

# **From Oxygen Generation to Metals Production: *in situ* Resource Utilization by Molten Oxide Electrolysis**

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# Why molten oxide electrolysis?

most metals are found in nature as oxides

“like dissolves like”

☞ **molten oxide electrolysis:**

extreme form of molten salt electrolysis  
where pure **oxygen** gas is by-product



# Relationship to ISRU



lunar regolith is a multicomponent silicate rich in **iron** and **titanium**.

☞ breathable oxygen and propellant?

☹ ferrites and titanates are liquid semiconductors

# Technical obstacles: unknowns

- ❑ composition of the electrolyte
- ❑ composition of the electrodes
- ❑ operating parameters



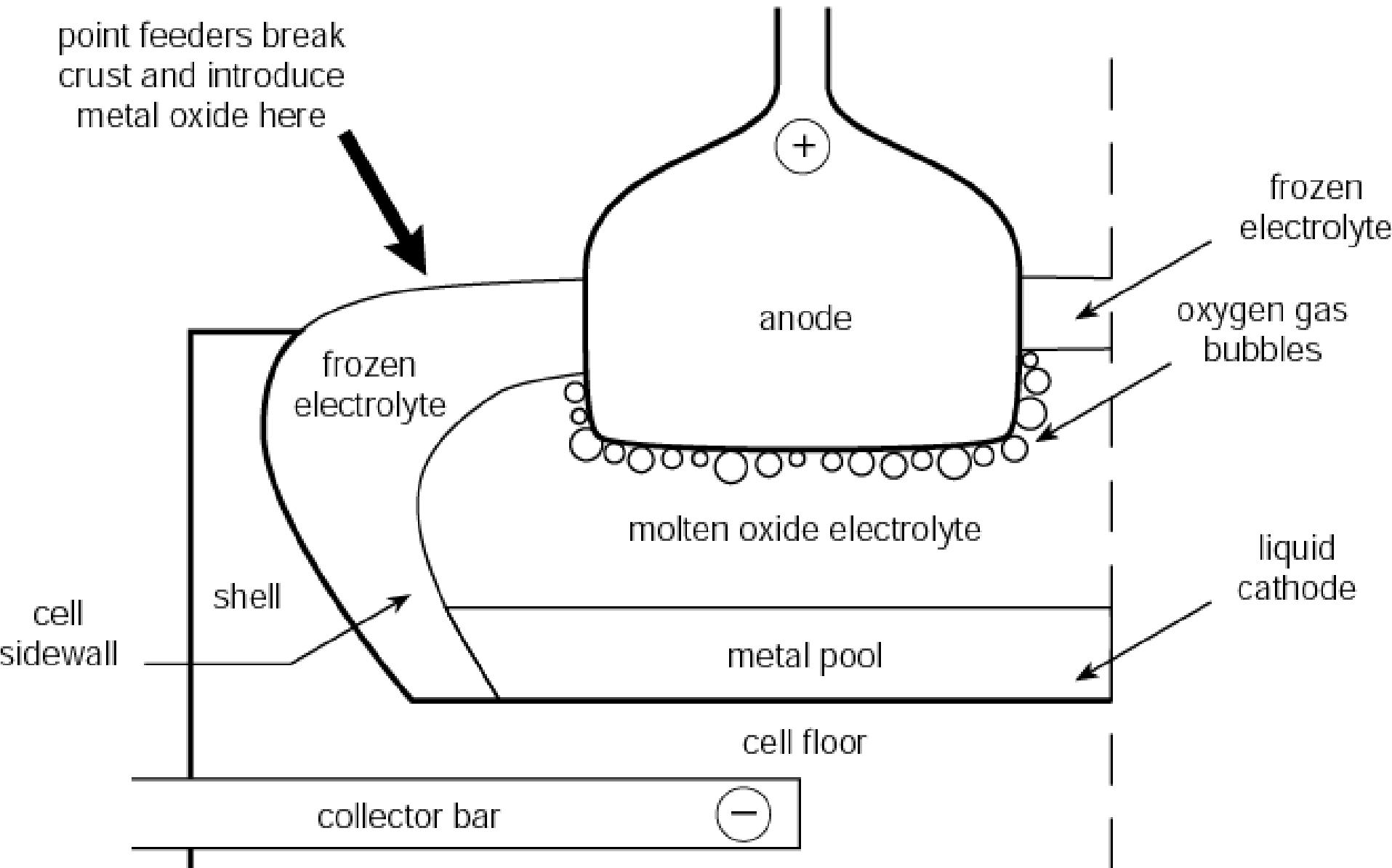
# Research program

- electrical conductivity measurements



# It's the electrical conductivity, stupid.

point feeders break  
crust and introduce  
metal oxide here



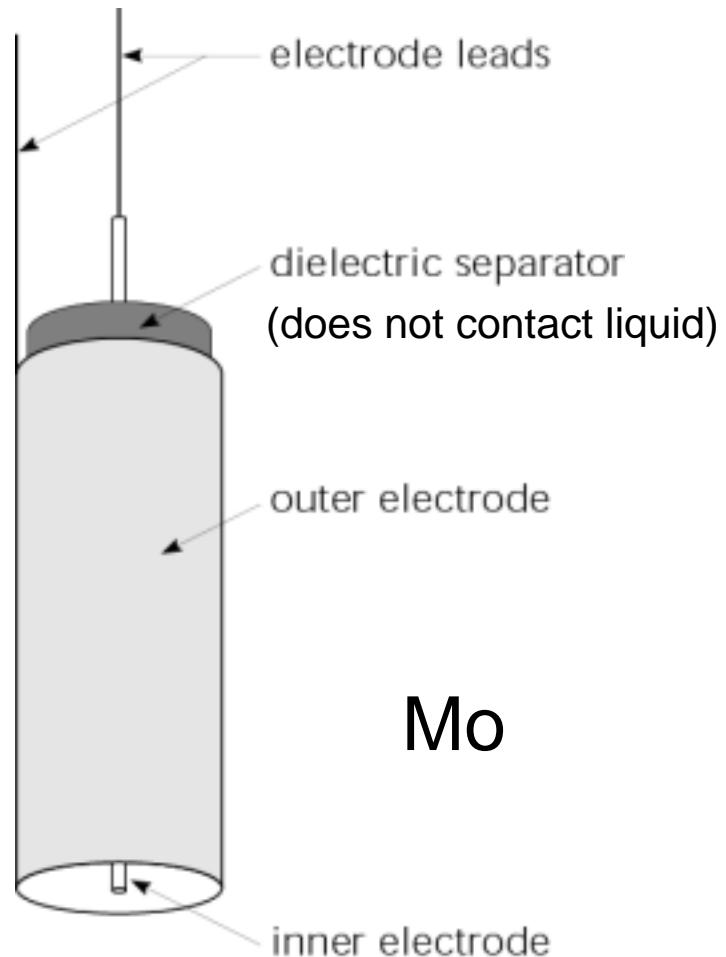
# Research program

- electrical conductivity measurements
- transference number measurements
- selection and testing of electrodes
- systems issues

