Development of an Electrochemical Oxygen Compressor and Generator for Spacesuit Oxygen Resupply

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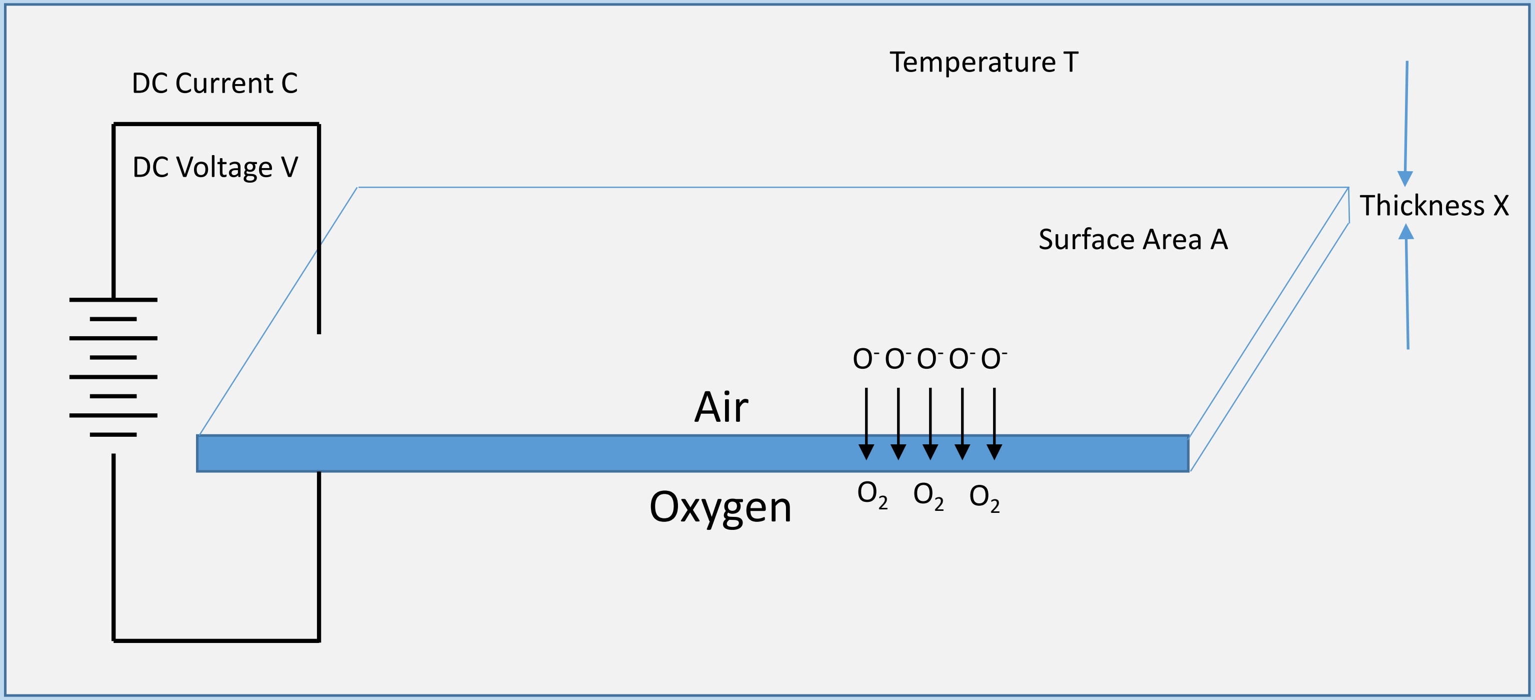
Agenda

- Oxygen Transport Membrane Fundamentals
- Spacesuit Oxygen Tank Recharge Application
- eCOG-C Feasibility Assessment
- Summary

Oxygen Transport Membrane Fundamentals

- **Function:** OTM can separate oxygen from other gases, because oxygen ions get electrochemically transported through some oxide materials "infinitely selective"
- **Hot:** Electrical resistance is essentially infinite at room temperature, common process temps are 650-750 C.
- **Thin:** Resistance across OTM is a function of membrane thickness. Thin membranes use less power.
- **Brittle:** The oxide materials that perform the best for OTMs are brittle, especially when they are thin.

