Sustainable Oxygen Extraction from Lunar Regolith via Molten Salt Electrolysis

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Space Resources Roundtable

02-05 June 2026

MAANA IN A NUTSHELL

Who we are

- Founded in 2018.
- Based in Luxembourg, LU
- 20+ employees
- Specialized in developing planetary surface assets for sustainable space exploration.
- Experienced in full design life cycle and in-house product development (concept, design, manufacturing, and testing), especially TRL 1 to 7.

Join my poster on Thursday 5 PM
Maana Electric's Technologies for Space Resource Utilization: A European Private-Sector Perspective

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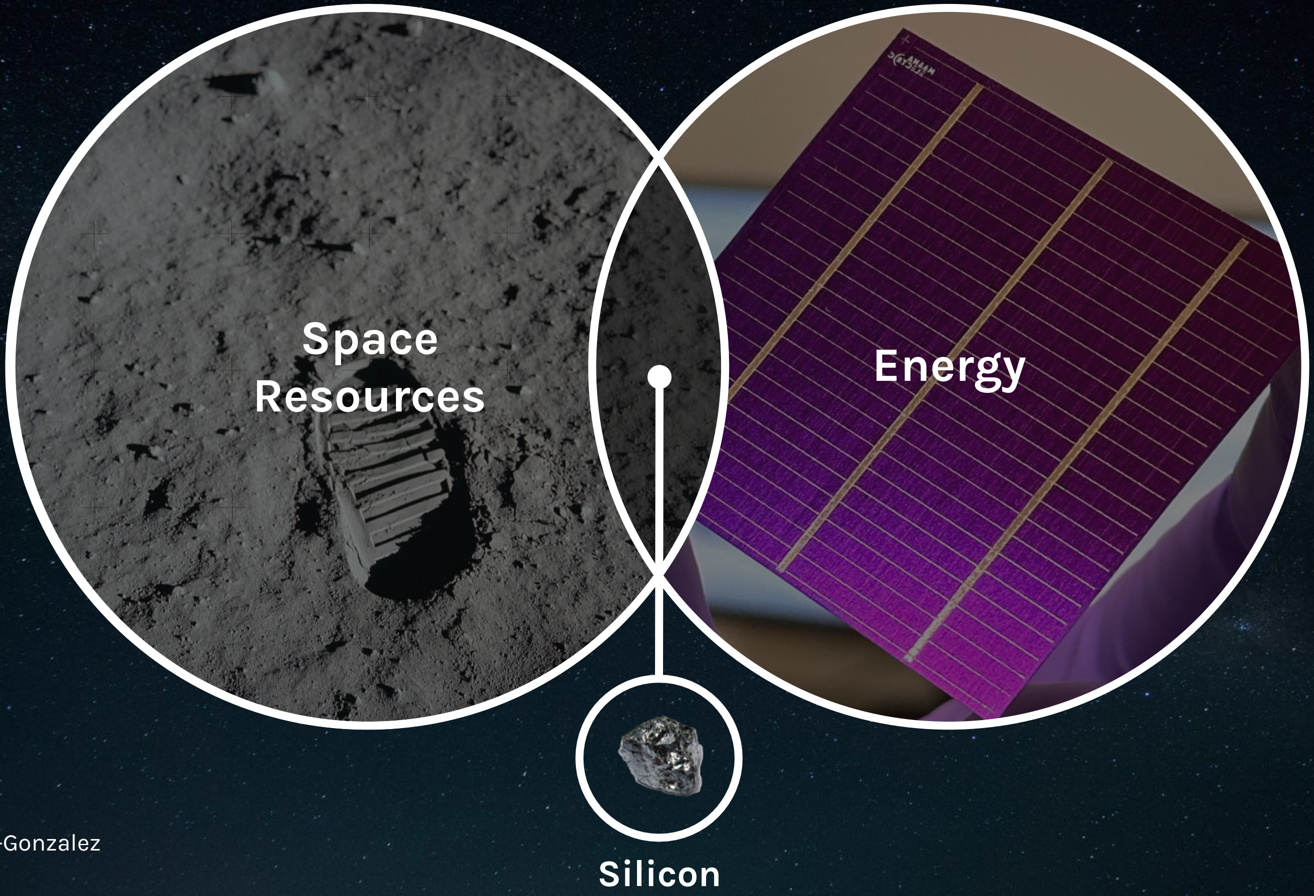
MAANA IN A NUTSHELL

