# Implications of Phenomena Observed during Molten Regolith Electrolysis

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# Why Oxygen?

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# Why Molten Regolith Electrolysis?

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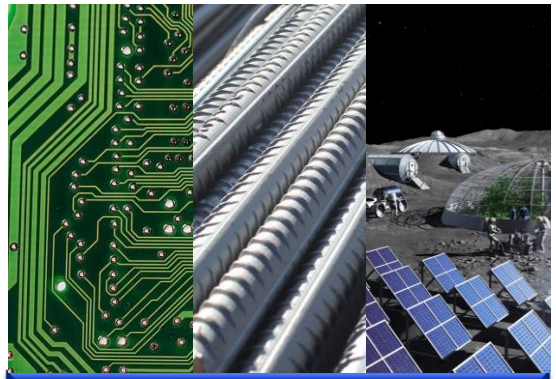
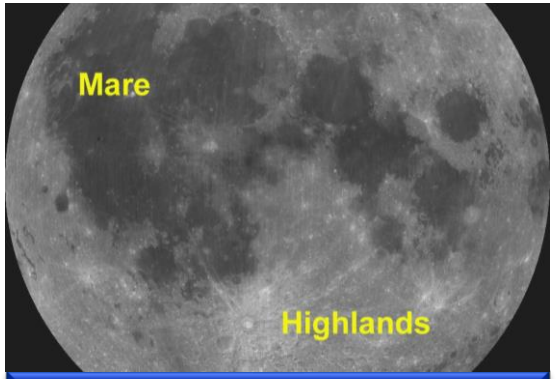
## High total extraction

- Possible to get almost all oxygen from regolith



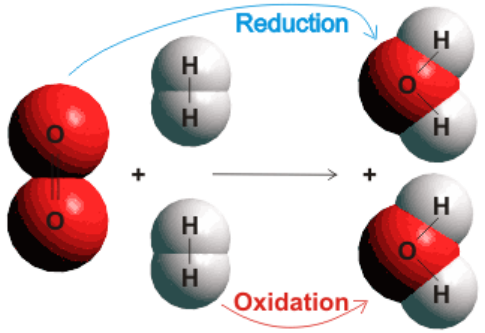
## Useful byproducts

- Silicon
- Iron
- Titanium
- REEs




## Area agnostic

- Mare or highlands
- Iron rich or poor




## No fluid consumables

- All processes will have wear from regolith abrasion, but most others require gas or ionic liquids

