Virtual Research Presentation Conference

Light-Driven Electrochemical Production of Oxygen and Fuel from CO_2 and Sunlight for Mars ISRU

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Program: Strategic Initiative
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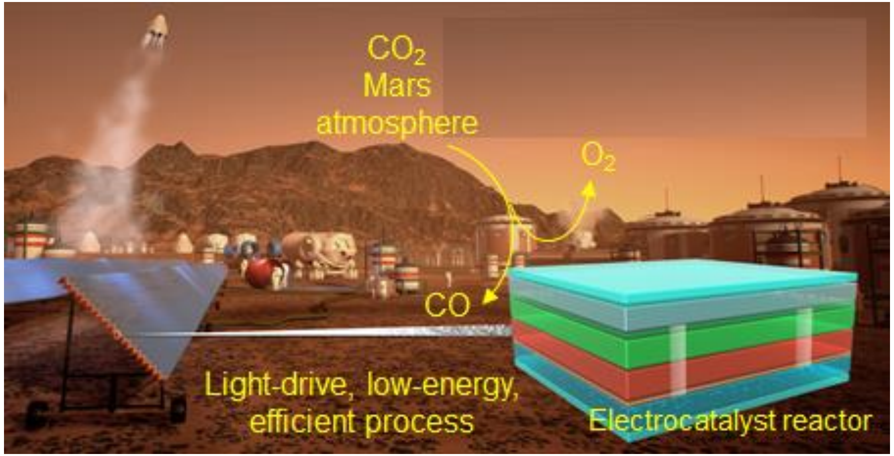
Oxygen generation on Mars is a critical technology

- Future human Mars missions
  - Preliminary estimates of 30,000 kg of O_2 for Martian ascent vehicle[1]
- Human presence
  - Each human exhales ~1 kg CO_2/day[2]
- Electrochemical reduction reactions:
  - Cathode: $CO_2 + 2H^+ + 2e^- \rightarrow CO + H_2O$
  - Anode: $H_2O \rightarrow 2H^+ + 2e^- + O_2$

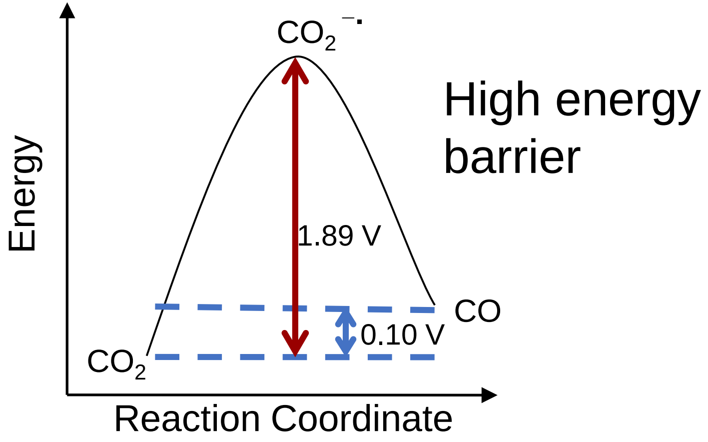


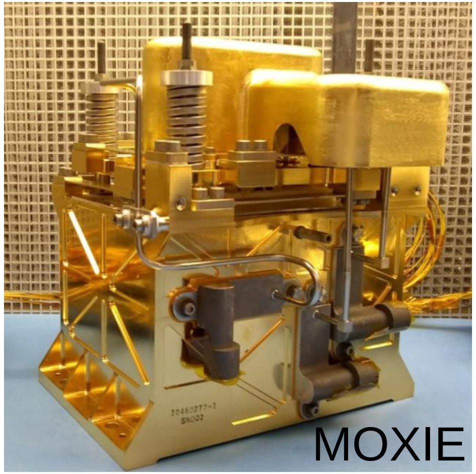
The goal of this project is to develop a low temperature O_2 generation process powered by sunlight

1. NASA's Human Exploration Design Reference Architecture 5.0 Addendum
2. D. E. Sherif and J. C. Knox, "International Space Station Carbon Dioxide Removal Assembly (ISS CDRA) Concepts and Advancements" *SAE Tech. Pap.* 2005-01-2892 (2005).