At the intersection of energy and resource utilization



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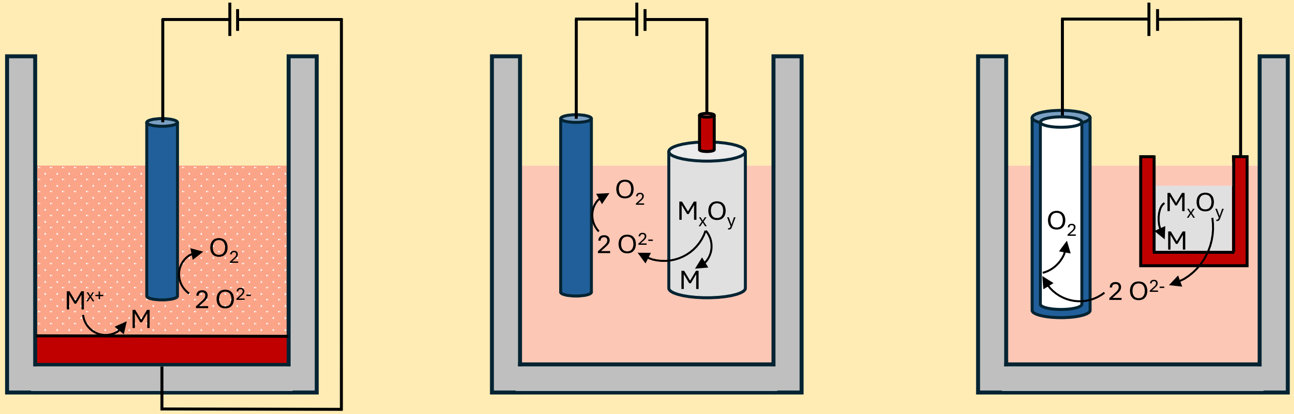
RESEARCH CONTEXT

Molten Salt Electrolysis (MSE)

Hall-Héroult style | FFC style | Hybrid style

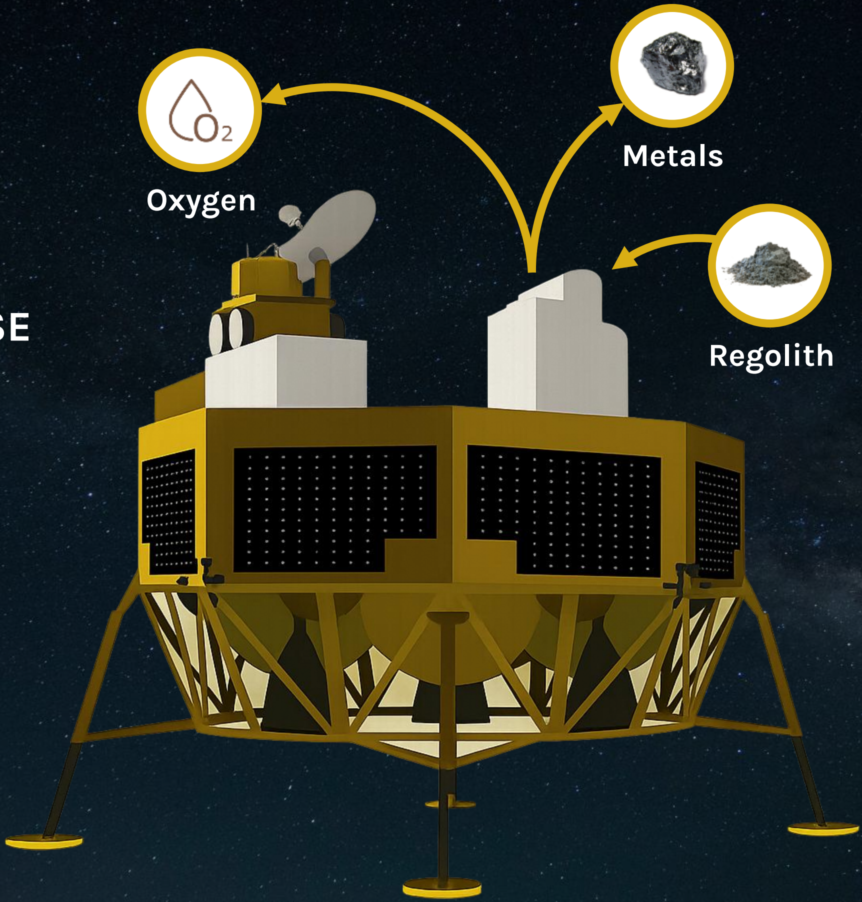


Hall-Héroult style	FFC style	Hybrid style
Molten **fluoride** salt	Molten **chloride** salt	Molten **fluoride** salt
Dissolved metal oxide	**Solid** metal oxide pellet/powder	**Solid** metal oxide