# MRE Reactor and Test Setup

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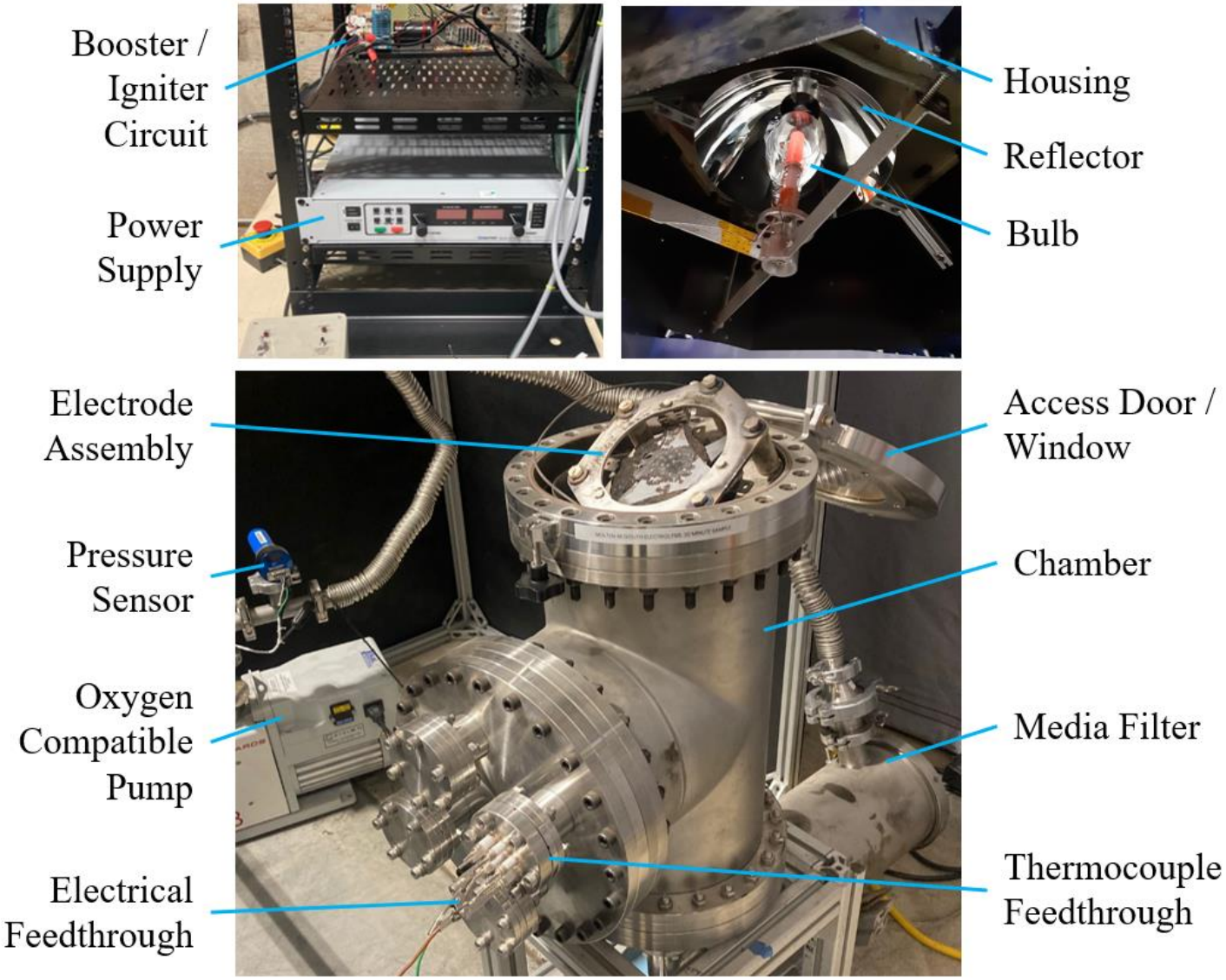

# Test Description

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- HBR performed several tests melting JSC-1A simulant in a vacuum chamber
- Ran solar concentrator for a total time of around ~30 minutes
- ~8kW lamp (less than 1kW absorbed by melt pool)
- Adjusted voltage until current increase was observed (ie either electrolysis or joule heating was observed)
- Ran test until significant drop off in current was observed
- Test purpose: determine ideal voltage parameters based on other test parameters
- Initial hypothesis: joule heating is not necessary with 1kW of power being absorbed into the melt pool
- Hypothesis likely proven wrong, joule heating likely observed before electrolysis.

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# Pressure as a Key Parameter