Problem Description

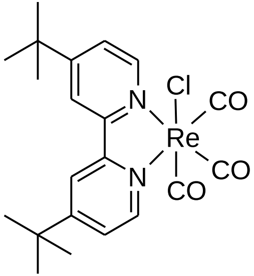
- CO_2 reduction is very challenging due to high energy barrier
- SOA: Solid Oxide Electrolysis Cell (SOEC) at 800 °C
- Oxide membrane enables conversion of CO_2 to CO and O_2 without protons
  - Cathode: $2\ CO_2 + 4\ e^- \rightarrow 2\ CO + 2\ O^{2-}$
  - Anode: $2\ O^{2-} \rightarrow O_2 + 4\ e^-$
- High temperature allows endothermic reaction
  - Some energy for conversion is provided by heat, rather than electrochemically
- Future Mars sample return missions and long term exploration will require access to O_2 for propellant and life support systems
- The Martian atmosphere provides an almost limitless supply of CO_2, which can be electrochemically converted into O_2



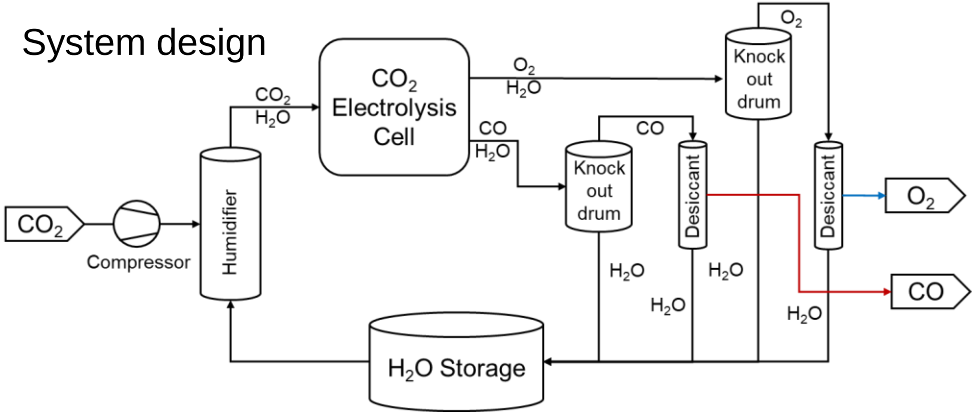


Methodology

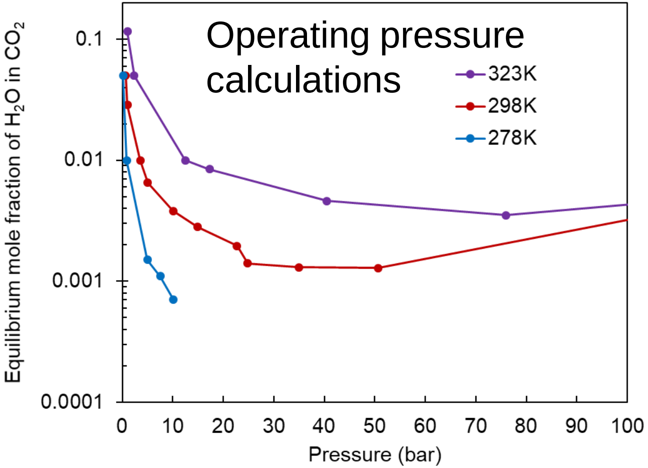
Catalyst



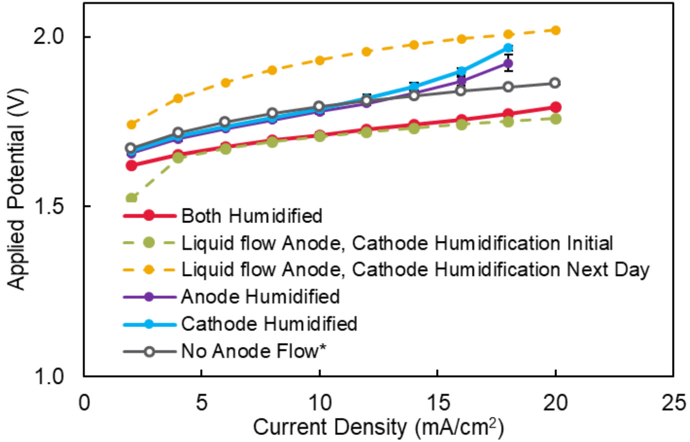
System design

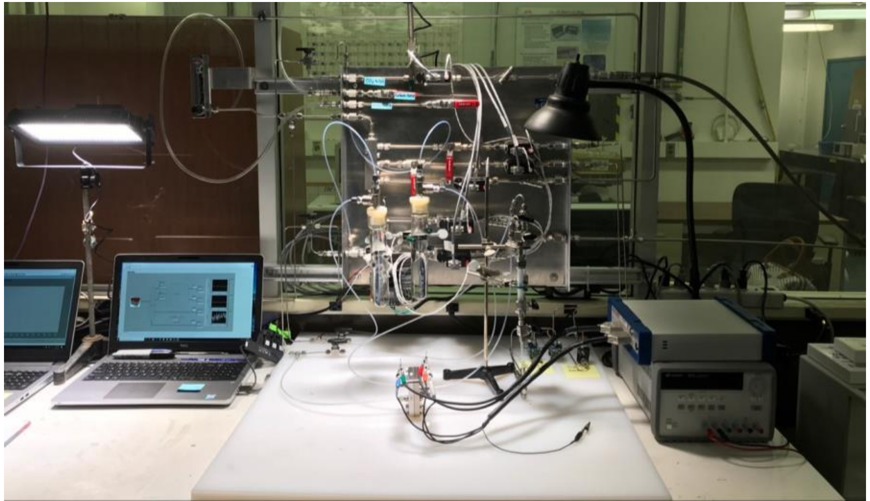


1. Develop efficient catalyst for CO_2 reduction
2. Integrate catalyst into flow electrolysis cell
3. Design an O_2 production system
4. Build a breadboard
5. Test electrochemical performance of system