Guerrero-Gonzalez, F.J. et al. (2026). *Electrochemical processing of planetary regolith in molten salts – A review.* **Journal of the Electrochemical Society**, 173(7), 072502. DOI:10.1149/1945-7111/ae5420.

TECHNOLOGY DEVELOPMENTS

ISRU demonstration missions



Hall–Héroult-based MSE

SOURCE
technology maturation

FFC-based MSE

ISRU-DM
breadboarding activity

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GREEN SILICON

Production of Si from low-value feedstock

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GREEN SILICON

Production of Si from low-value feedstock

PATENT-PENDING PROCESS

Feedstock

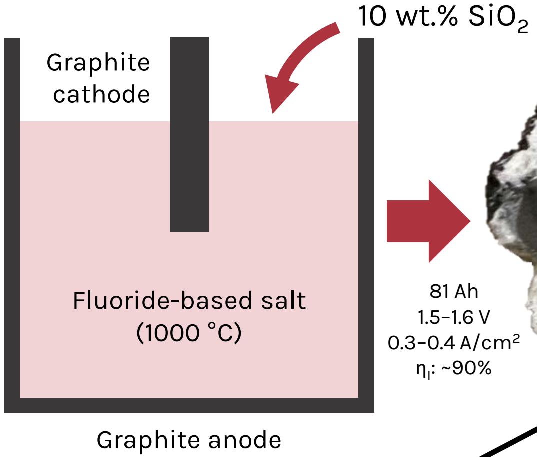
High-purity SiO_2 (>98%)

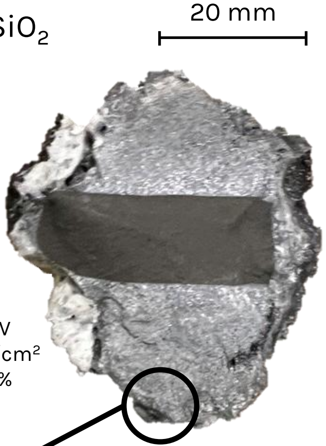
Molten Salt Electrolysis

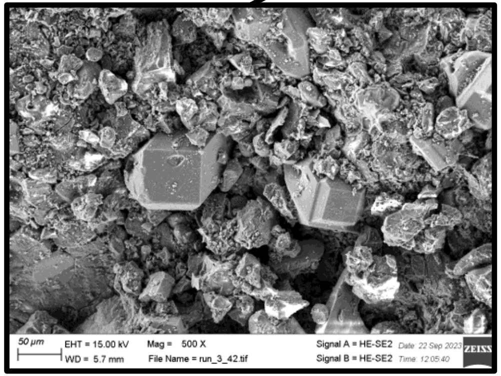
Porous silicon deposit

Product

Metallurgical-grade silicon (>99.9%)







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ROADMAP

Translating technologies from Earth to space

- ► Process maturation for silicon and O_2 from lunar regolith.
  Luxembourg National Research Fund (2023-2026)

- ► Technology demonstration in relevant environment (TRL 5).
  esric esa BSGN SPACE RESOURCES ACCELERATOR (2026-2027)

- ► Demonstration mission: 50 g of silicon and O_2 on the Moon.
  (2029+)

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CLOSING GAPS

Translating technologies from Earth to space

IDENTIFY SUITABLE OXYGEN-EVOLVING ANODES

EXTEND ELECTROLYTE LIFETIME

ELECTROLYTE LIFETIME

Bath poisoning

- Electrolytes shall allow for the reduction of all minerals present in lunar regolith before decomposing themselves.
- Alkaline earth metals (Ca, Mg) are the hardest to reduce.
- CaF_2 could reduce all lunar regolith compounds, preventing bath poisoning.
- CaF_2 melting point is high (1418 °C).