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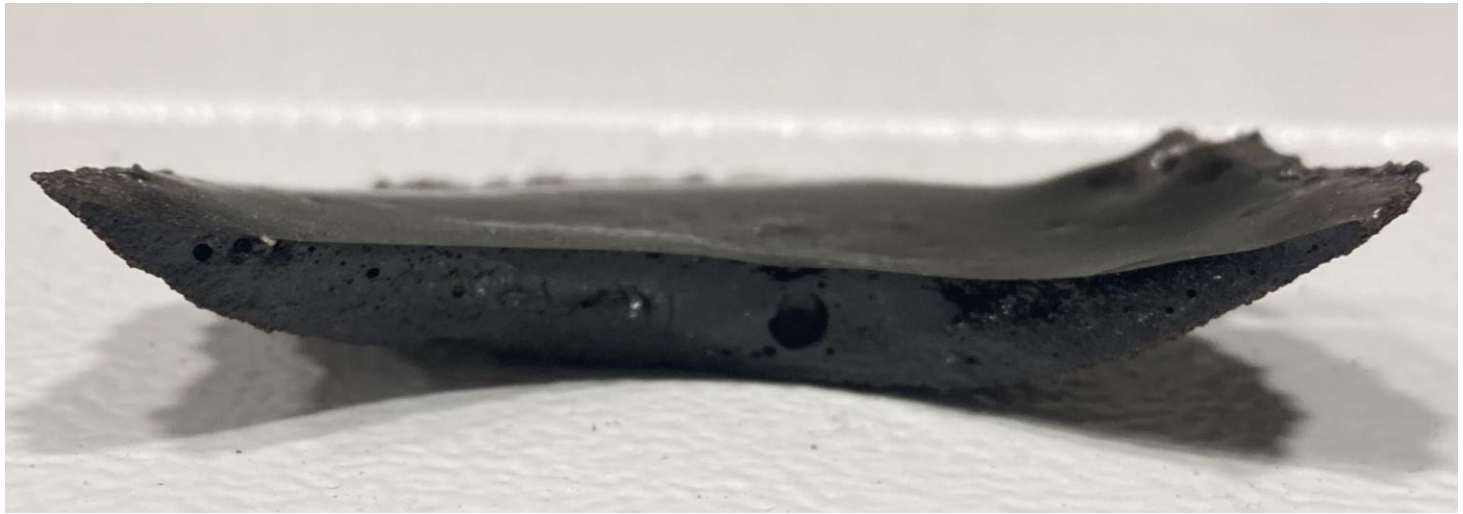
- Pictured is a melt pool formed in vacuum (top) and ambient (bottom).
- Note the large central cavity, the multiple vesicles, and the difference in color between them.
- System pressure is tunable in an MRE reactor, so pressure is a key parameter to balance with temperature and current and material.
- Oxygen hanging around in bubbles changes electrical behavior, oxygen in the environment changes reoxidation behavior



