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Abstract

Title: Advances in Molten Oxide Electrolysis for the Production of Oxygen and Metals from Lunar Regolith

Authors: Donald Sadoway, Laurent Sibille, Aislinn Sirk, Orlando Melendez, Peter Curreri, Dale Lueck, Jesus Dominguez, Jonathan Whitlow

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In the light of this information and in consideration of available electrolytic technologies, the authors have determined that direct molten oxide electrolysis at temperatures of ~1600 °C is the most promising avenue for further development. Results from ongoing studies as well as those of previous workers will be presented. Topics include materials selection and testing, electrode stability, gas capture and analysis, and cell operation during feeding and tapping.

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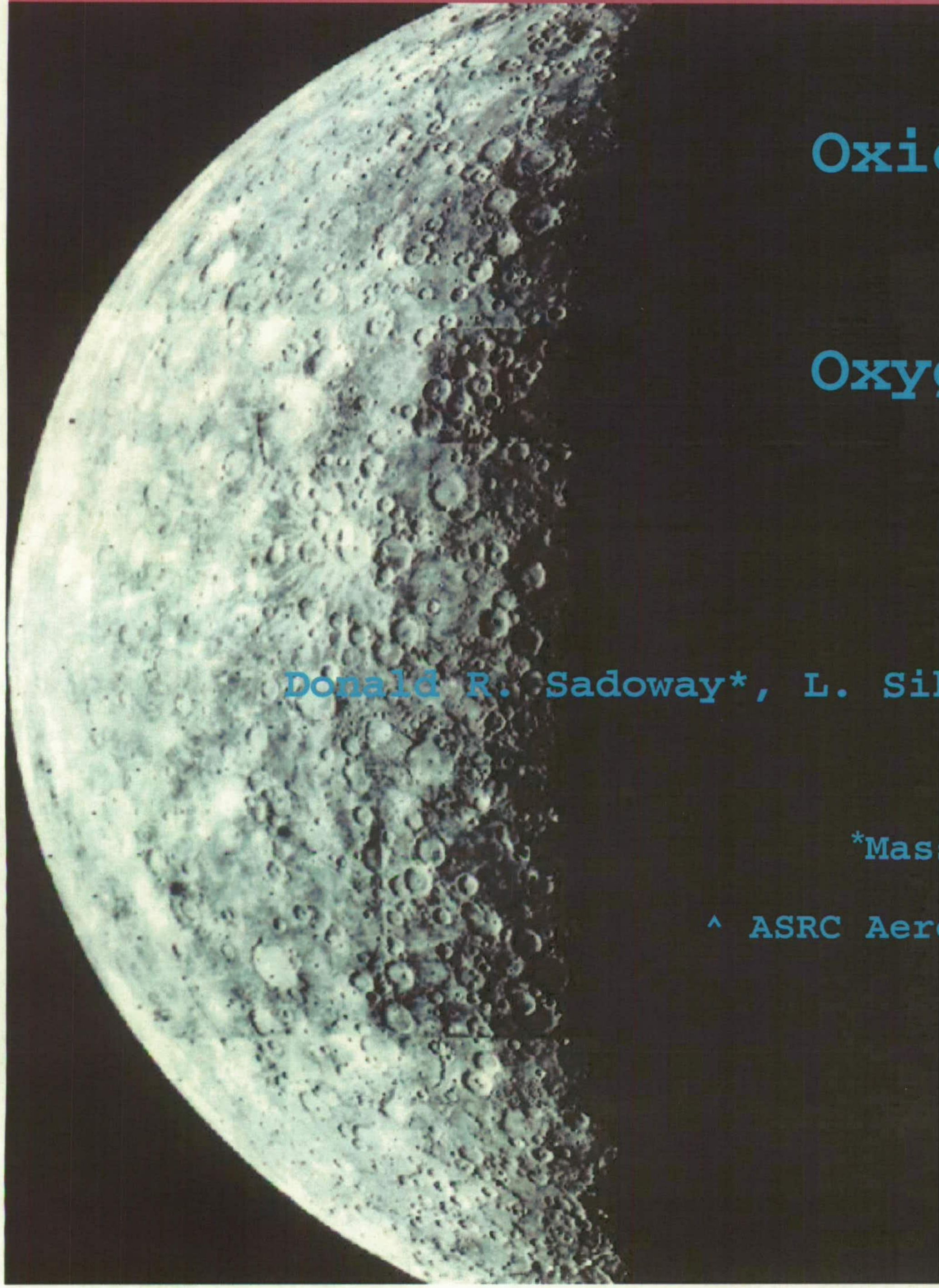


Advances in Molten Oxide Electrolysis for the Production of Oxygen and Metals from Lunar Regolith

Donald R. Sadoway*, L. Sibille^, A. Sirk*, O. Melendez[◊], D. Lueck[◊], P. Curreri[°]