Average elemental composition of Highland regolith (Stoeser et al., 2010).

	Highland (wt.%)
O	44.6
Si	21.0
Al	13.3
Ca	10.7
Fe	4.9
Mg	4.6
Ti	0.3
Other	0.6

Mainly from anorthosite → Ca

Mainly from pyroxenes & olivines → Mg

Melting point of fluoride-based salts. Eutectic binary and ternary mixtures.

	Melting point
CaF_2	**1418 °C**
LiF-CaF_2	770 °C
LiF-NaF	649 °C
LiF-KF	493 °C
FLiNaK	454 °C

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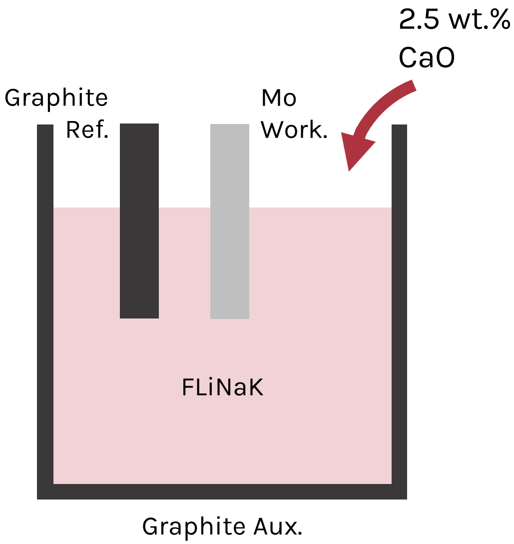
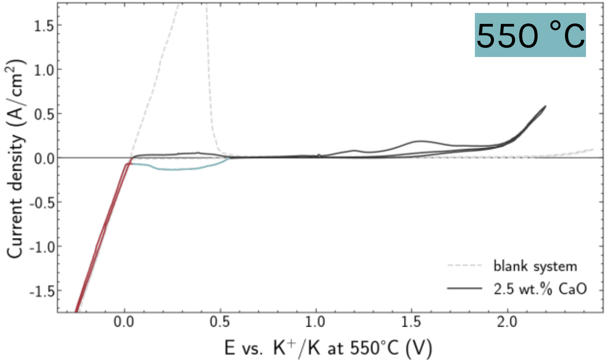
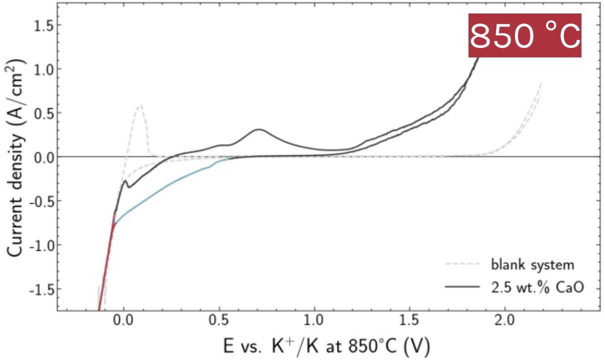
ELECTROLYTE LIFETIME

