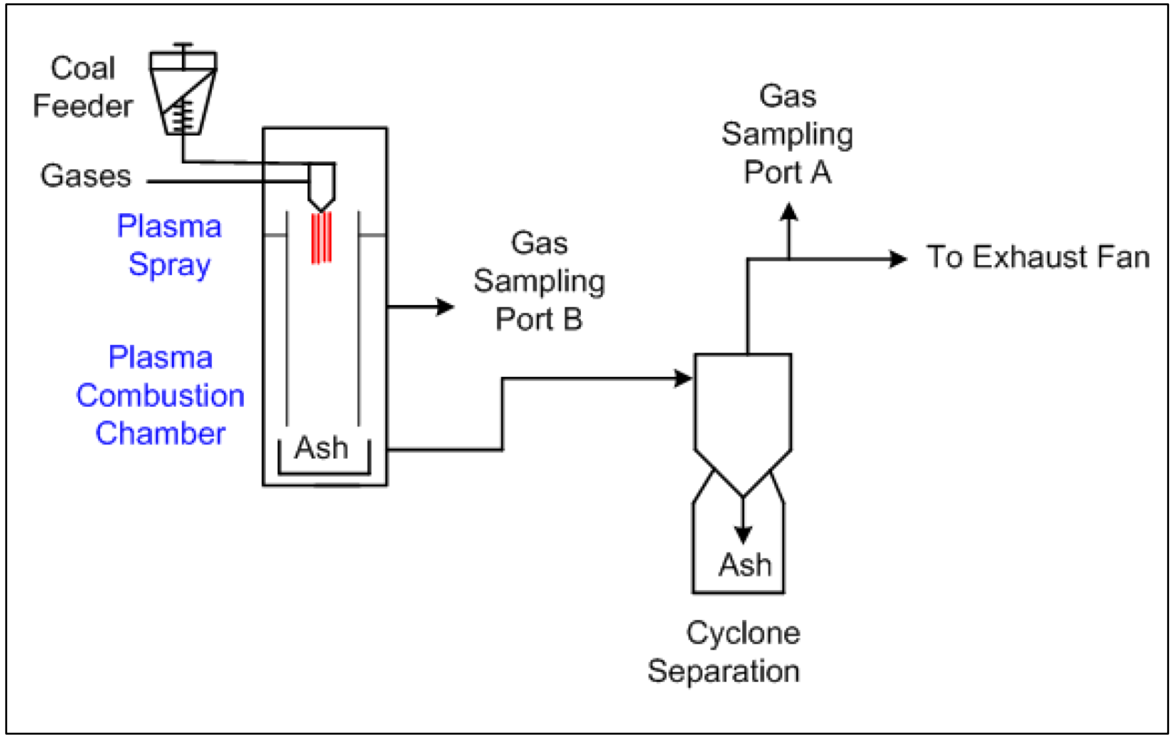


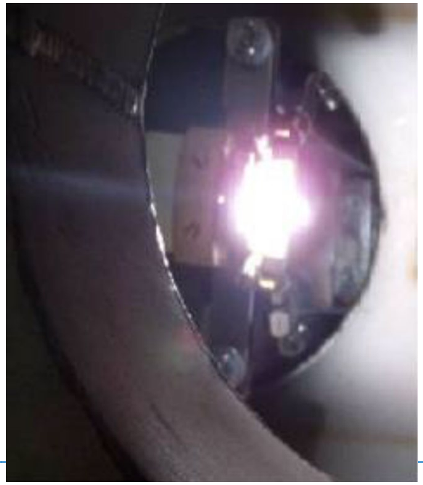
- Novel process to simplify the transformation of CO_2 to hydrocarbons by combining Reverse Water Gas Shift and Fischer Tropsch Synthesis into a single reactor
  - Reverse water gas shift (RWGS) hydrogenates CO_2 to syngas - CO and H_2
  - Fischer Tropsch Synthesis (FTS) converts syngas to liquid fuel
- Program Accomplishments:
  - Developed a highly selective RWGS catalyst (patent pending)
    - Avoids losses from methanation
    - Active at moderate temperature and up to 20 bar