*Massachusetts Institute of Technology

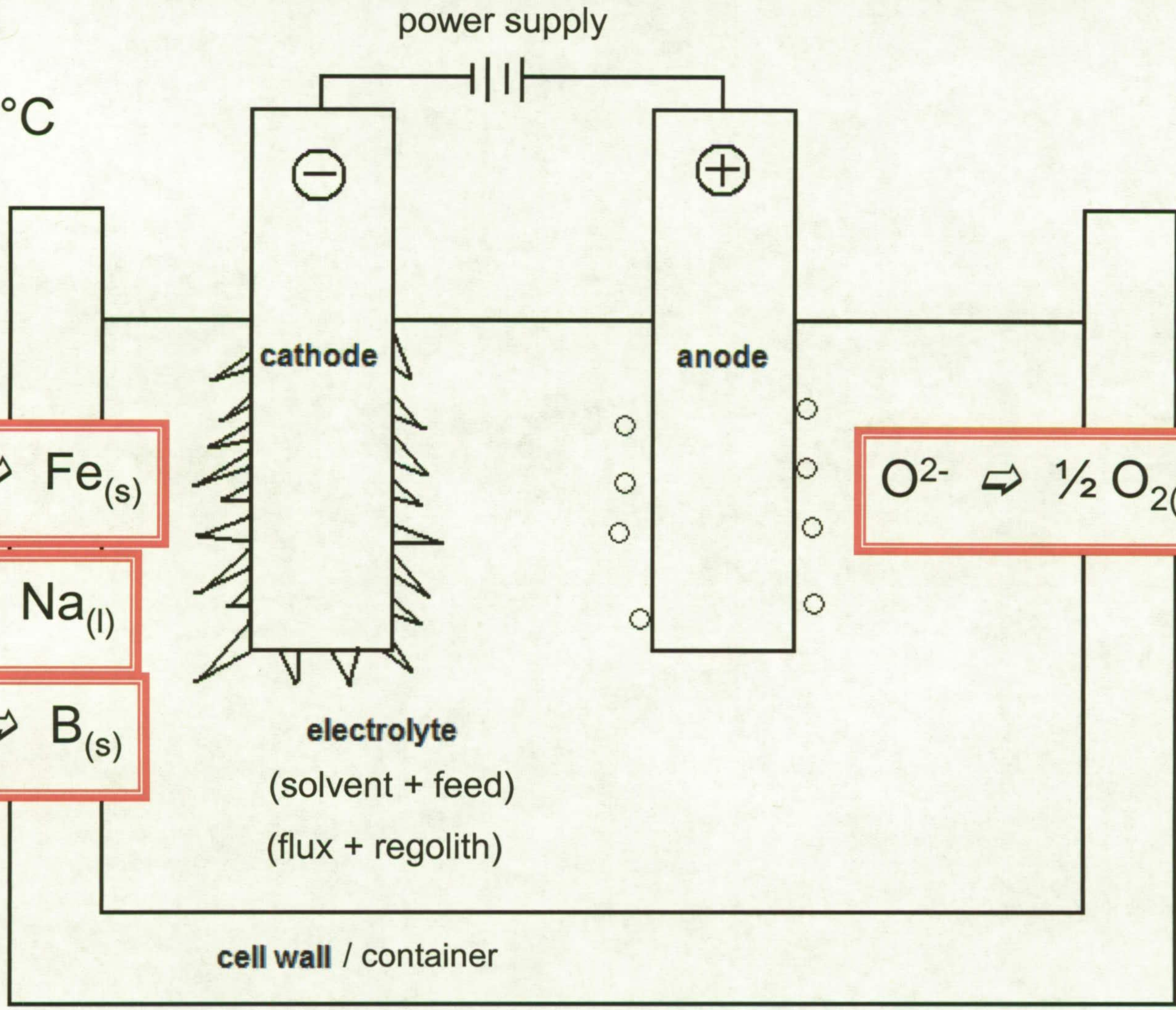
^ ASRC Aerospace Corp., Kennedy Space Center

[◊]NASA Kennedy Space Center

[°]NASA Marshall Space Flight Center

Fluxed Molten Oxides

T ≈ 1600°C



$Fe^{2+} + 2e \Rightarrow Fe_{(s)}$

$Na^{+} + e \Rightarrow Na_{(l)}$

$B^{3+} + 3e \Rightarrow B_{(s)}$

$O^{2-} \Rightarrow \frac{1}{2} O_{2(g)} + 2e$

perating parameters / figures of meri

- electrolyte chemistry: regolith + flux
- cell feed: regolith
- temperature: 850°
- electrode material: Ir anode; Mo cathode
- current density: 2 A cm^{-2}
- crucible material: Mo, carbon
- current efficiency: 80%
- voltage efficiency: 50%
- specific energy: 16 kWh/kg = 58 MJ/kg