Oxygen Transport Membrane Fundamentals



Oxygen Transport Membrane Fundamentals

- **One solution to the hot, thin, brittle problem: OTM is embedded in a multi-layer wafer, that supports the OTM structurally, and creates a reservoir for oxygen**

Photo of cell stack

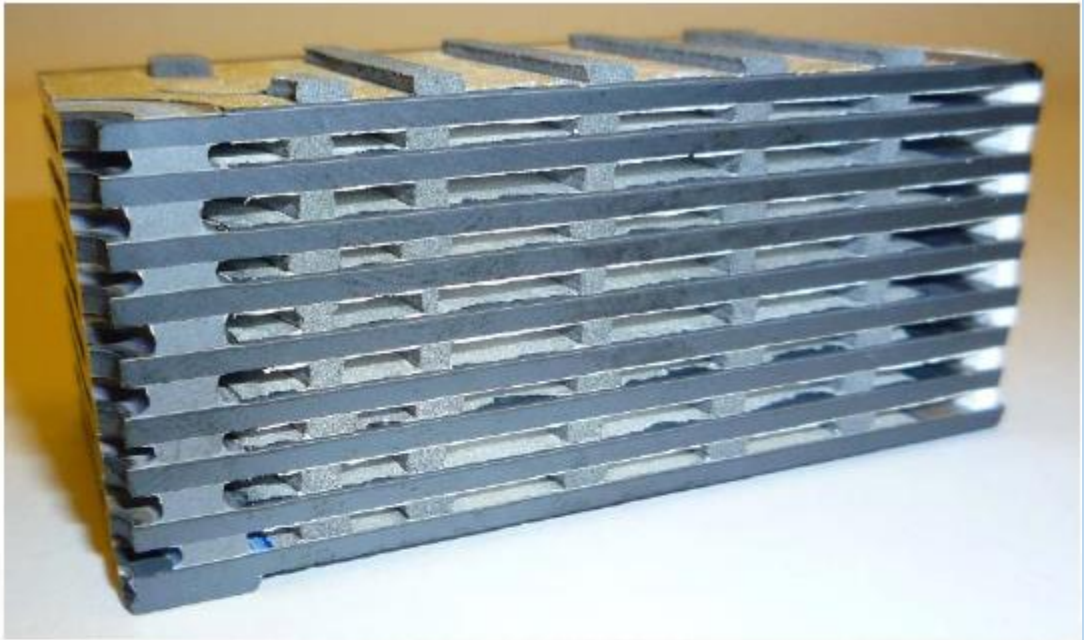


Photo of cutaway

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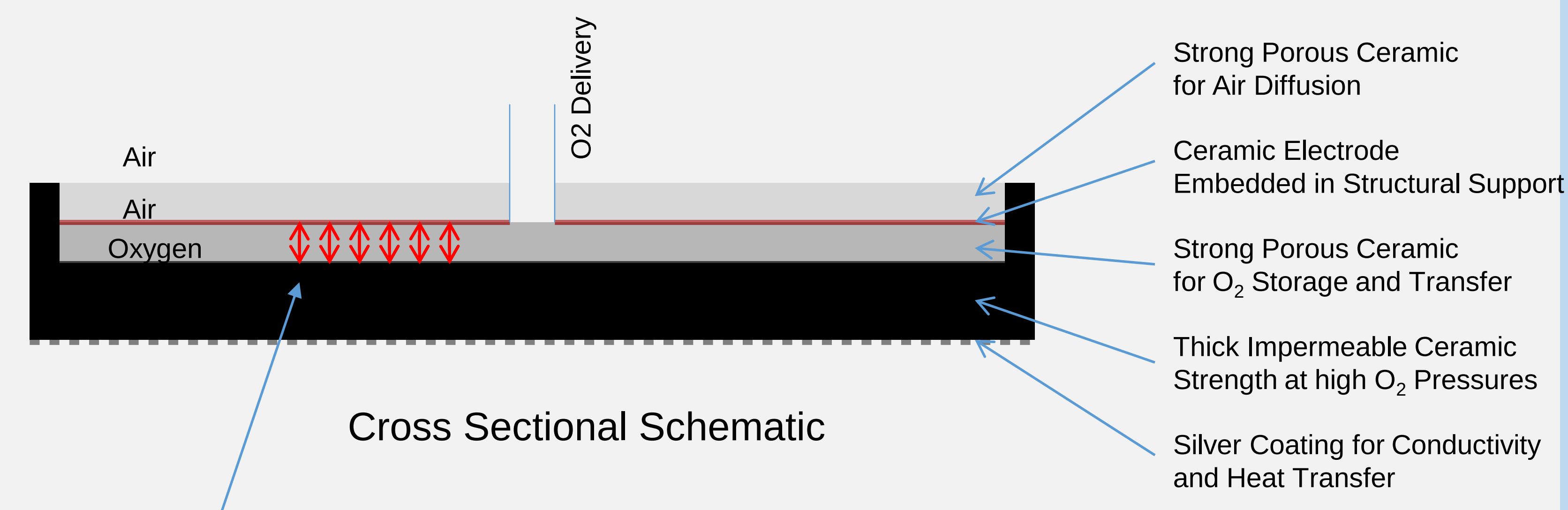
Oxygen Transport Membrane Fundamentals