6. Measure water loss, flow rate, pressure, temperature, system stability and other performance parameters for full system comparison to MOXIE



Results





a) Molecular CO_2 catalyst developed

b) Catalyst integrated into flow cell

c) End-to-end electrochemical CO_2 reduction system designed

d) Breadboard system built

e) Electrochemical performance evaluated

f) Many system-level performance metrics measured

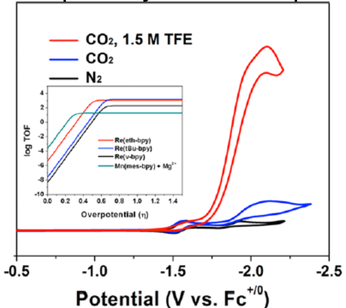
   a) Flow rate effects measured

   b) Humidification effects measured

   c) Long term catalyst stability partially measured

   d) Temperature and pressure not investigated

   e) Water capture system not implemented



Publications and References

References:

1. NASA's Human Exploration Design Reference Architecture 5.0 Addendum
2. D. E. Sherif and J. C. Knox, "International Space Station Carbon Dioxide Removal Assembly (ISS CDRA) Concepts and Advancements" *SAE Tech. Pap.* 2005-01-2892 (2005).

Publications:

1. Almagul Zhanaidarova, Curtis E. Moore, Milan Gembicky and Clifford P. Kubiak, *Chemical Communications*, 2018, **54**, 4116-4119.
2. Almagul Zhanaidarova, Andrew L. Ostericher, Christopher J. Miller, Simon C. Jones and Clifford P. Kubiak, *Organometallics,* 2019*,* **38***,* 1204-1207.