Introduction to a Bosch Process Architecture for ISRU and Terrestrial Applications

Developing key technologies to enable the Bosch process on the Moon, Mars, and Earth

Beau Compton (GRC); Principal Investigator | Jackson Stewart (GRC); Technical Lead | Timothy Giesy (MSFC); Technical Lead

National Aeronautics and Space Administration

Introduction

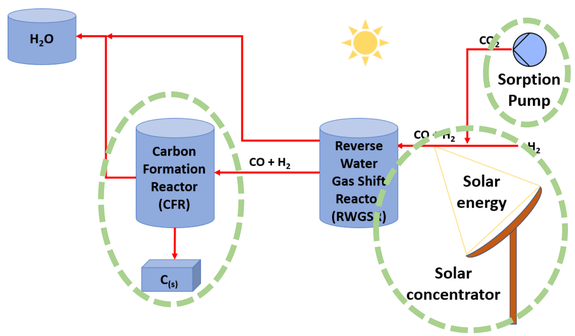
The Carbon Utilization Technology for Lunar and Atmospheric Systems (CUTLAS) project, an Early Career Initiative (ECI) funded by NASA STMD, is developing three technologies to enable the Bosch process for in-situ resource utilization (ISRU) and terrestrial carbon capture and processing. Combined with an electrolyzer, the Bosch process can be largely automated and produce oxygen for life support and propulsion. Carbon is needed for the carbothermal reduction process on the Moon. At sufficient scales, the Bosch process could reduce post-combustion CO2 emissions and/or lower terrestrial CO2 levels.

The Bosch process utilizes several sub-reactions to facilitate the overall reaction:

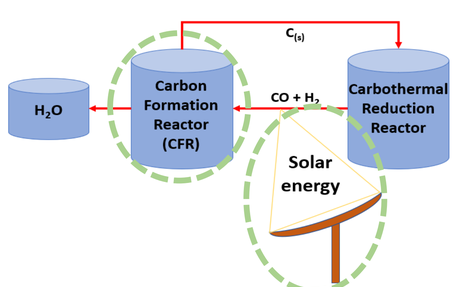
$$CO_2 + 2H_2 \leftrightarrow 2H_2O + C_{(s)}$$

Architectures

Technologies developed by CUTLAS



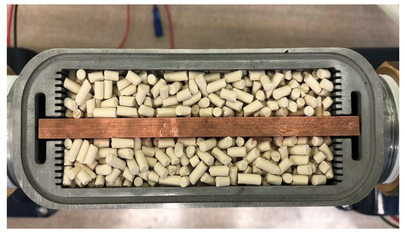
Bosch process architecture for atmospheric applications (Mars and Earth)



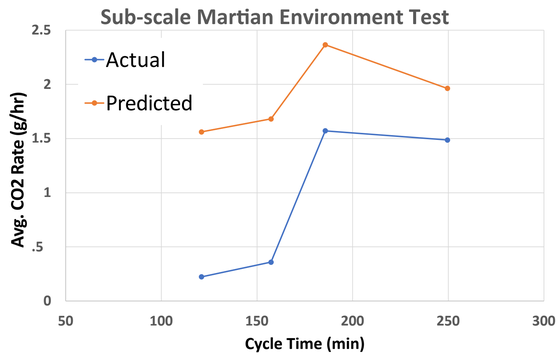
Architecture for lunar carbothermal reduction using Bosch process technology

Current Work

Rapid Cycle Adsorption Pump (RCAP)

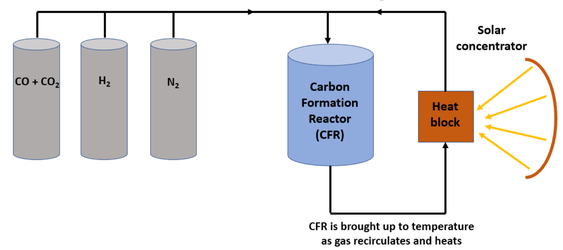


Inside view of the RCAP, showing zeolite pellets, copper heat exchange plate, and RCAP housing



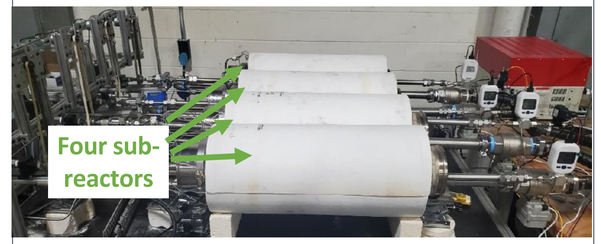
Solar Concentrator Heating

Current solar concentrator being tested



Simplified diagram of gas heating concept

Carbon Formation Reactor (CFR)



Test setup of a sub-scale CFR developed by pH Matter

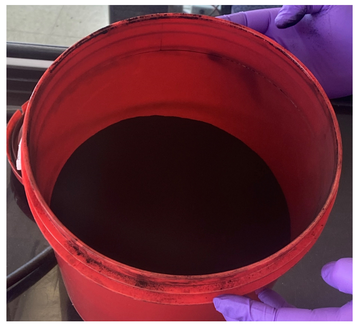


Photo of carbon powder produced

Discussion

RCAP

- The RCAP thermally cycles solid state adsorbents to capture, purify, and compress CO_2, a process known as temperature swing adsorption (TSA)
- Several adsorbent types are being studied:
  - Zeolite (13X)
  - Metal organic framework
  - Activated carbon
- Current results for a sub-scale Martian test using zeolite demonstrate the importance of cycle time and heat transfer for reaching equilibrium adsorption

Solar Concentrator

- The solar concentrator uses concentrated solar energy to heat the reactants to 500 °C
- Due to the complex geometry of the reactors and large surface area, directly heating the reactor walls is unfeasible. Heating the gas reactants directly before entering the chamber provides a simpler and more efficient solution
- Temperature controlled heating loads peaked at 6400 W in lab tests

CFR

- The CFR facilitates two reactions at 500 °C, the Boudouard reaction and CO Hydrogenation reaction, with the later being the most prevalent:

$$CO + H_2 \leftrightarrow H_2O + C_{(S)}$$

- Originally designed to work with a Solid Oxide Co-Electrolyser (SOCE) and then the ISS ECLSS system, the CFR operates at 1/10th of the scale required for ISRU and 1/100th of the scale for terrestrial carbon capture.
- pH Matter, the external partner of the CUTLAS project, is developing an ISRU scale CFR with improved automation