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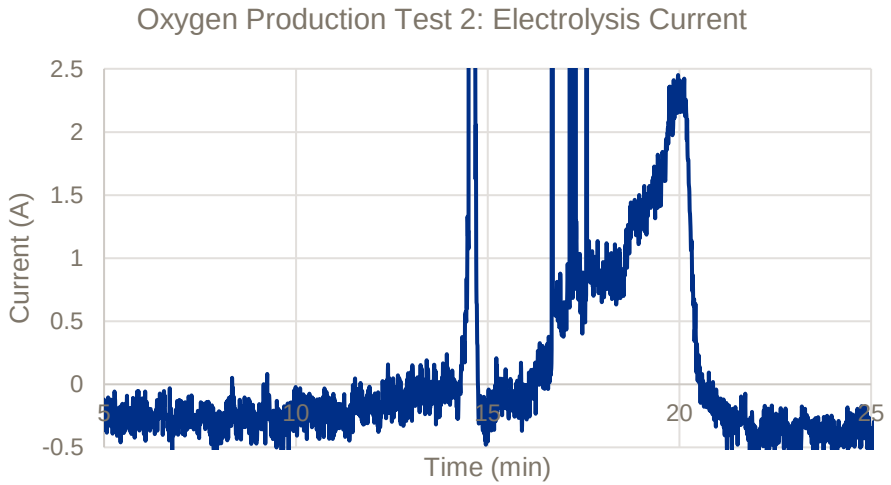
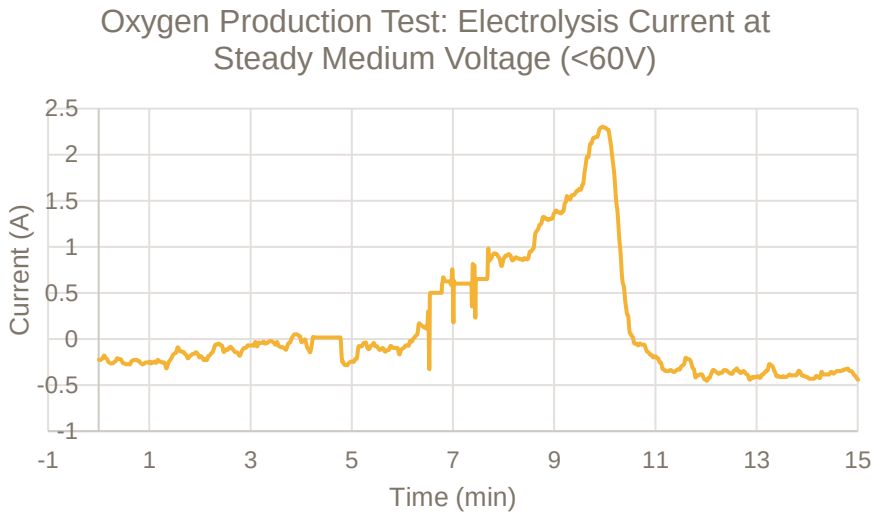