Reduction behavior of Ca^{2+} in FLiNaK

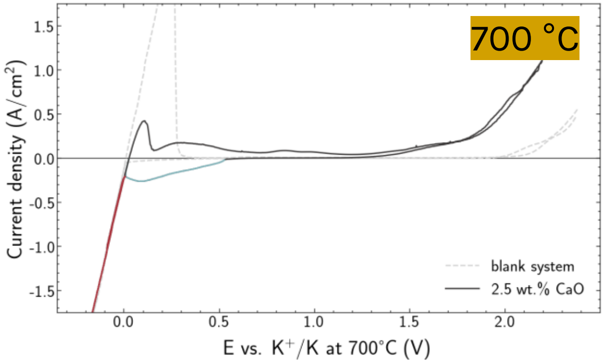


Cyclic voltammograms of FLiNaK-CaO (2.5 wt.%) on Mo electrode at 100 mV/s





- K signal
- Ca signal



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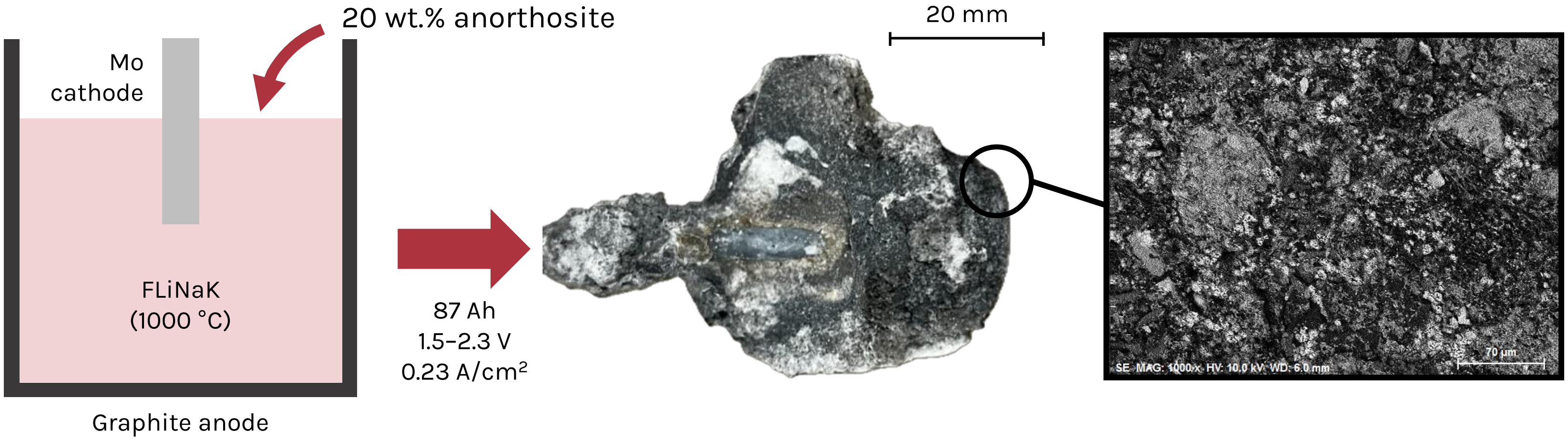
SELECTIVE SILICON DEPOSITION

Reduction of lunar anorthosite simulant in FLiNaK



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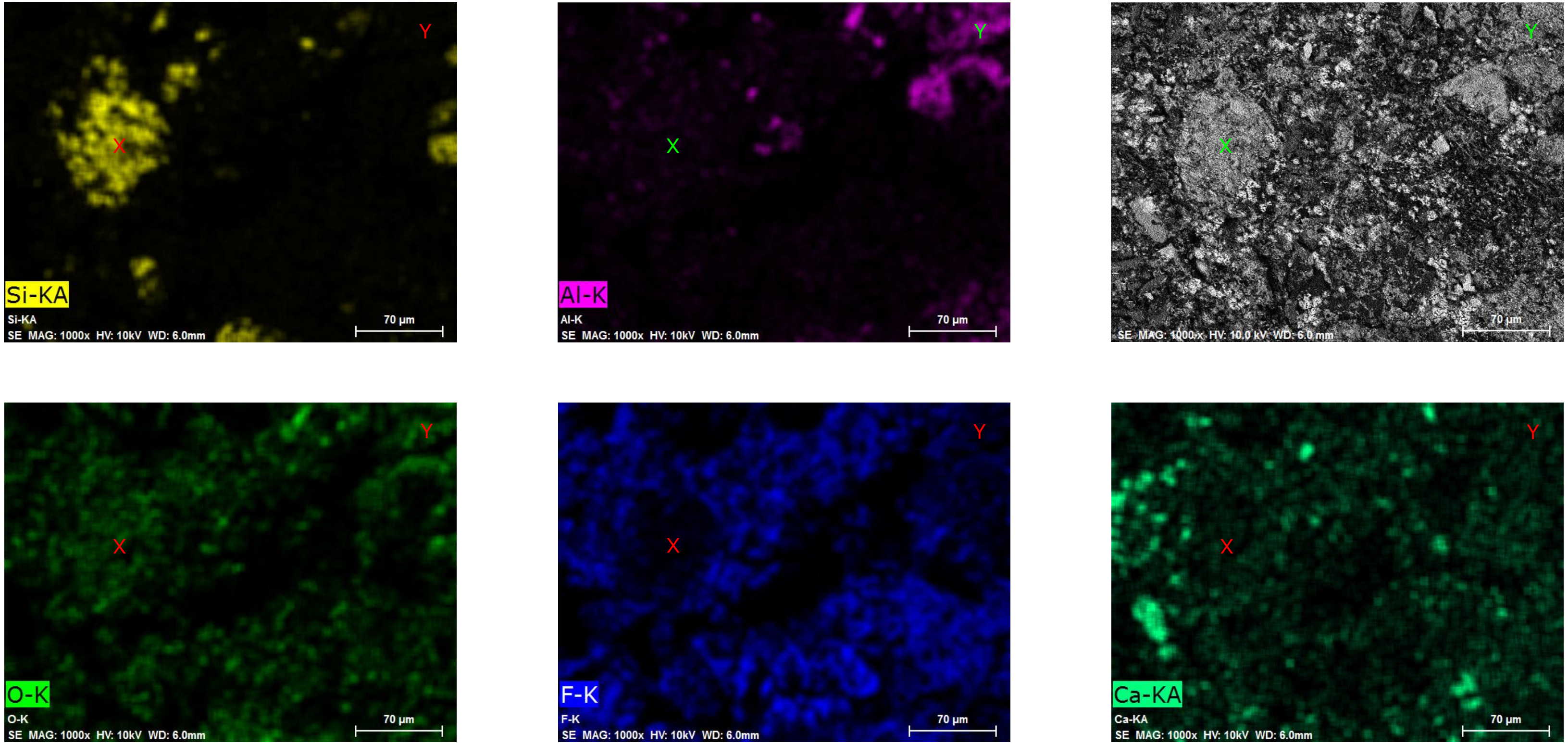