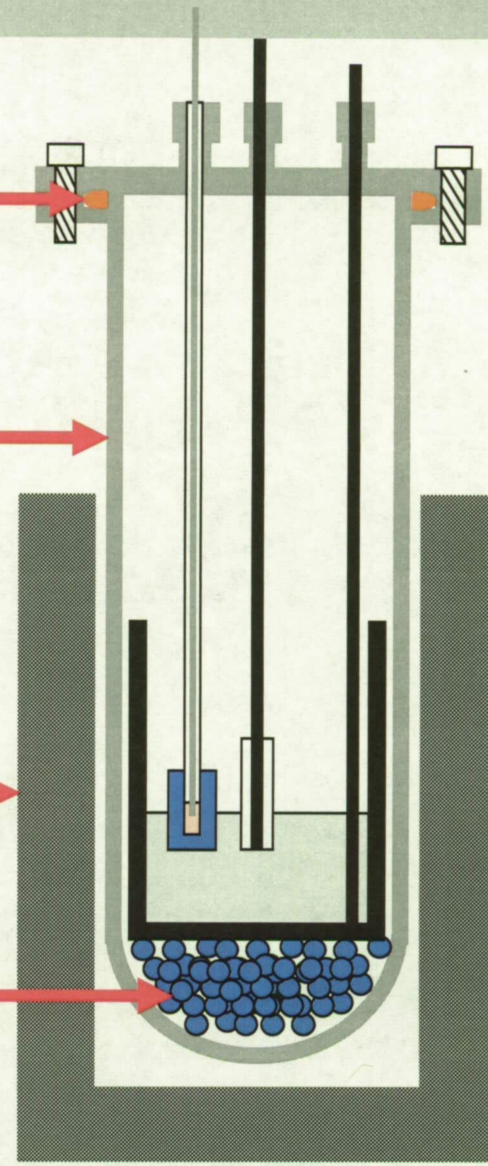
previous work at MIT

Viton O-ring

60 mm ø alumina crucible

tube furnace

alumina beads



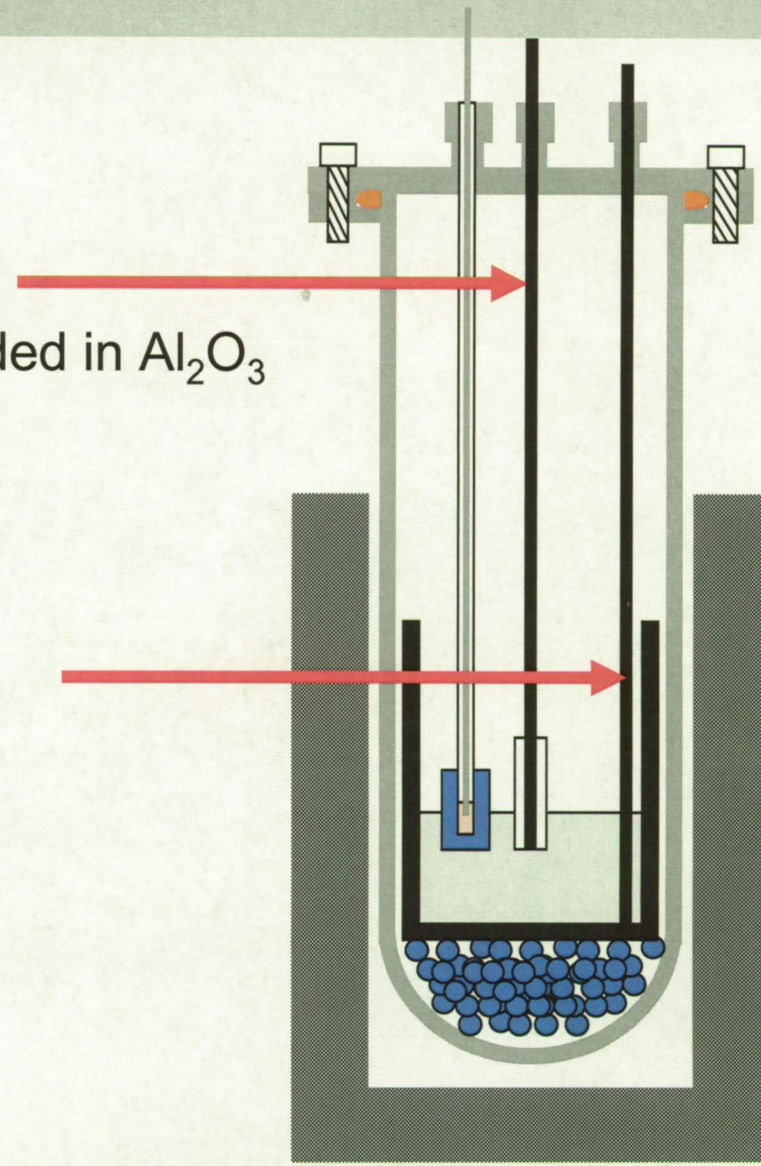
cell design

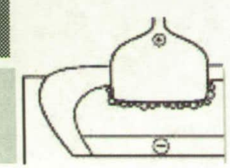
working electrode

- graphite, Ni, or Pt shrouded in Al_2O_3
- 6 mm ø planar

counter electrode

- carbon crucible