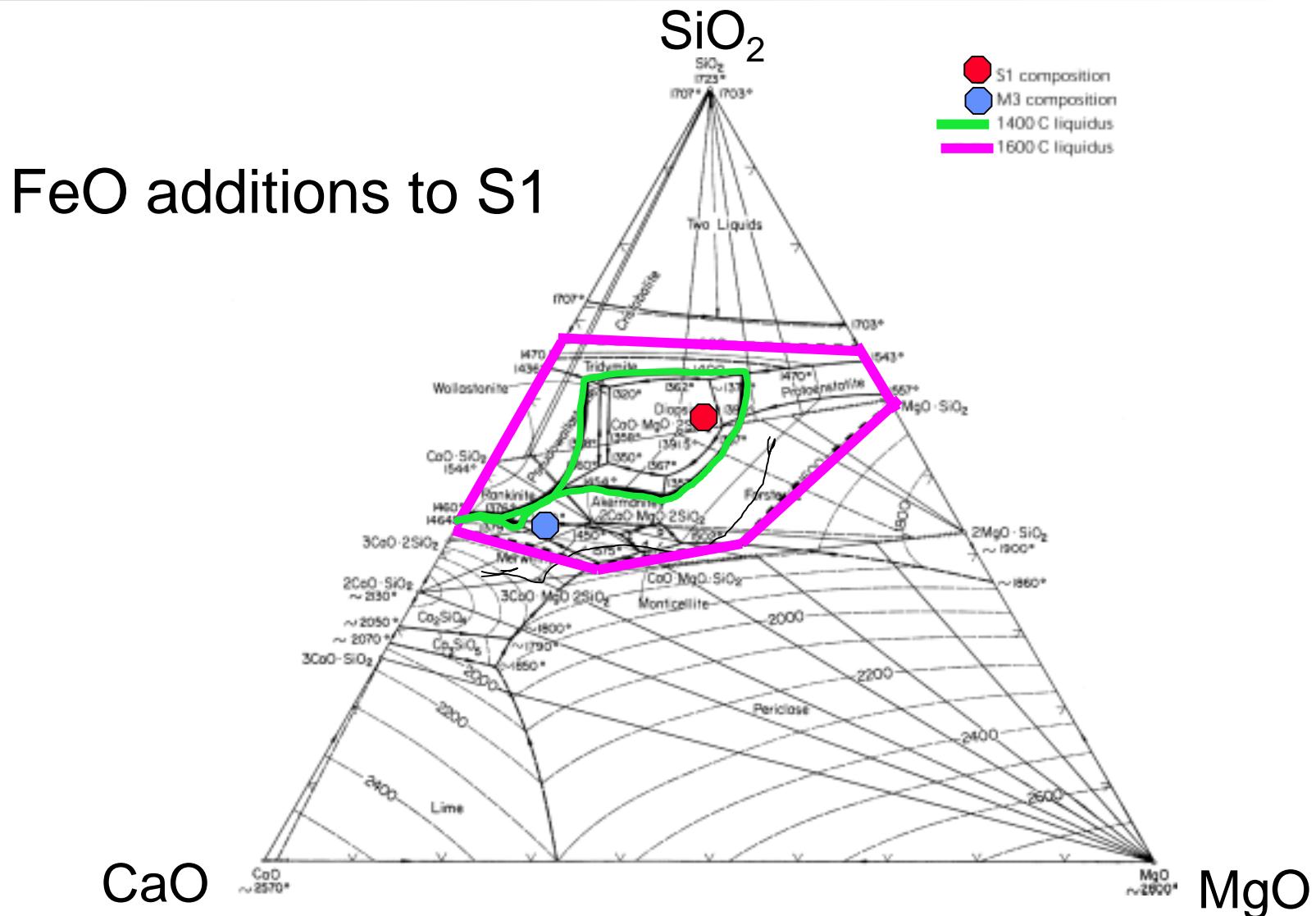


# all-metal, coaxial-cylinder electrode

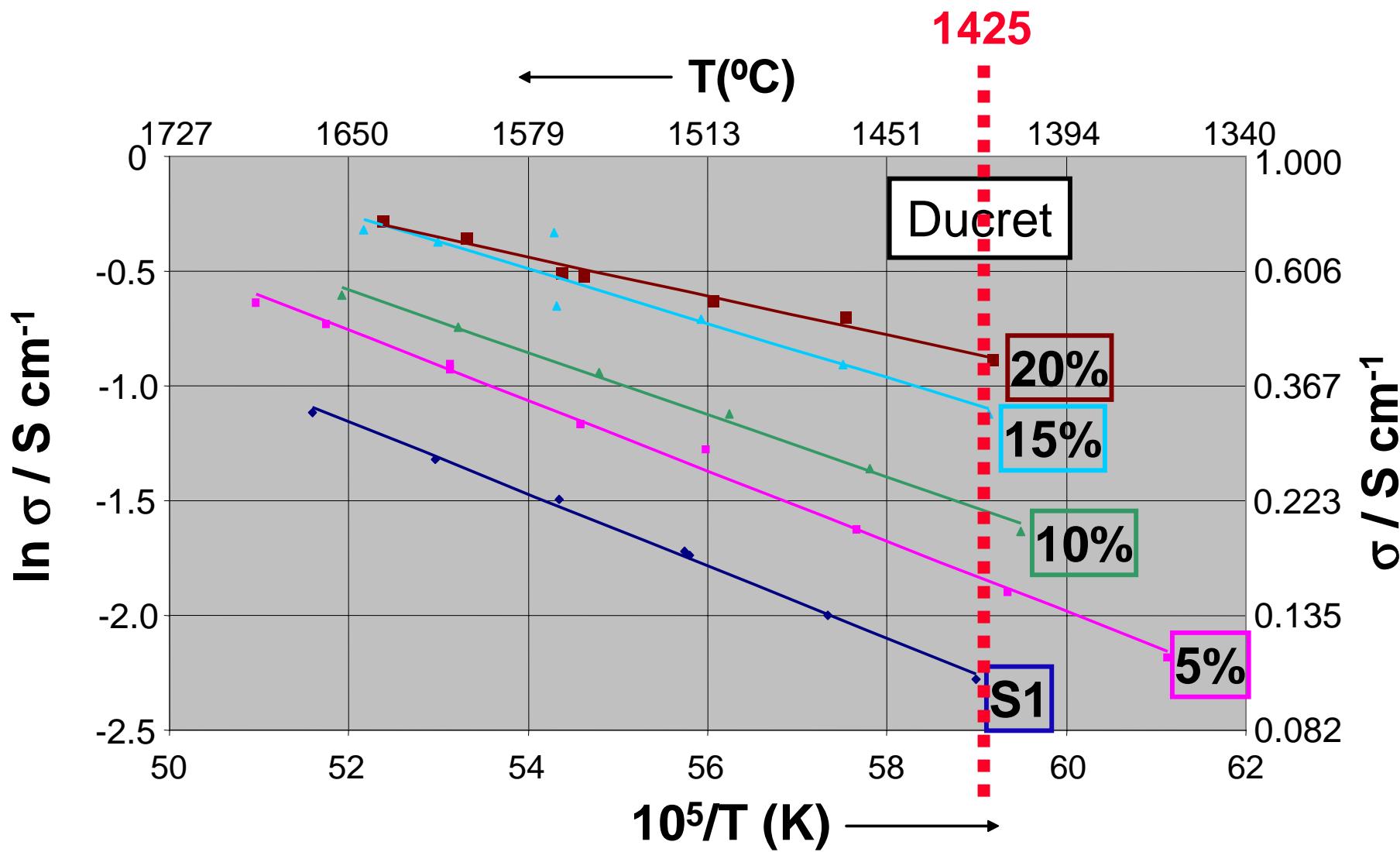
enabling high-accuracy conductivity measurements in the most chemically aggressive melts