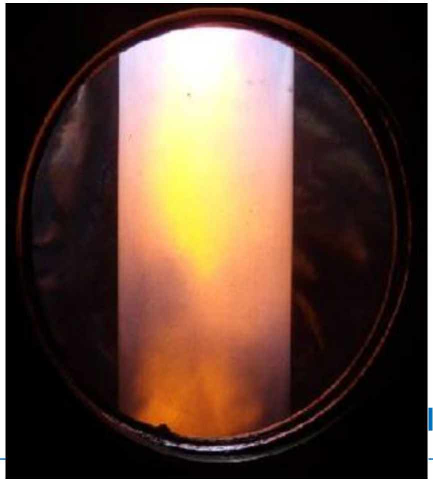
Carbon Dioxide Utilization

- Coal to Jet
  - $CO_2 + C \rightarrow 2CO$
  - Thermal Plasma Spray (Argon)









High Power Impulse Plasma Source (HiPIPS)

Dr. Josh Magnum

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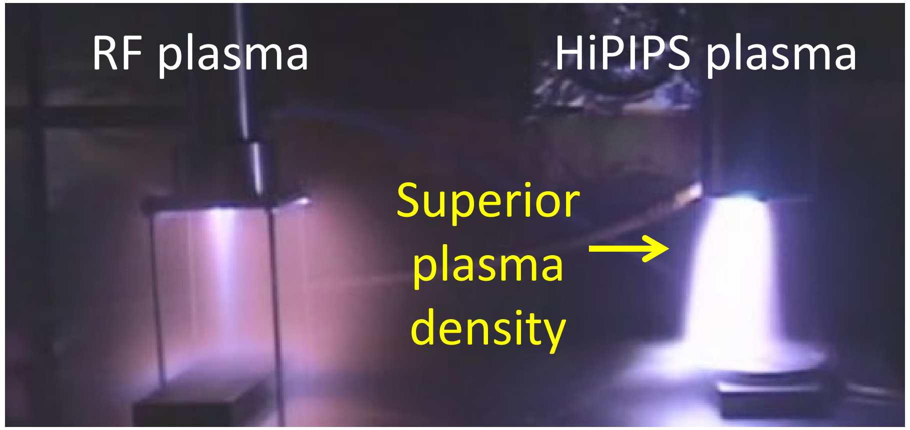
HiPIPS plasma features

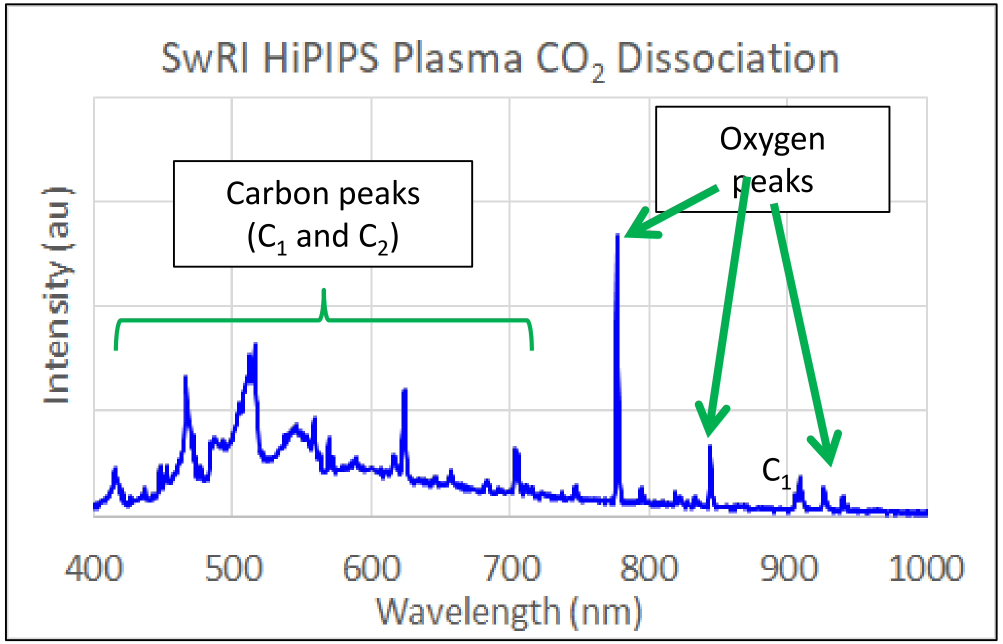
- High density plasma (high reactivity).
- Low average power consumption.
- Low temperature operation (50 °C).
- Wide pressure operational range (0.001 atm – 15 atm).



HiPIPS vs. traditional plasma when operating at the same power (35 watts)

Applications

- CO_2 dissociation at low power (35 watts).
- Atmospheric pressure, < 50°C.