- graphite rod contact

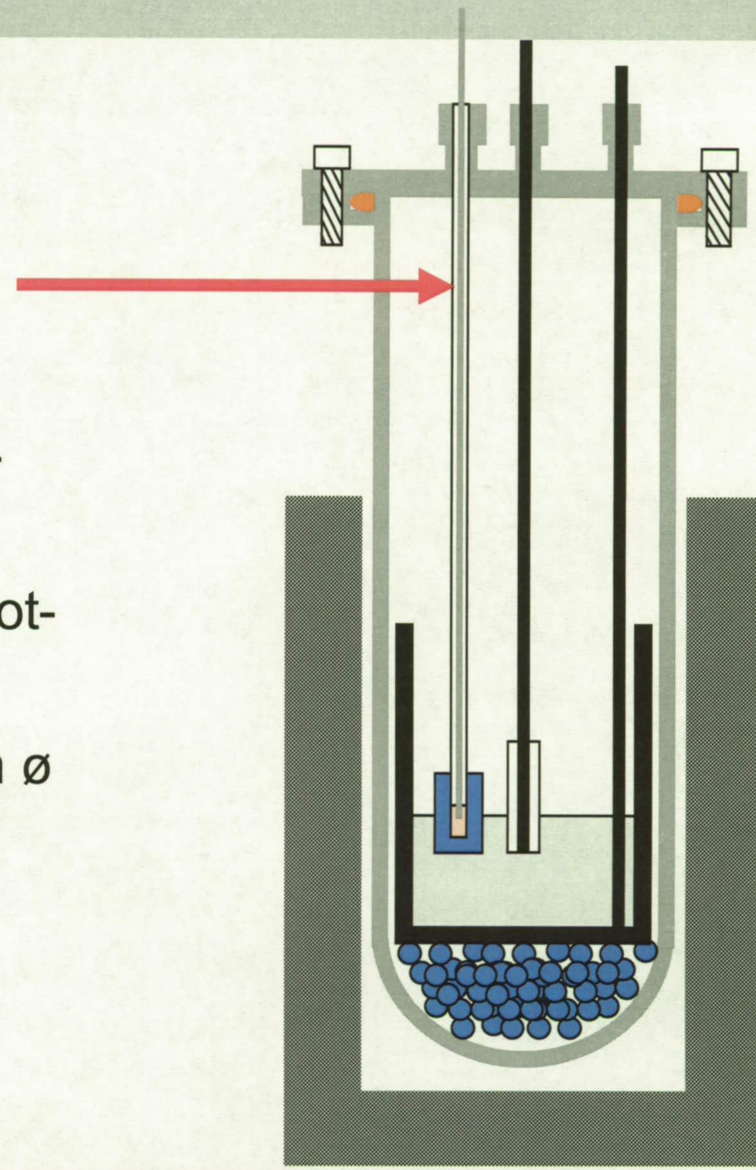




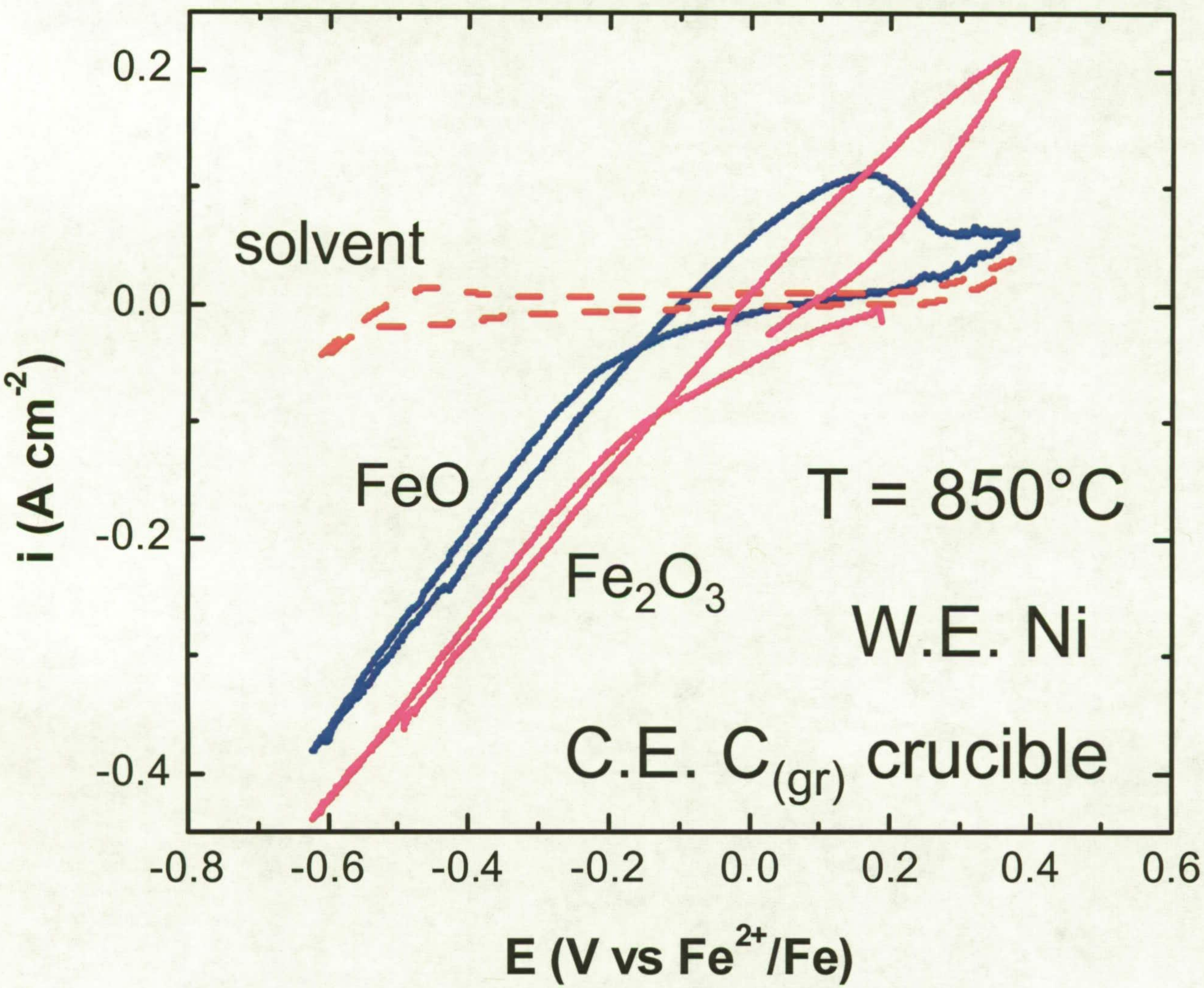
cell design

reference electrode

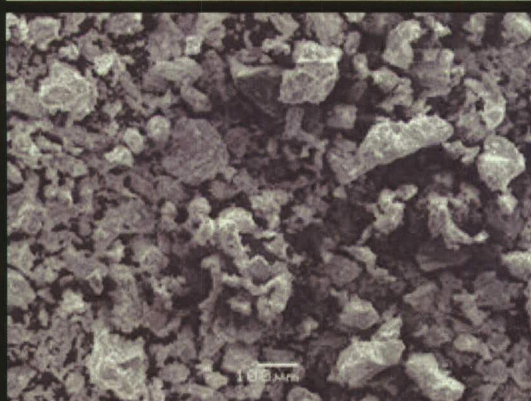
- Fe^{2+}/Fe couple
- Fe rod in melt of 10% FeO - supporting electrolyte
- alumina tube capped with hot-pressed BN
- contact via drill hole 0.4 mm ø