- **The current OTM has an internal reservoir in each wafer. Oxygen puts the wafer in tension. The wafer can hold 300 psi, but not 600 psi.**



Cross Sectional Schematic

Oxygen exerts pressure force on the wafer

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Spacesuit O_2 Tank Recharge

High Pressure O_2 Gas Tanks

Pressure:	No Issues: Pressurization is done prior to launch
Purity:	No Issues: Purity can be validated prior to launch, risk of contamination after launch is low
Safety:	Favorable: No energy is added to the system during the mission
Summary:	Great for missions with few planned EVAs. Concerns about size and weight for exploration

Cryogenic Liquid O_2 (LOX)

Pressure:	Pressurization occurs as heat is added to the system
Purity:	No Issues: Purity can be validated prior to launch, risk of contamination after launch is low
Safety:	Lots of stored energy. Apollo 13 mishap involved LOX
Summary:	Best suited for short duration missions with many planned EVAs

Low Pressure Water Electrolysis + Drier + Mechanical Compressor

Pressure:	Demonstrated with technology demonstrator systems
Purity:	In-flight purity verification will likely be required; contamination risk is credible (compressor)
Safety:	Adding energy to O_2 during mission – compressors that keep O_2 cool can be large
Summary:	May trade well for exploration missions, especially if reliable purity verification is developed

Low Pressure Water Electrolysis + PSA O_2 Concentrator + Mechanical Compressor

Pressure:	Demonstrated with technology demonstrator systems
Purity:	In-flight purity verification will likely be required; severe concerns about PSA product purity
Safety:	Adding energy to O_2 during mission – compressors that keep O_2 cool can be large
Summary:	PSA product purity concerns need to be addressed before this can be evaluated

High Pressure Water Electrolysis + O_2 Drier

Pressure:	Demonstrated with technology demonstrator systems (thick end caps)
Purity:	Must remove water, verification may be easier if only water needs to be measured
Safety:	Fundamental safety issue: stack has hydrogen, high pressure O_2, and ignition source
Summary:	Safety issues cannot be designed out of the system