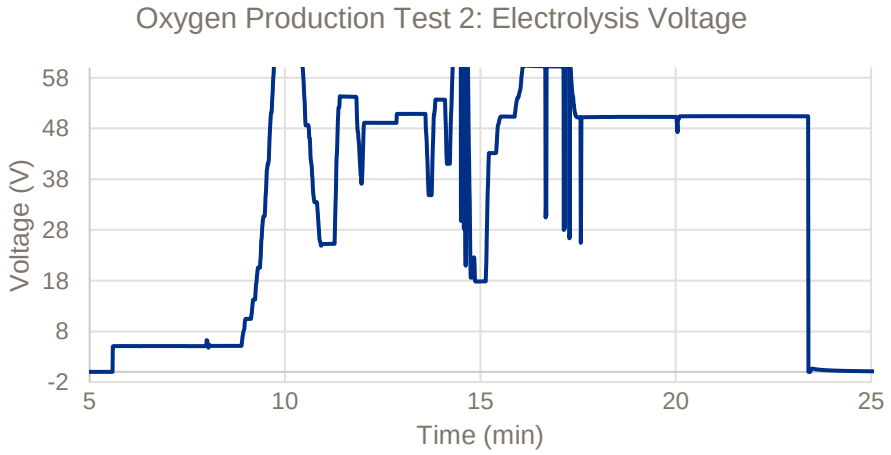
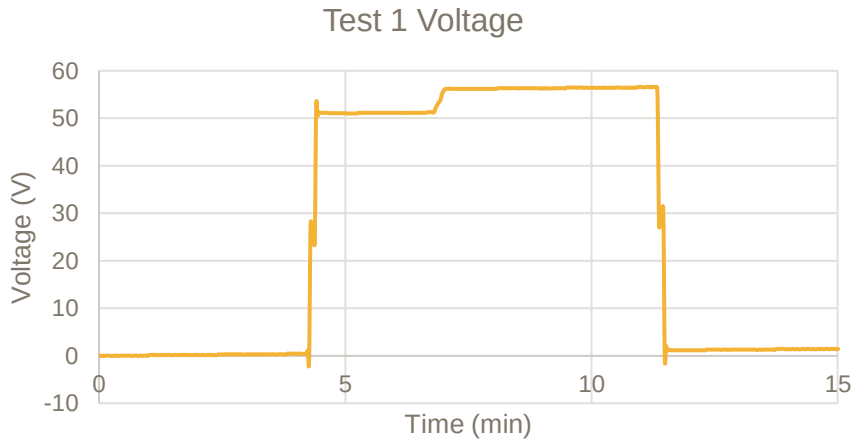
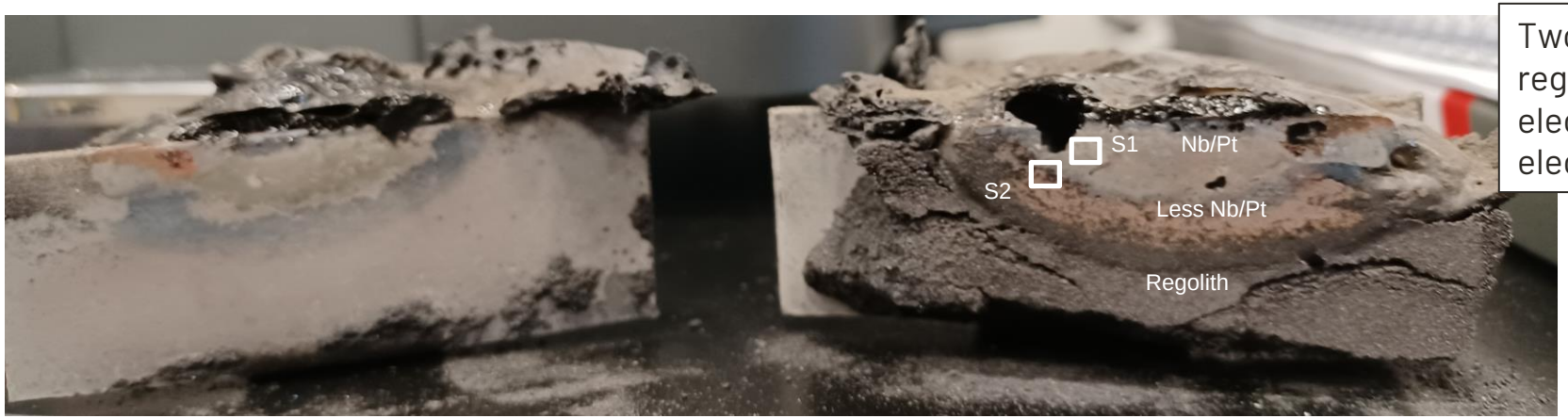
# Initial Results: Dynamic Power Behavior