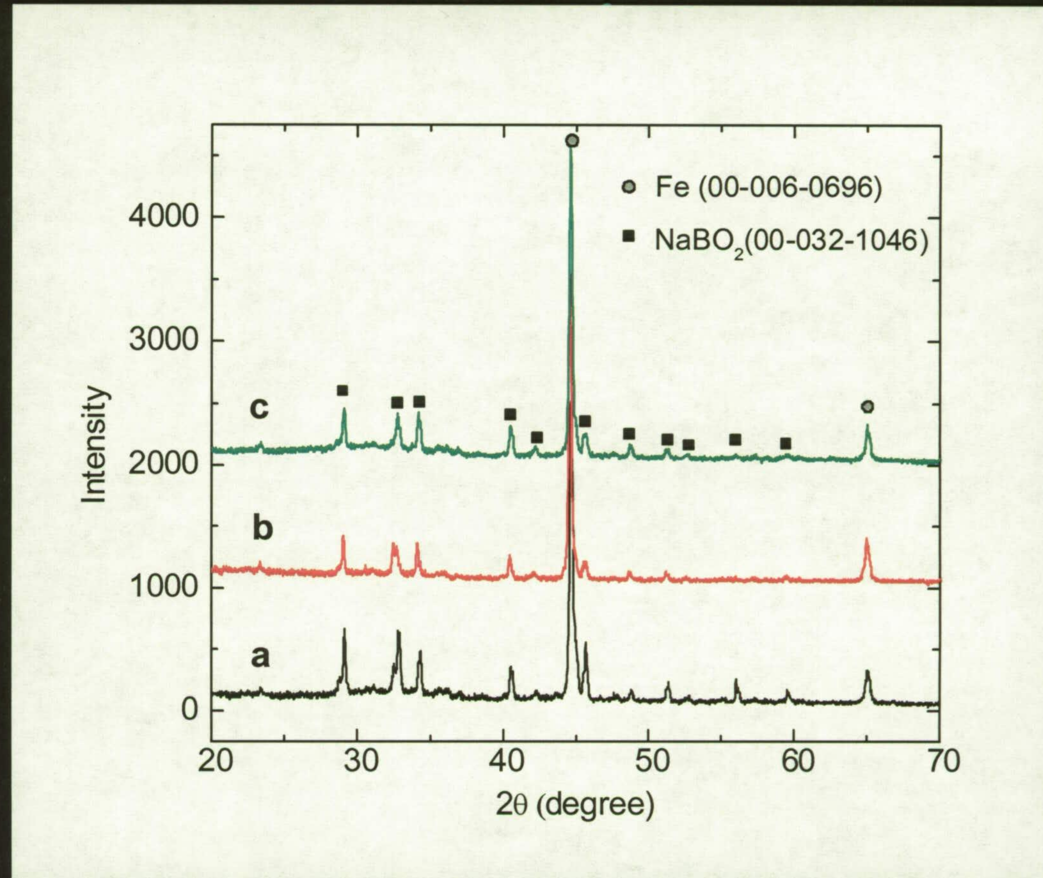


cyclic voltammetry of surrogate me



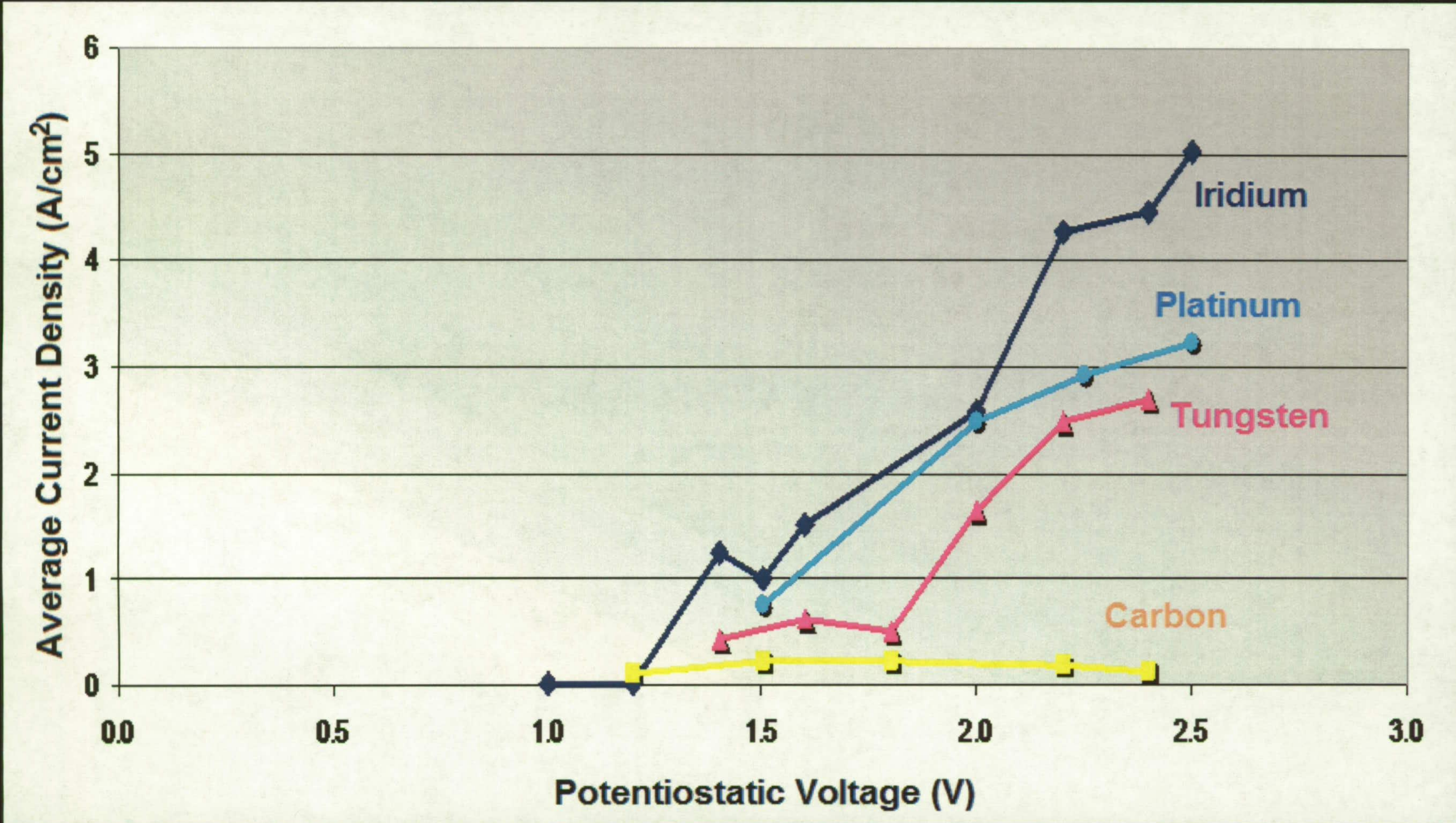
potentiostatic electrolysis at

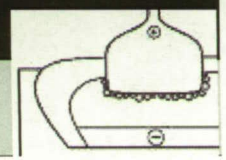




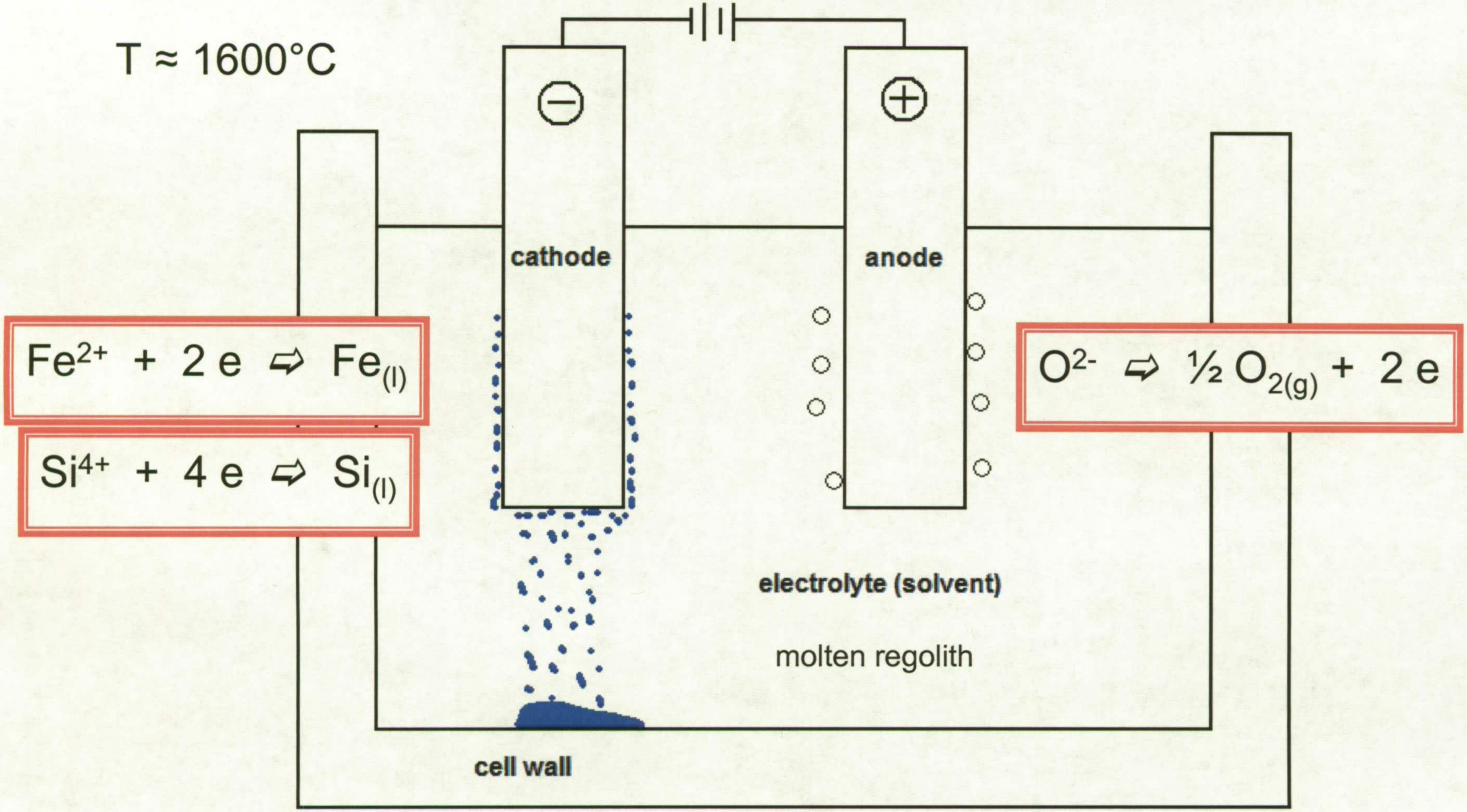
current efficiency: ~80%

testing candidate anodes in fluxed oxide bath