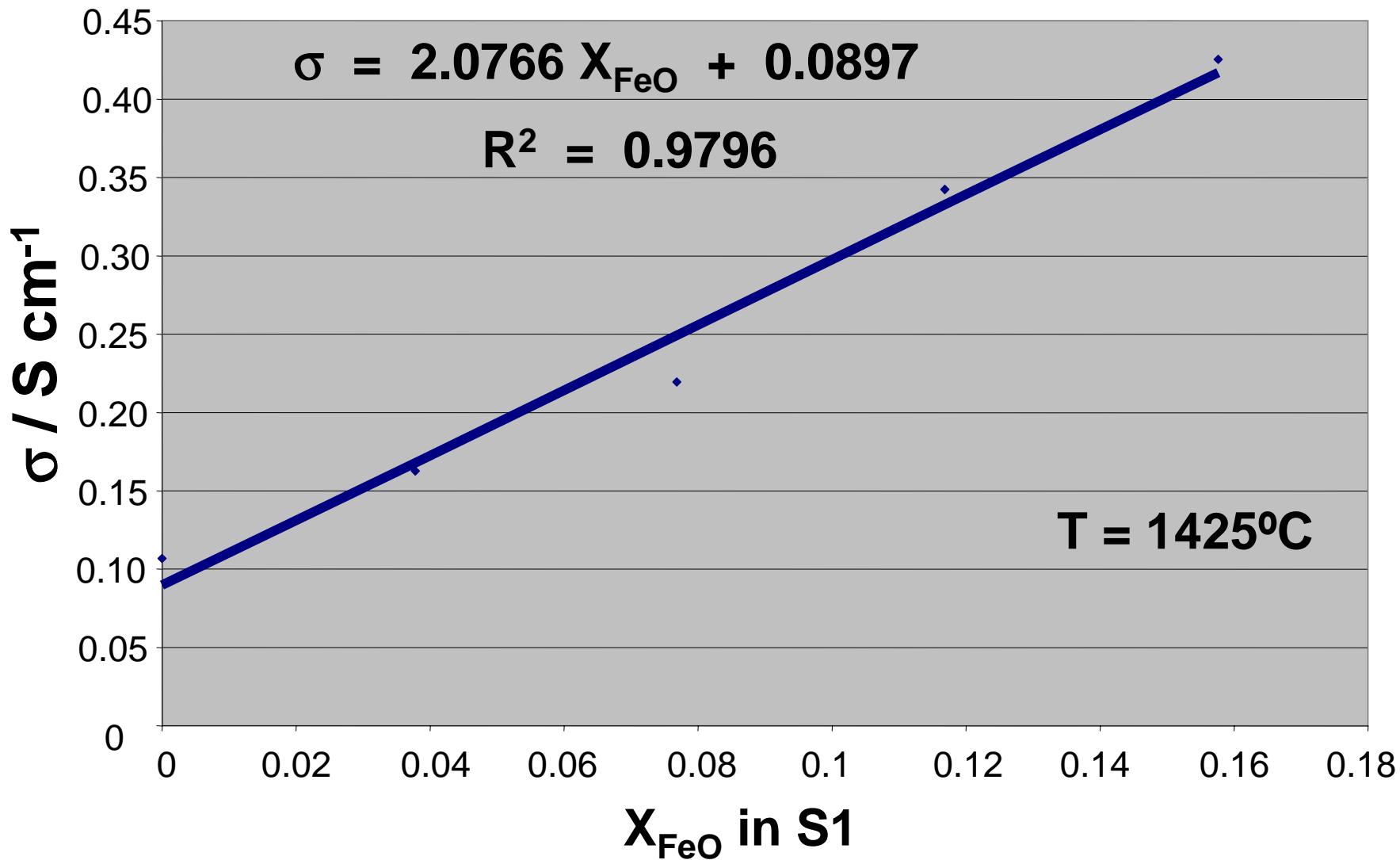
# solvent compositions