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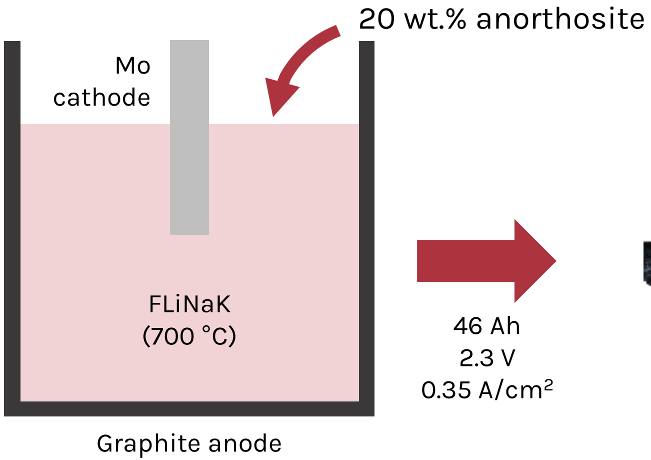
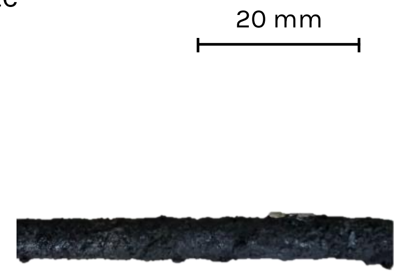
SELECTIVE SILICON DEPOSITION