Molten Oxide Electrolysis



Electrolysis of JSC-1a on Mo electrodes

Working electrode: Mo rod

Reference electrode: Fe rod

Counter electrode: Mo rod

Electrolyte: JSC-1a

Container: MgO crucible

Temperature: ~1350°C

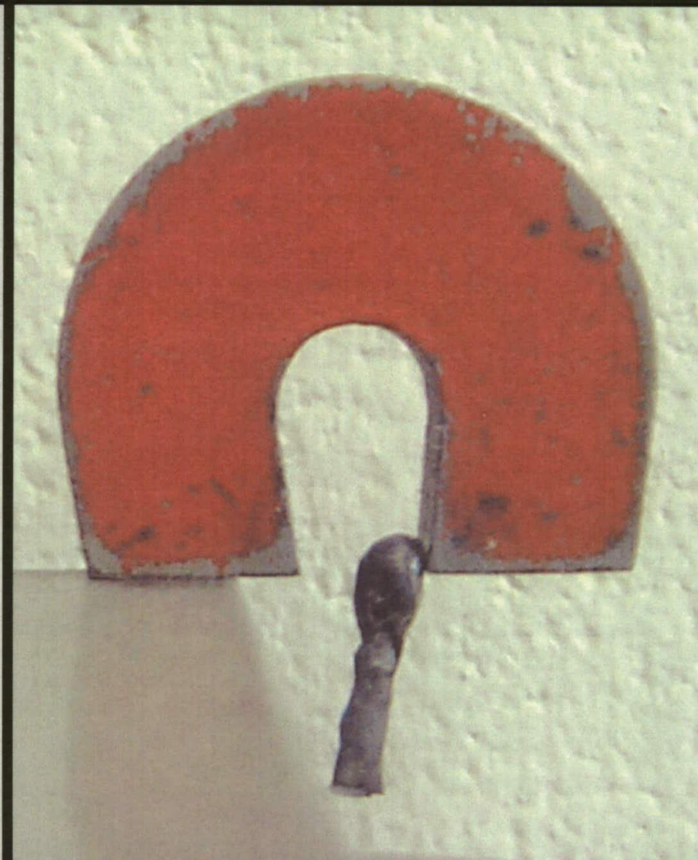
Instrument: PARSTAT with PowerCV, PowerStep and PowerCorr software

