GaLORE (Gaseous Lunar Oxygen from Regolith Electrolysis): Recent Technology Advances for a Cold-Walled Molten Regolith Electrolysis Reactor.

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MRE (Molten Regolith Electrolysis)

The MRE reactor design enables electrolysis of regolith into metal and oxygen without the need for fluxing agent, and without catalyst or consumable materials.

$$Regolith \rightarrow Metal + O_2$$

Produces oxygen and a ferrosilicon alloy, with other inclusions, that can be further processed. Operating temperature for MRE is set at (or above) 1600°C to keep regolith and metal products (ferrous alloys) in molten state.

Challenge: Containment materials fail in corrosive environment of molten metals, regolith and high temperature oxygen

Aim to demonstrate a "cold-walled" reactor design for molten regolith electrolysis, wherein regolith is melted locally between two electrodes.

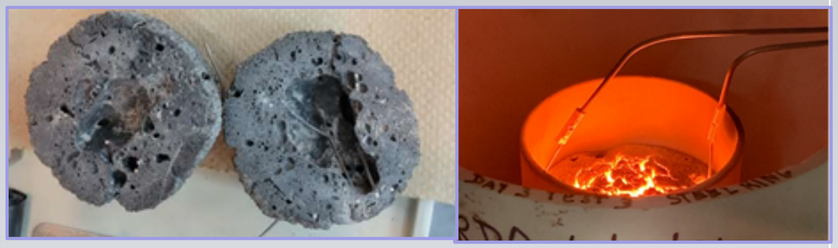
- Reduces corrosive interfaces between molten regolith and permanent components of the MRE reactor
- Reduces total power expenditure.

- **Phase 1: Test heater types, downselect**
  - Resistive heaters (KSC)
  - Solar simulator/concentrator (Honeybee Robotics)
  - Induction heating (RDO Induction, inc)
- **Phase 2: integrate selected heater type into electrolysis test cell**
  - Demonstrate cold-wall capability

Resistive Heating

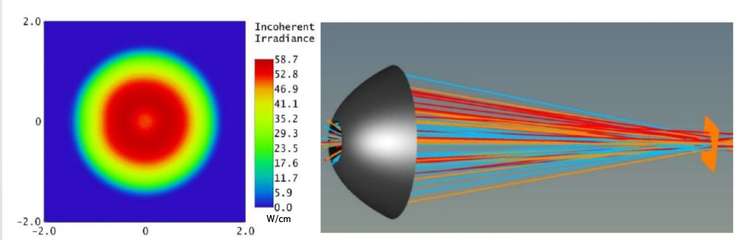
Bury resistive heaters capable of supplying 1 kW heat into bed of regolith. Performed under vacuum (<10 Torr)

- Ran heaters until failure
- Regolith formed glassy, porous region encased in sintered shell. (below)



Solar Simulator/Concentrator

6.5kW Xenon arc lamp with conical reflector irradiating surface of regolith bed with up to 1 kW power (below).

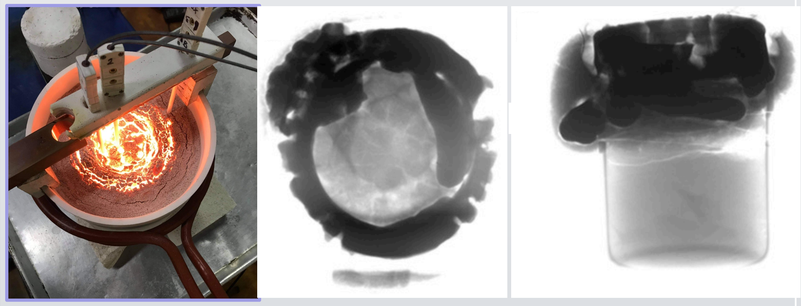


JSC-1A exposed to concentrated light for up to 10 minutes. Melting performed under vacuum (<100 mTorr) and at atmospheric pressure.

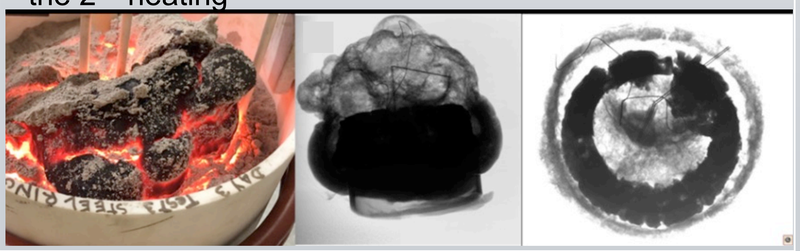
Under vacuum, regolith melted under concentrated light formed a very porous melt (above) that penetrated roughly 1cm into the surface of the regolith bed.
Testing under ambient condition formed a similar penetration depth but without large pores.

Induction Heating

10 cm diameter steel ring were placed 2cm deep in crucible of LHS-1 regolith and heated with an induction system capable of supplying 8 kW of power to an induction coil placed outside the crucible, coaxial and parallel to the tantalum disc. Heating occurred at ambient pressure and for 1 hour.



X-ray imaging of the produced melt (above) shows partial destruction of the steel and a solid mass of melt formed during heating.
Subsequent re-heating of the same sample under the same conditions formed a foamy crust of solid regolith on top unseen during the first melt, suggesting that the initial melt formed small pores that expanded during the 2nd heating



Electrolysis Test Cell

A test cell has been developed at KSC for a cold-walled reactor concept demonstration using an induction heating system directly on a 4 cm diameter electrode with an electrolysis circuit capable of supplying up 14 kW of power to the produced melt.