Role of temperature: 700 °C



46 Ah
2.3 V
0.35 A/cm²



Volatile Si(II) species
Partial Si(IV) → Si(II) reduction

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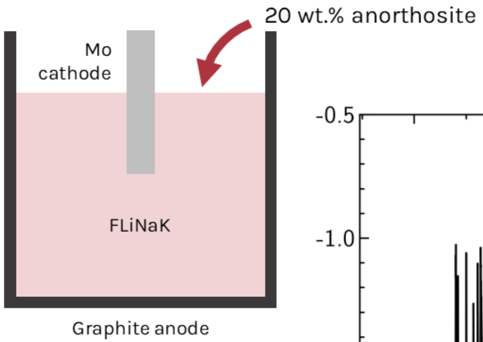
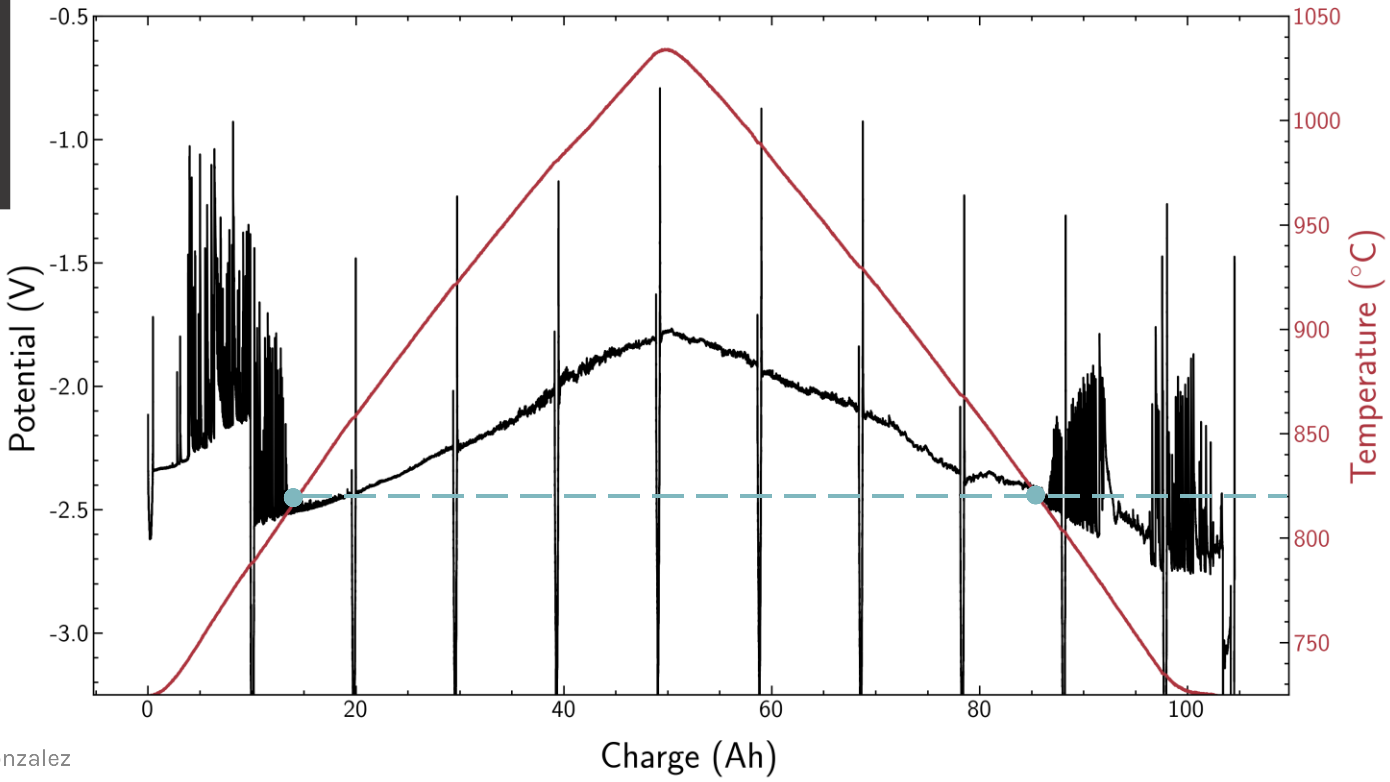
SELECTIVE SILICON DEPOSITION

Role of temperature: From 700 °C to 1000 °C and back





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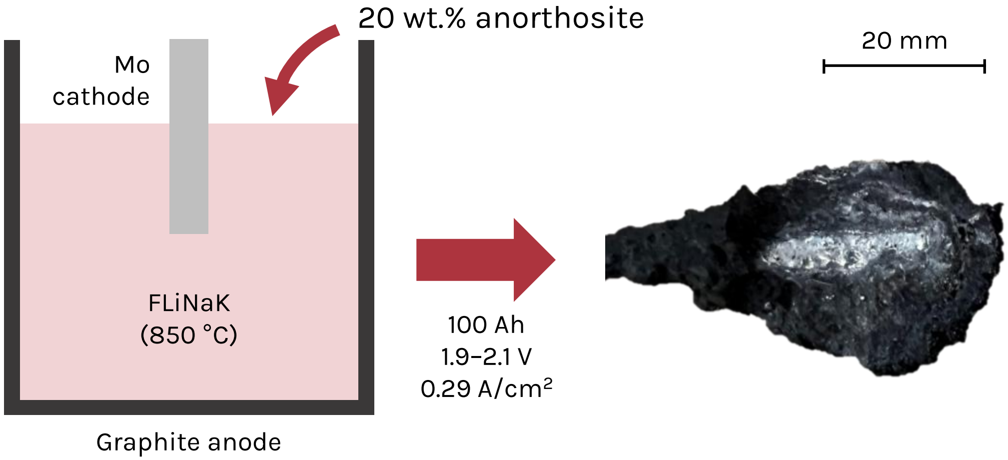
SELECTIVE SILICON DEPOSITION