In-situ plasma optical emission spectroscopy

Coupled Syntheses via Electrochemical & Non-Thermal Plasma Processes

Dr. Mike Miller

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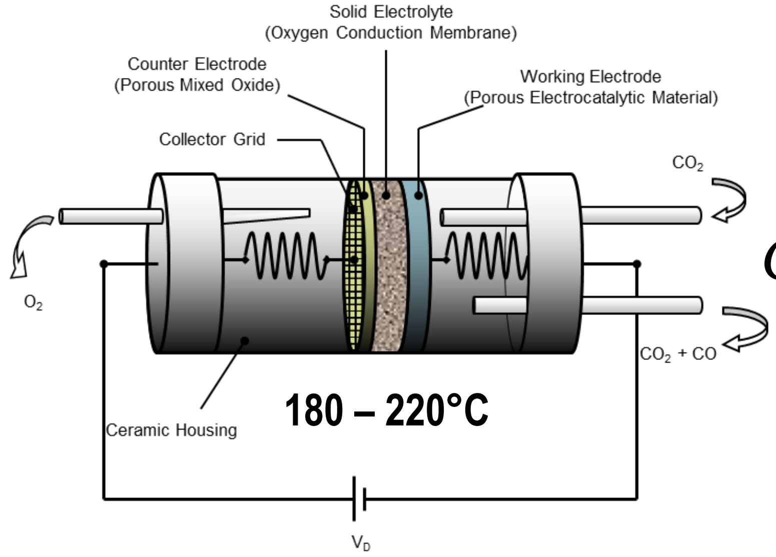
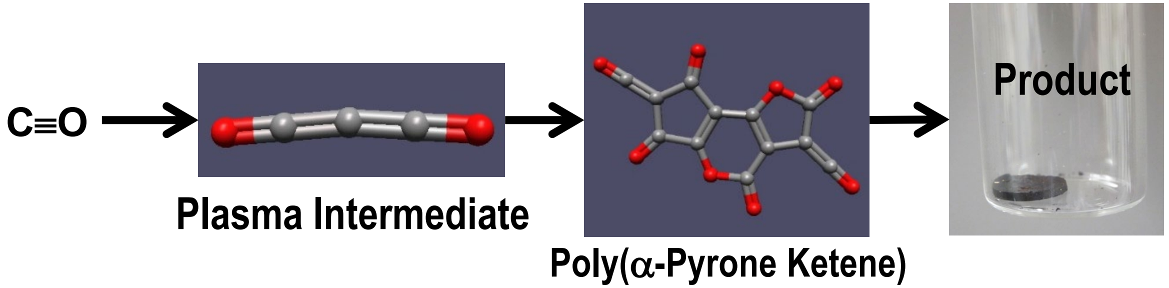
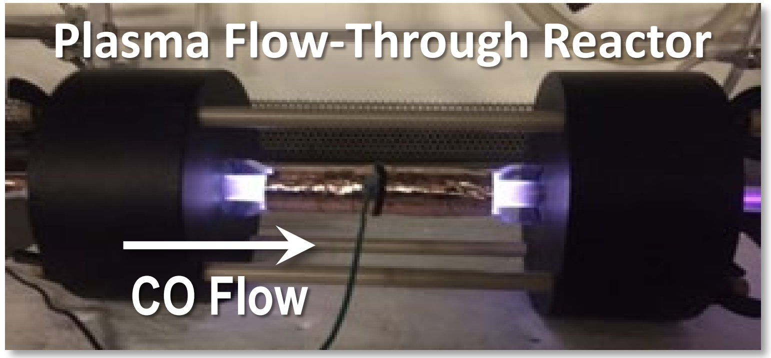
Thermo-Electrochemical Conversion



$$CO_2 \rightarrow CO + \tfrac{1}{2} O_2$$





Thermo-catalytic solid electrolytes
- ZrO_2 (Y_2O_3 stabilized)
- ThO_2 (Y_2O_3 stabilized)
- RuO_2 (Y_2O_3 stabilized)
- La_2O_3

Substrates for catalytic electrode
O^{2-} conduction membrane

Other Plasma Conversions Reactions:
$H_2S \rightarrow H_2 + S_l$ ΔH^0_{298} = 0.24 eV/molecule
81–96% conversion via non-thermal plasma

Electrolytic Conversion:
$H_2O \rightarrow H_2 + \frac{1}{2} O_2$ E^0 = 1.23 V
$H_2S \rightarrow H_2 + S$ E^0 = 0.171 V

Advanced Plastics Recycling

- Pyrolysis
- Reduce CO_2 emissions by 50% compared to burning
- Potential for net-zero plastics if buried.
- ISCC Plus