PEM Electrolyte Electrochemical O_2 Compressor

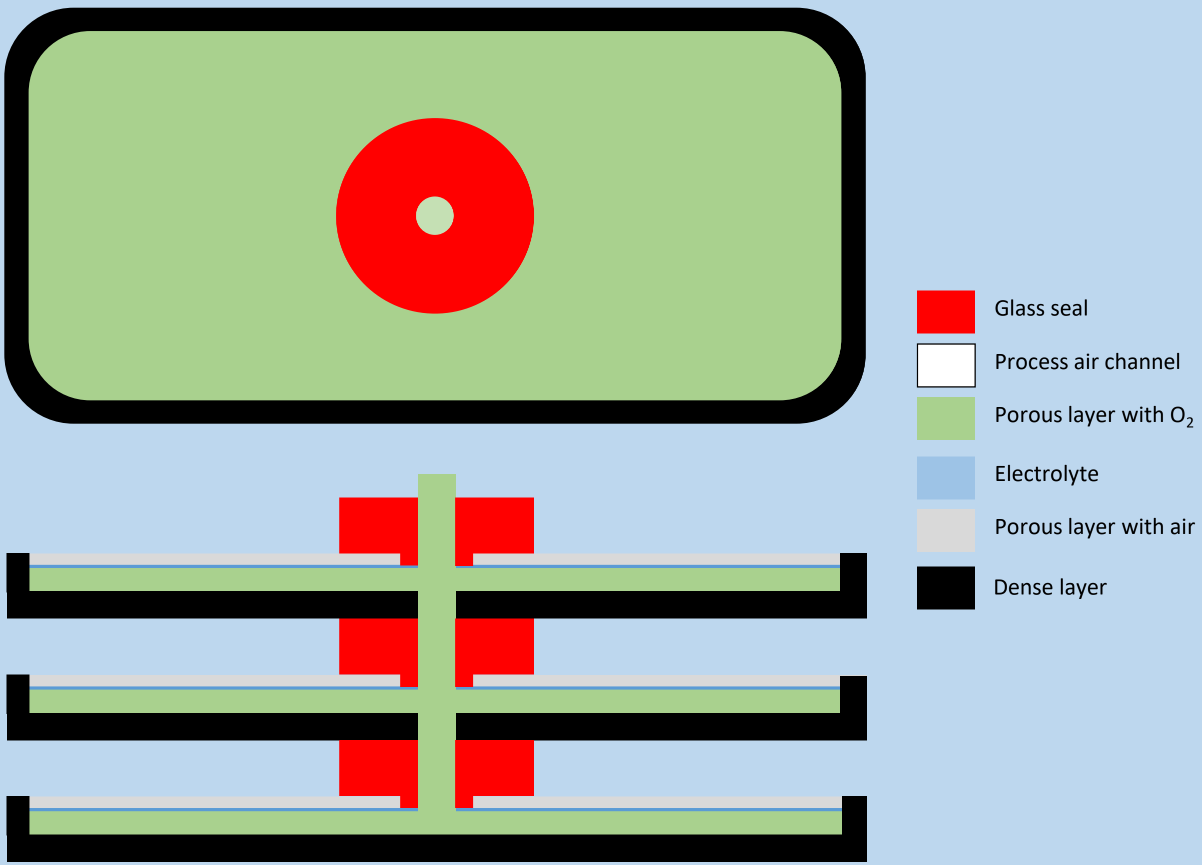
Pressure:	14,000 kPa demonstrated with lab prototype
Purity:	Must remove water, verification may be easier if only water needs to be measured
Safety:	Fundamental, but less severe: solid fuel (not H_2), high pressure O_2, and ignition source
Summary:	Kinetics needs to be demonstrated before this can be evaluated

Electrochemical Oxygen Generator & Compressor (eCOG-C)

Pressure:	14,000 kPa demonstrated with lab prototype
Purity:	No in-flight purity verification needed
Safety:	Adding energy to O_2 during mission - high temp hazards, but fire triangle ok (no fuel)
Summary:	Good potential for human exploration: solid state, high purity, no fuel near O_2