Role of temperature: 850 °C



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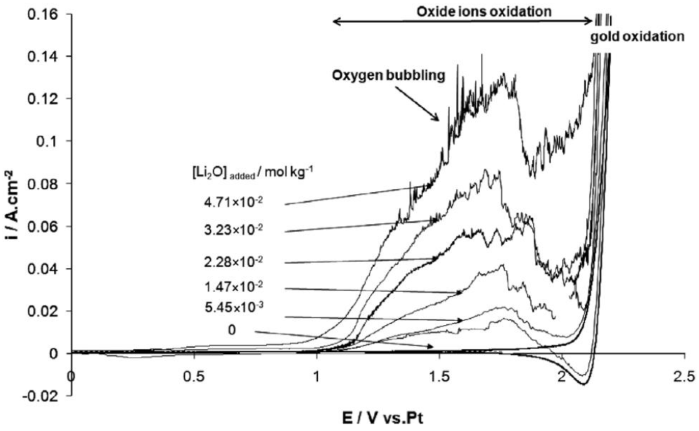
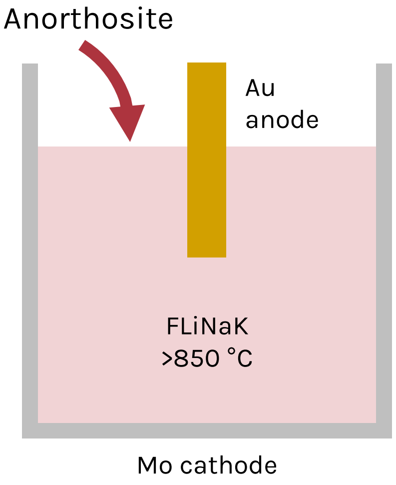
ANODIC OXYGEN EVOLUTION

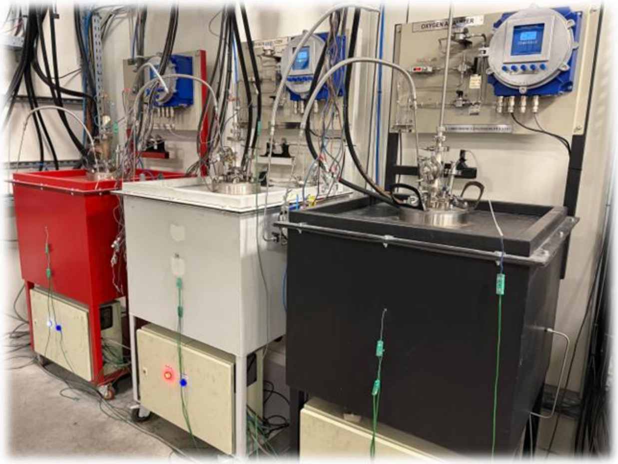
Gold as candidate electrode material

- The principal pathway for anodic chemical corrosion in fluoride melts is *dissolution of oxidized anode material in the melt* (Guerrero-Gonzalez et al. 2026)
- Gold oxides are thermally unstable >227 °C, allowing O_2 evolution
- Gold melting point is low (1064 °C).



Cyclic voltammograms of LiF-NaF-Li_2O on Au electrode at 100 mV/s and 800 °C (Massot et al., 2007)





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OUTLOOK

Sustainable Oxygen Extraction from Lunar Regolith via MSE

- **Calcium can be reduced in FLiNaK** at different temperatures, preventing bath poisoning in the long term.
- **Low-temperature electrolysis** at 850 °C allows reduction of lunar anorthosite simulants into metals. However, higher temperatures result in better products.
- **Selective deposition of silicon** without aluminum co-deposition in FLiNaK has been proven.
- **Current work** is tackling:
  - Oxygen-evolving gold anode testing at >850 °C.
  - Evaluation of alternative candidate materials for increased operational temperature.

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