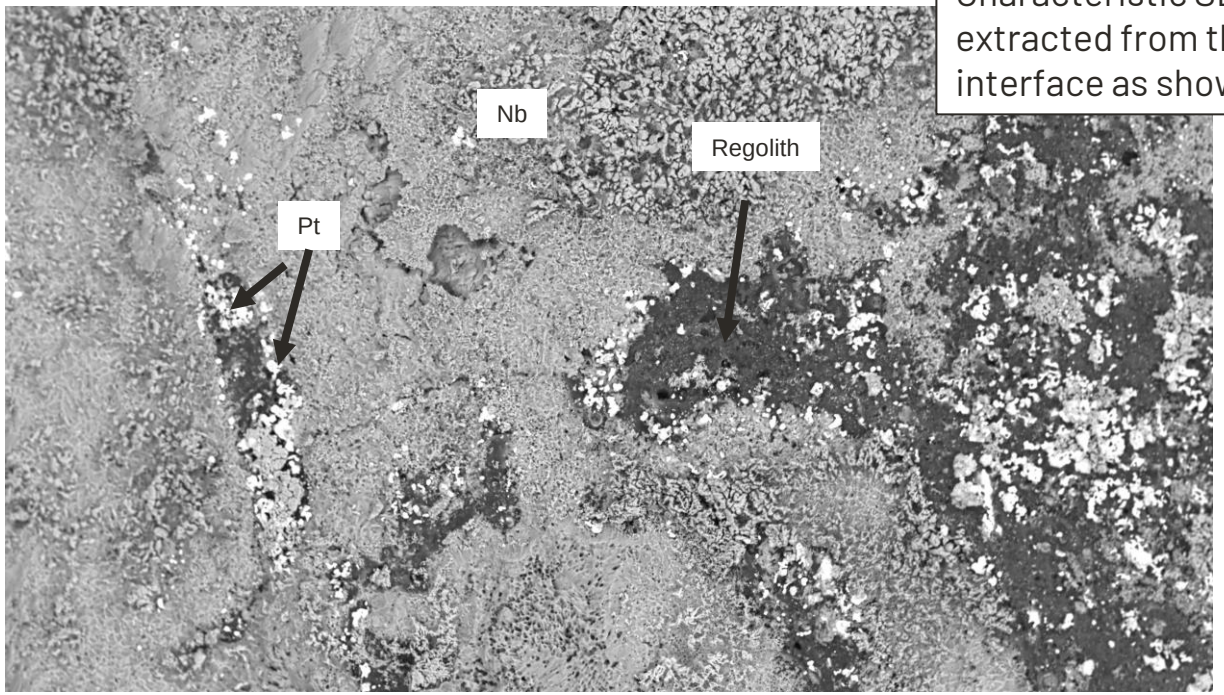



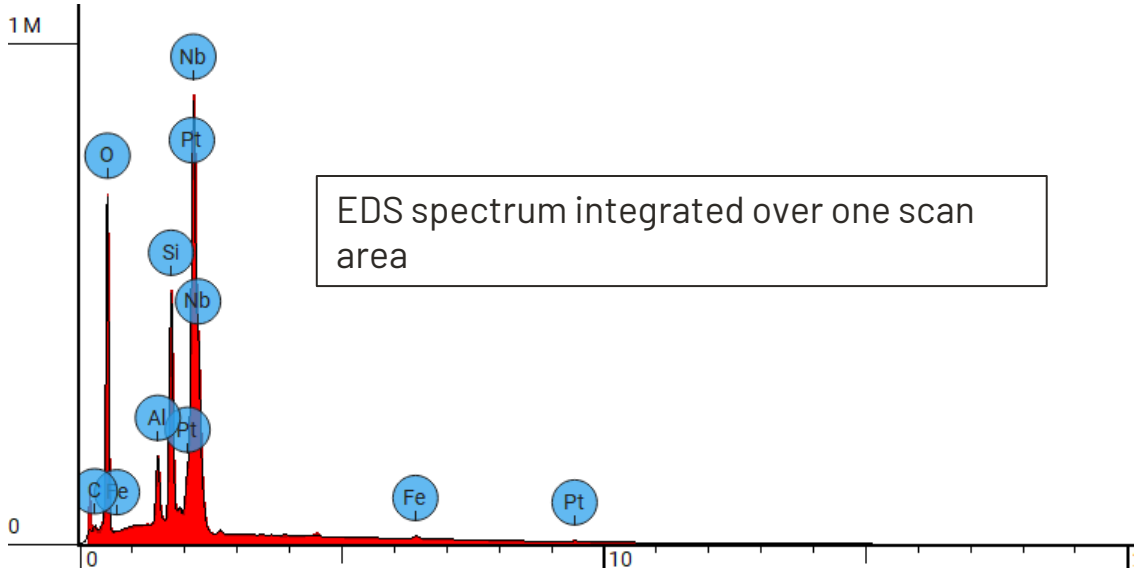




Two samples extracted from face of regolith which separated from the electrode (note, it is unknown which electrode was the cathode)



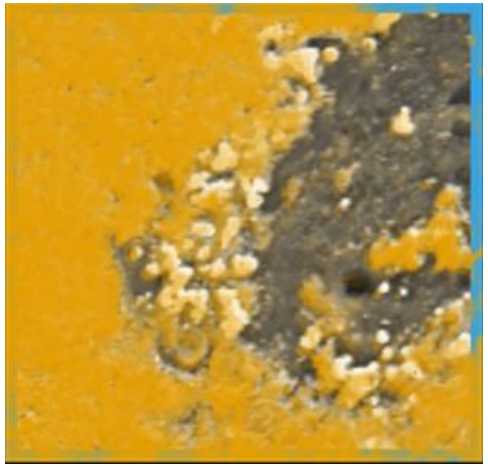

Characteristic SEM image of S1 and S2, extracted from the regolith/electrode interface as shown above