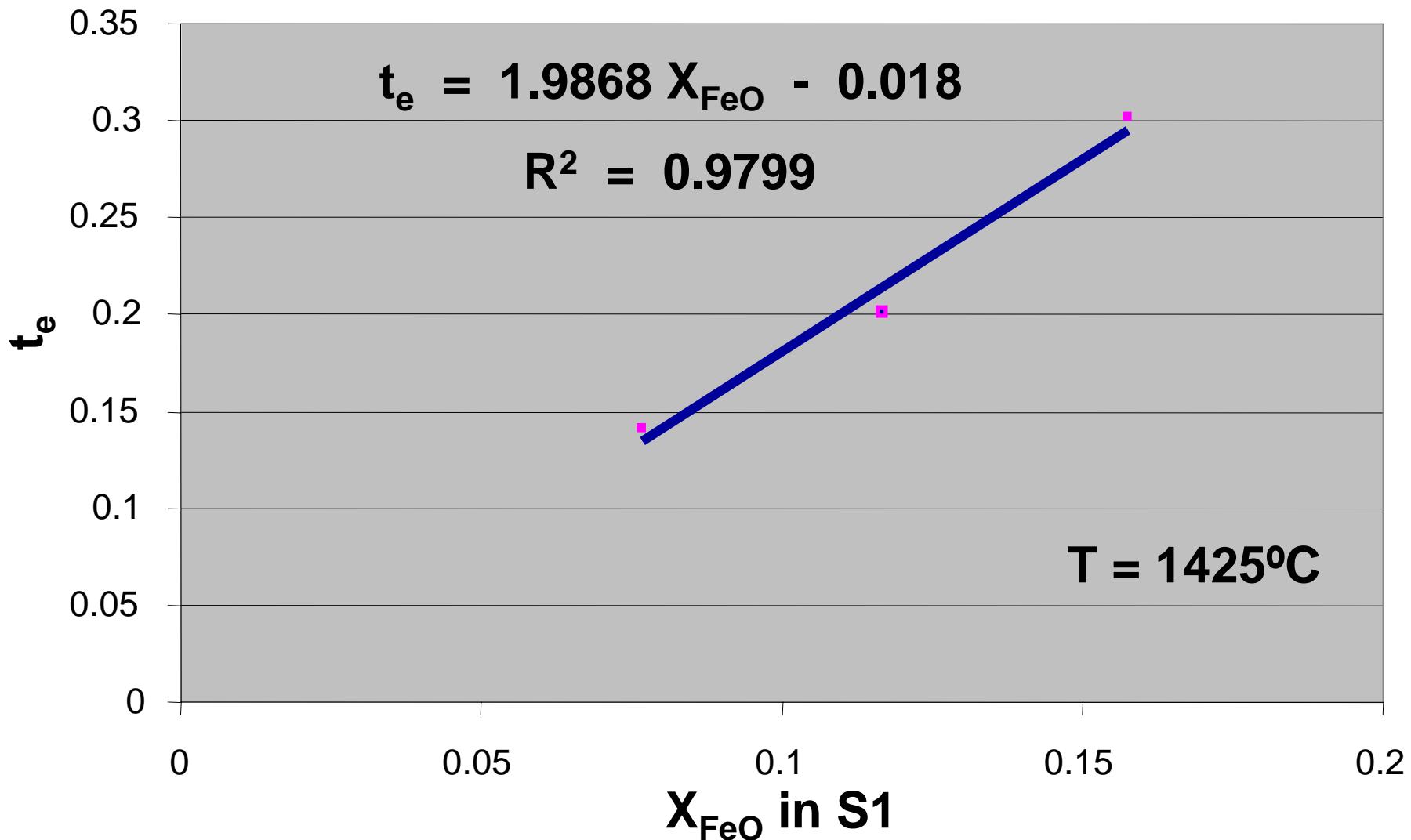
# effect of FeO addition: $\sigma = \sigma(T, c)$