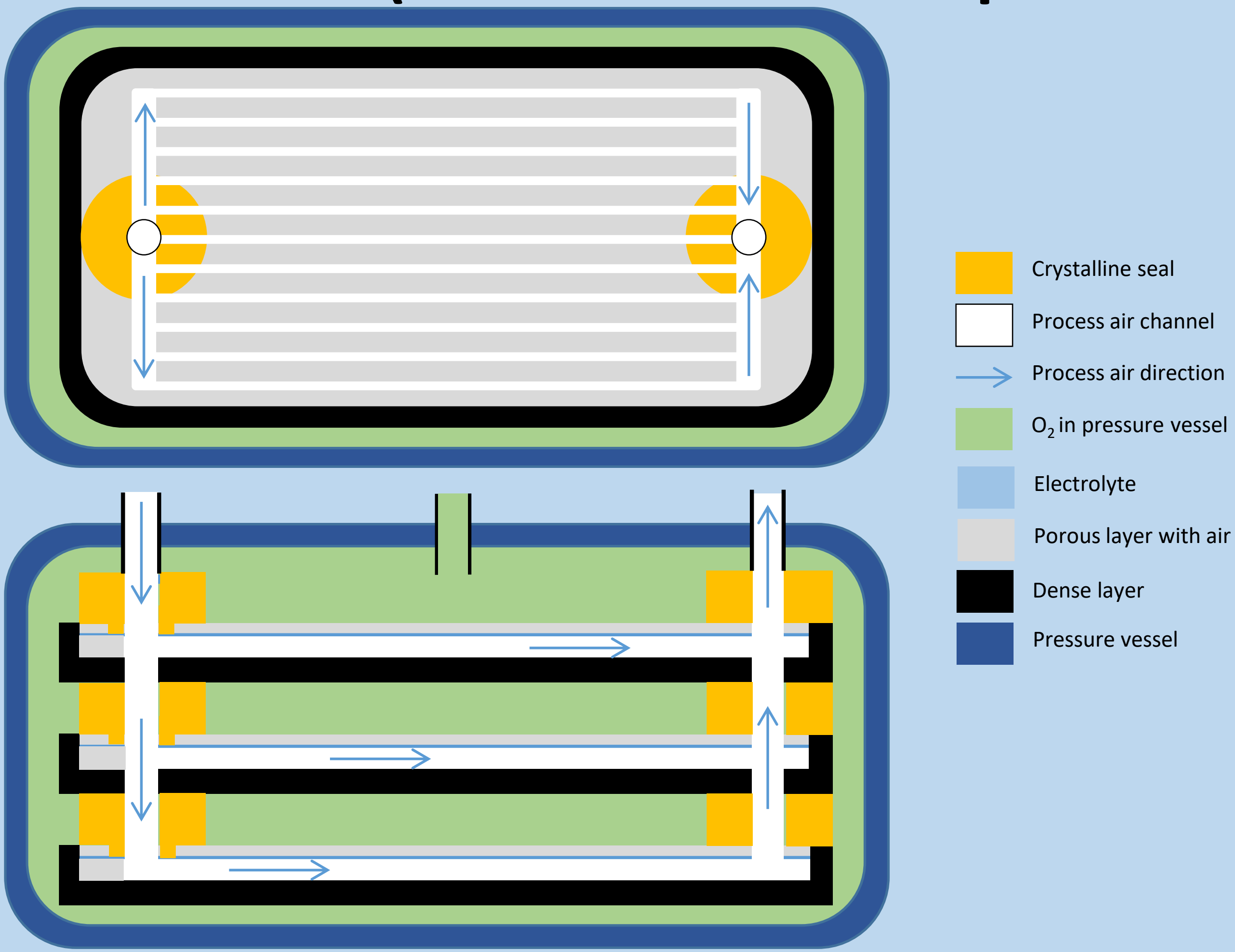
Feasibility Assessment

- **The current OTM wafer has an oxygen reservoir internal to the wafer. Glass seals connect the wafers**