Heat source: carbon tube furnace

CE RE WE MgO crucible

As received cathode after electrolysis

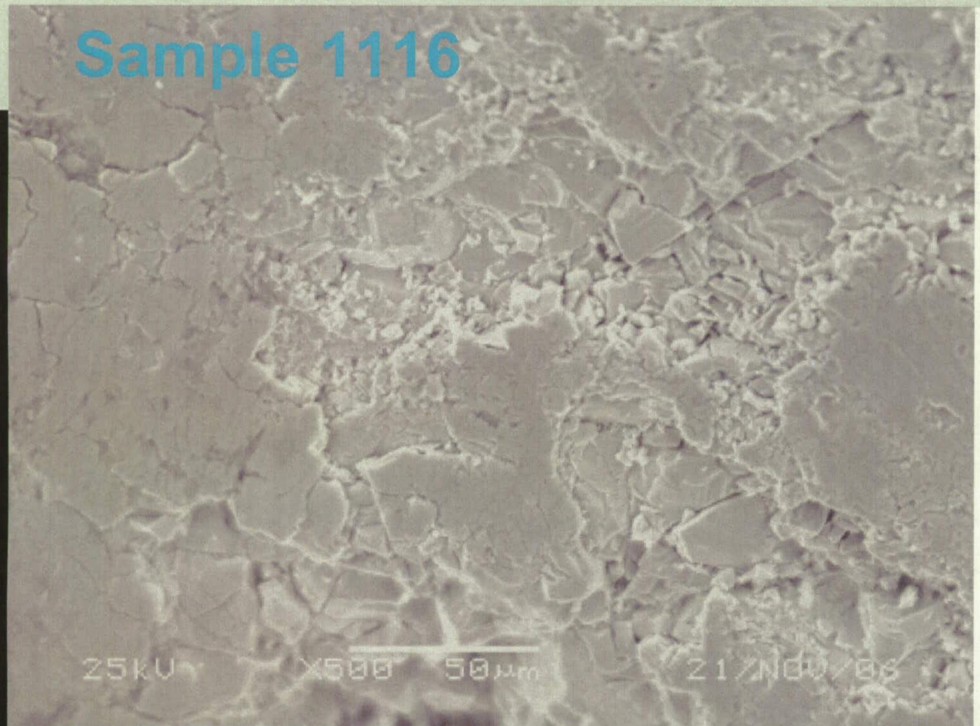
Cathode after removing the slag layer

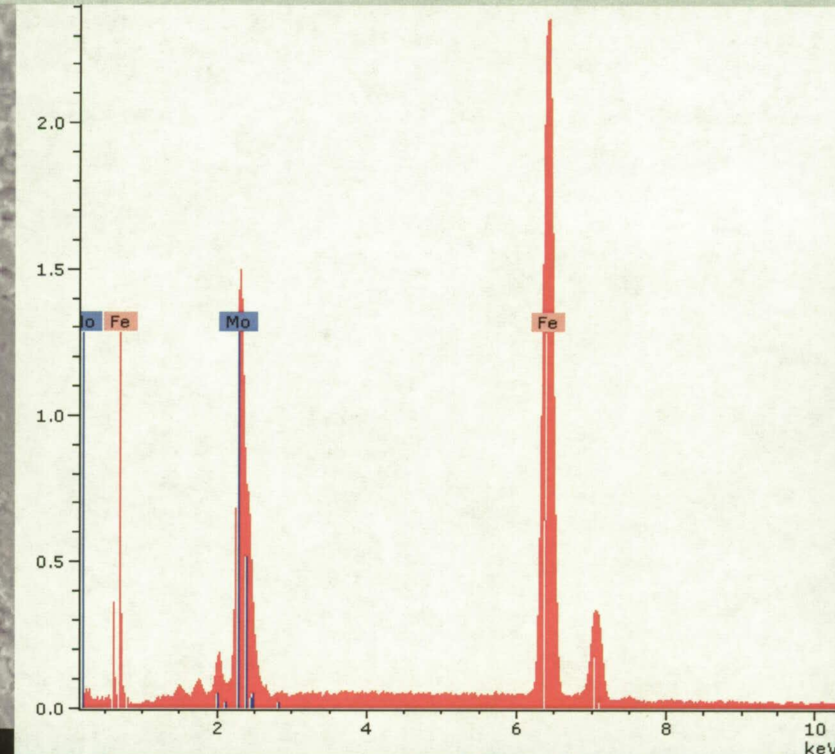


The product with Mo rod held by a magnetic vertically

Cross section of the cathode

cathodic product (Mo anode, Mo cathode)