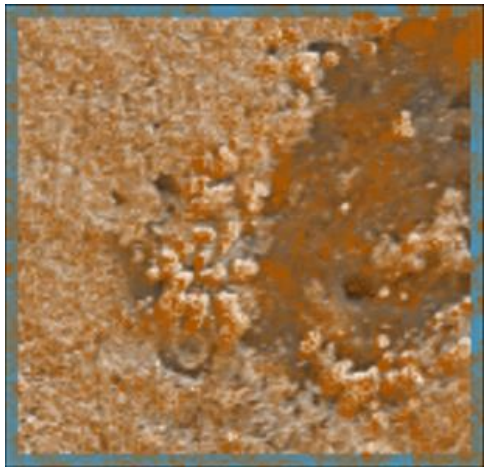

EDS spectrum integrated over one scan area

# SEM results

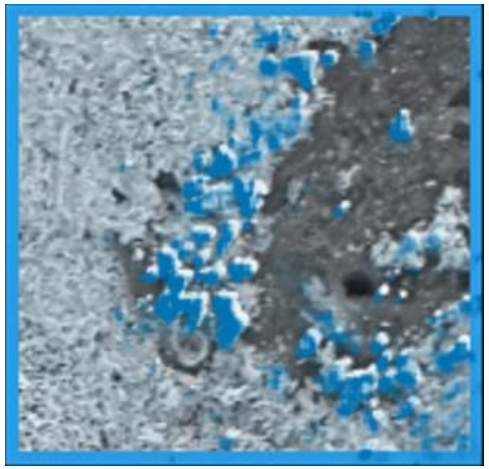
- Niobium is electrode, platinum is coating, the others are simulant.
- Spot shown is where molten simulant breached electrode.



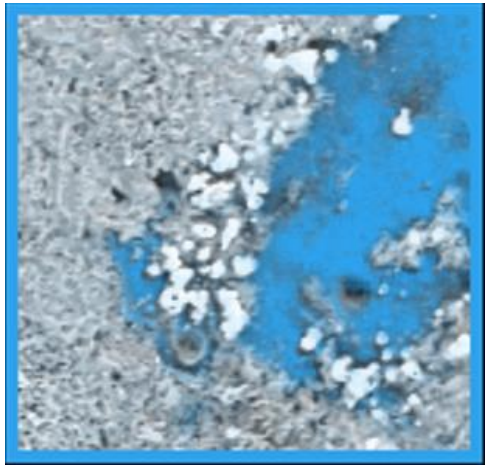
Niobium



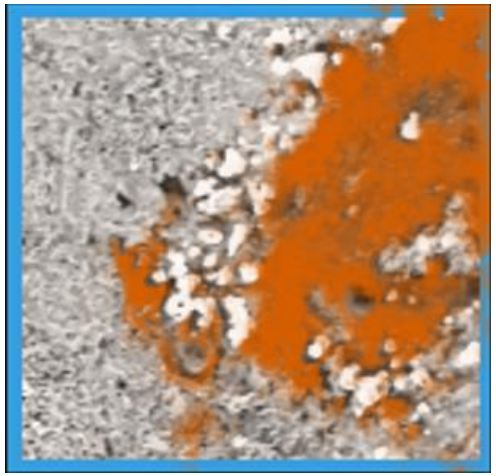
Iron



Platinum



Aluminum



Silicon

# Key Takeaways

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- Platinum separation from surface is obvious. Could be from poor plating or from stripping / alloying under melt.
- Apparent high incidence of platinum and iron together likely means platinum is alloying with iron.
- Silicon and aluminum completely overlapping as expected
- No reduced pockets of silicon or aluminum present.
- In the ~20 minute time frame of the test, the system is either not reaching steady state OR only the iron oxide is evolving its oxygen
  - Higher joule heating is likely necessary
  - Higher electrical current for electrolysis may also be necessary (though the two are linked in this case)

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# Potential Future Challenges of MRE

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- Necessity of Joule heating
- Poor density separation of molten material
- Intermediate alloys (ferrosilicon, eutectic silicon aluminum, etc)
- Small % shifts in materials changing electrochemistry
- Oxygen production blocking electrical paths
- Glass deposition on instruments
- Granular conveyance

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