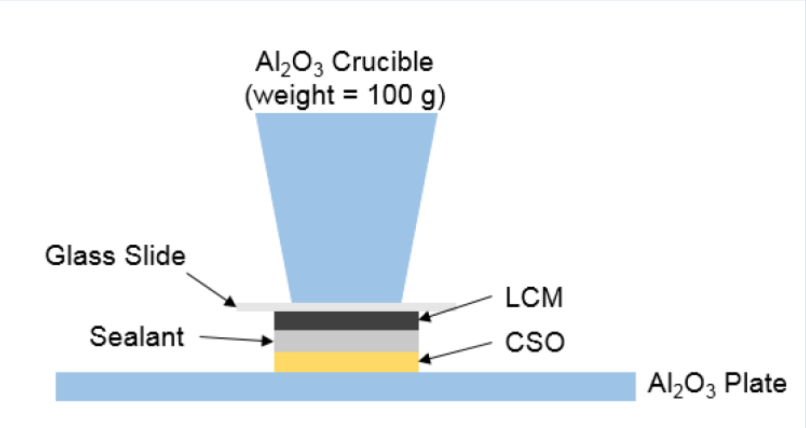


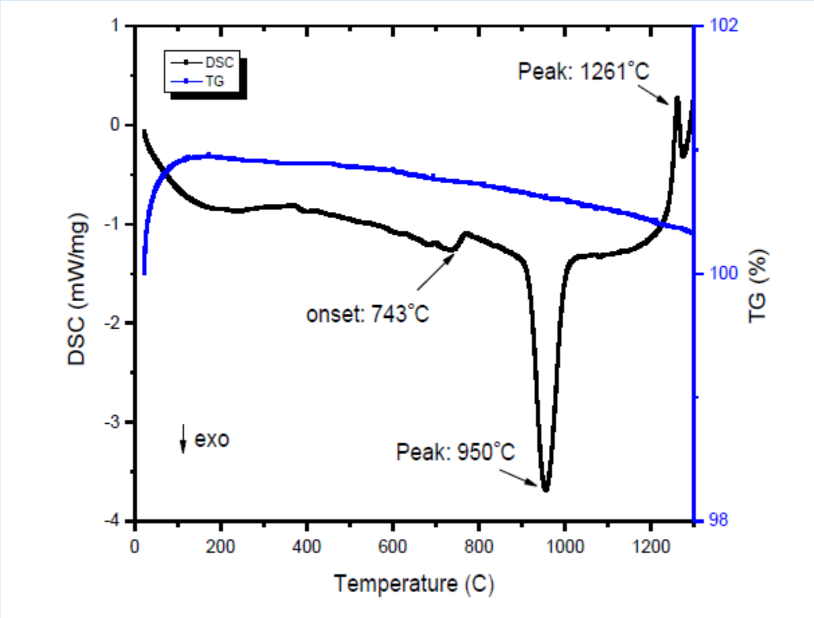
Feasibility Assessment

- **eCOG-C flows low pressure air internally, oxygen is external to the wafer (contained inside a pressure vessel)**