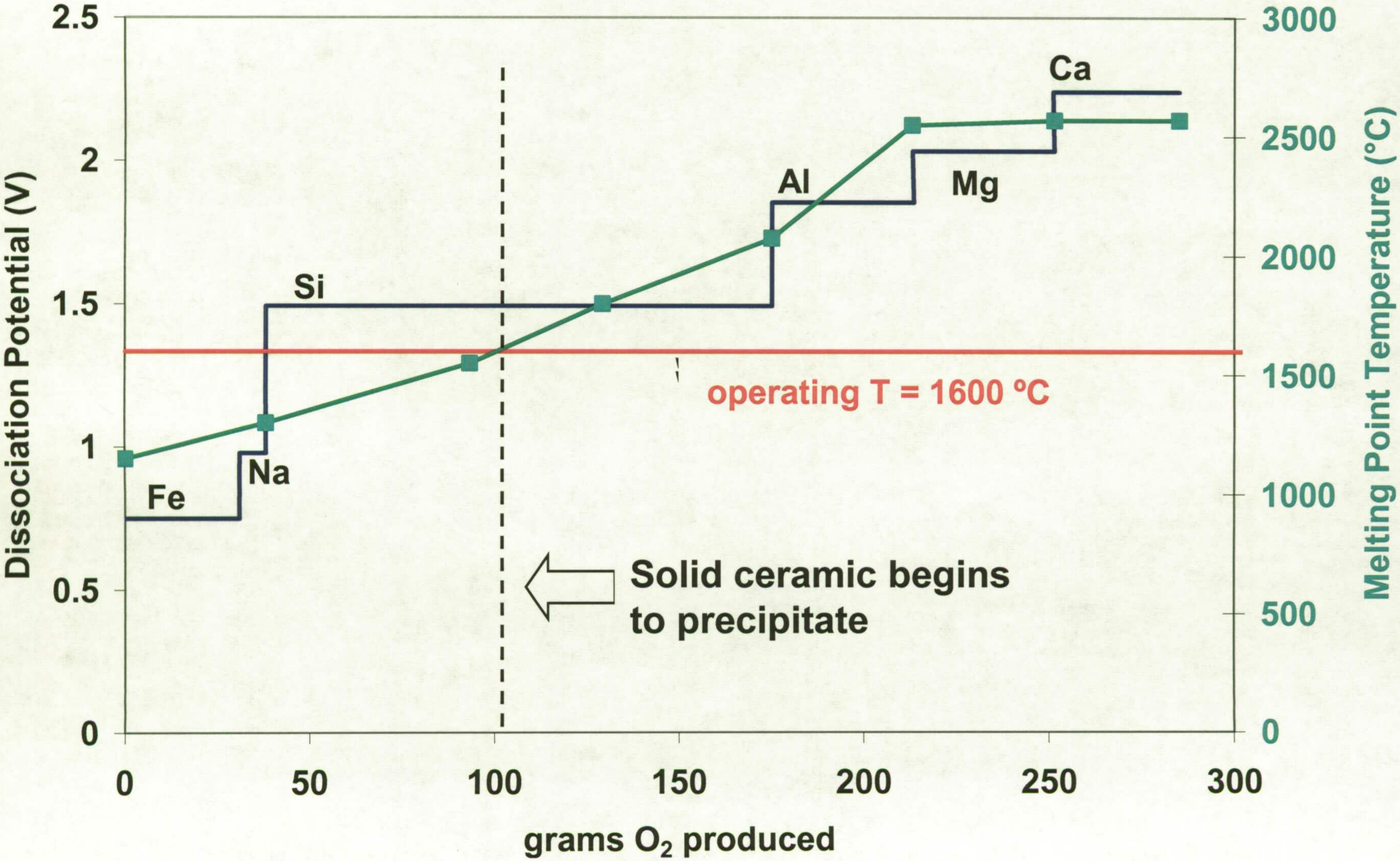




SEM and EDS confirmed iron deposition

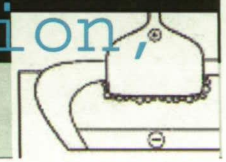
Element	Series	unn. C [wt.-%]	norm. C [wt.-%]	Atom. C [at.-%]
Iron	K-series	59.92	57.74	70.12
Molybdenum	L-series	43.86	42.26	29.88

variation in electrolyte solidification temperature under galvanostatic electrolysis



status report

- MOE works at the lab scale
- production of oxygen repeatedly verified
- much to be learned by analogy with Al smelting
- capacity for metal & semiconductor extraction
- technical questions remain: electrode life, separation of cell products, management of electrolyte composition, start-up, thermal management



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Donald R. Sadoway
L. Sibille
A. Sirk
O. Melendez
D. Lueck
P. Curreri

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ASRC Aerospace
ASRC-24
Kennedy Space Center, FL 32899

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14. ABSTRACT
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15. SUBJECT TERMS
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				15	19b. TELEPHONE NUMBER *(Include area code)* (321) 867-4422