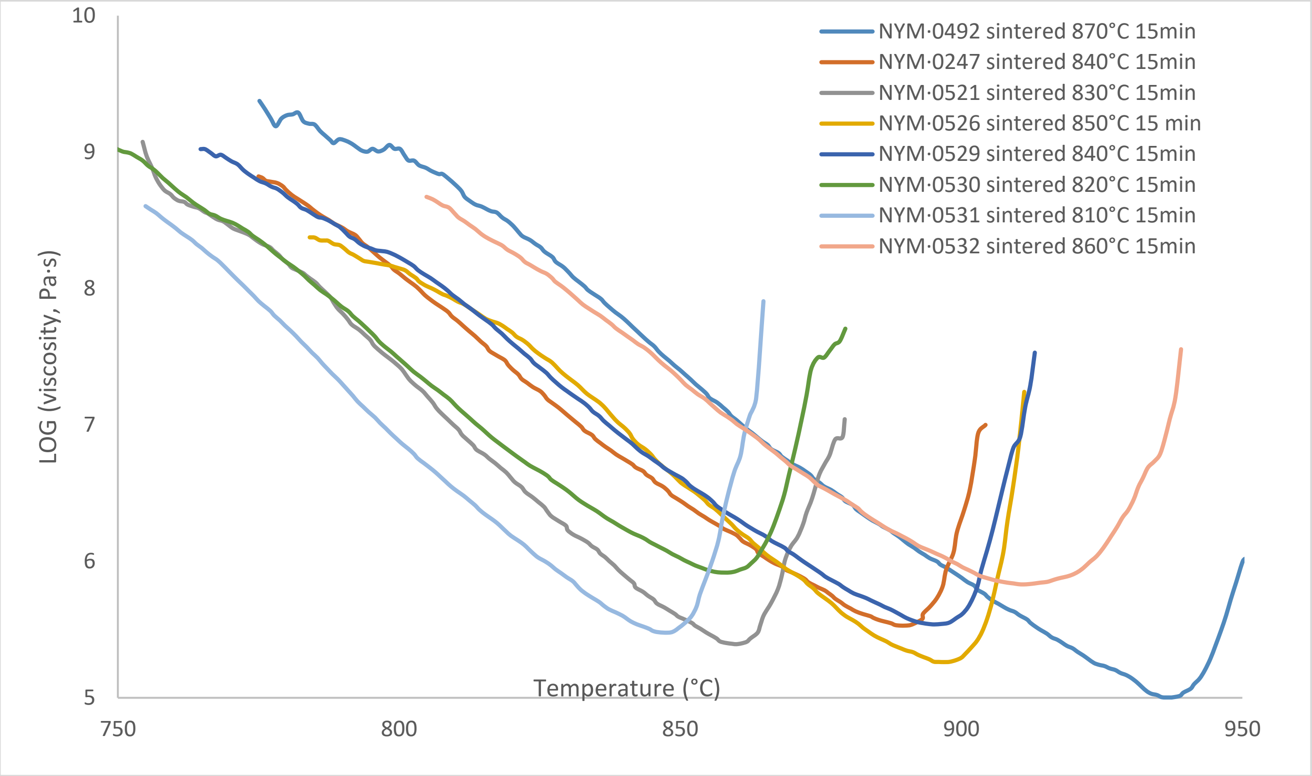


Feasibility Assessment





Feasibility Assessment



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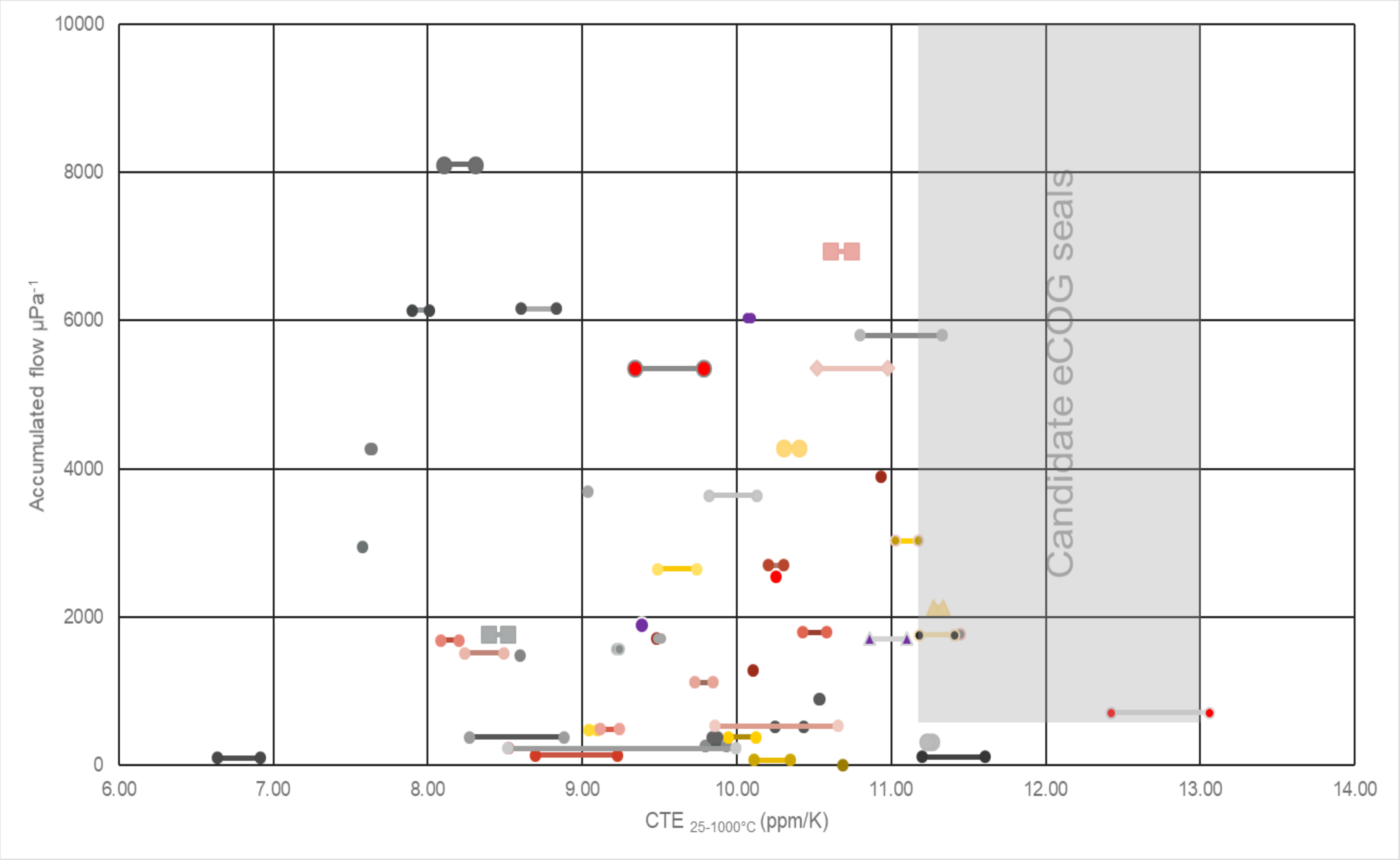
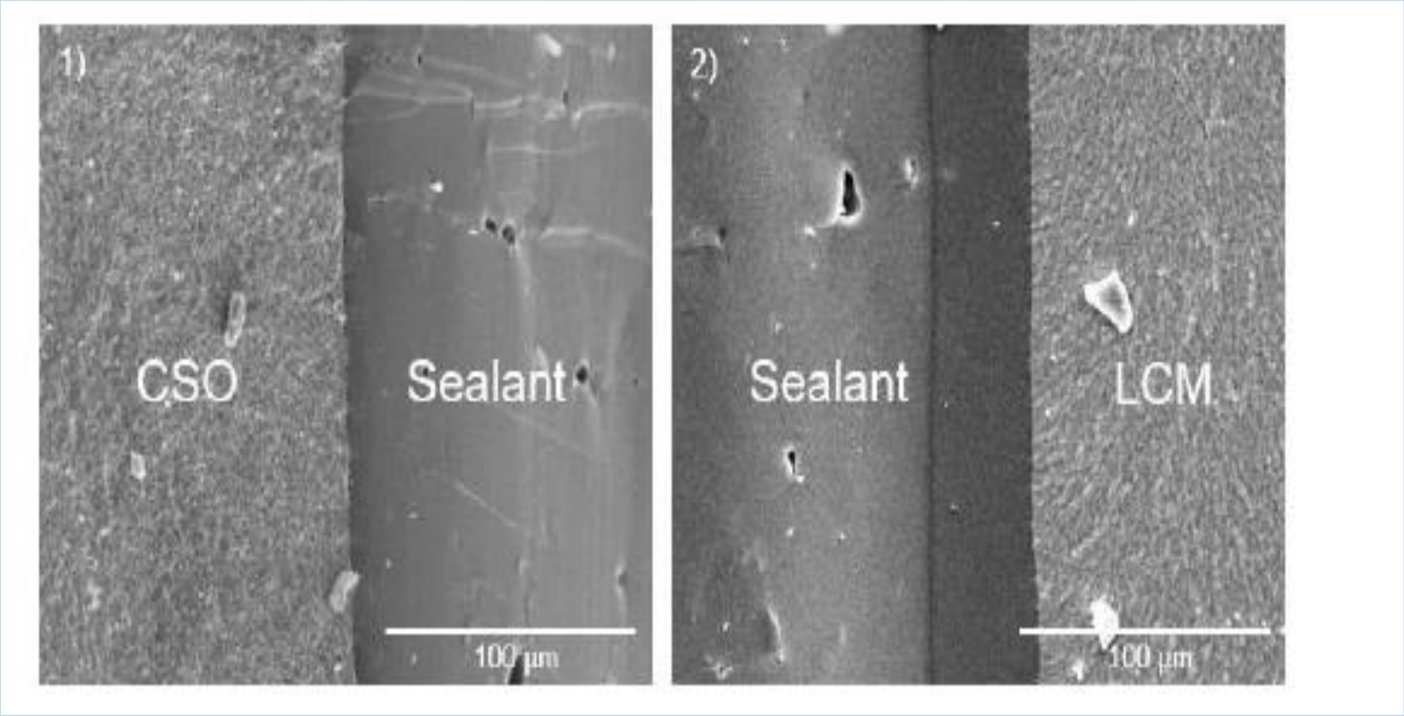
Feasibility Assessment



Feasibility Assessment



Summary

- Wafers can be reconfigured to place the oxygen external to the wafer. This puts the wafer in compression and makes >3000psi oxygen delivery possible.
- The #1 technical risk is developing a crystalline interconnecting seal that is strong, adheres to the wafers, and has a coefficient of thermal expansion that matches the wafer.
- The #2 technical risk is developing a modified wafer that has internal flow channels.
- Preliminary assessment of seal and wafer is favorable

Thank You