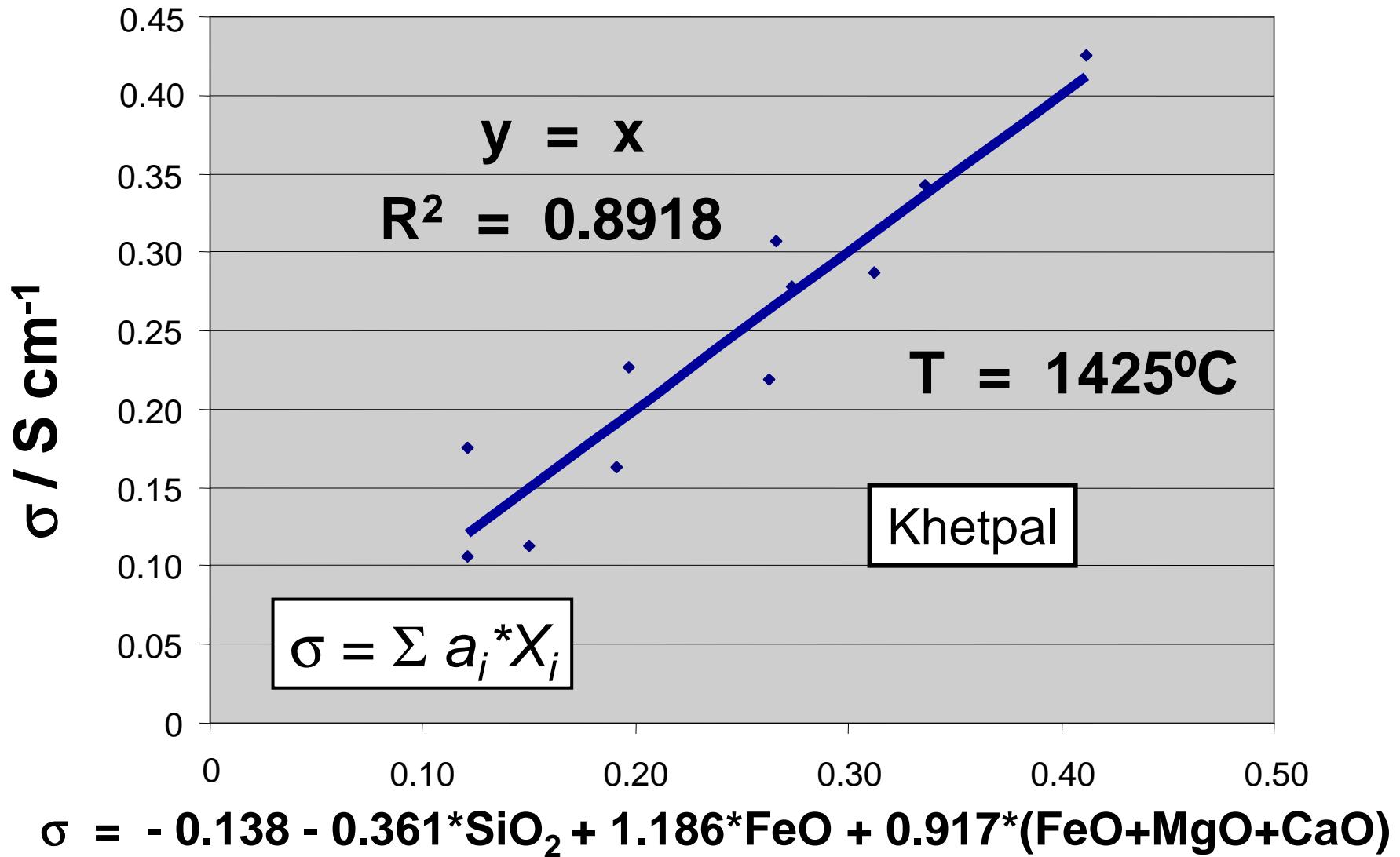
# FeO greatly raises conductivity



# FeO acts as an electron donor



# regression of conductivity data



# materials selection for electrolysis cell

- **anode material**

- ✓ extreme temperature
- ✓ electronic conductor
- ✓ oxidation resistance

platinum

- **cathode material**

- ✓ iron (m.p. 1535°C ) ?

molten copper  
“host”

- **container material**

- ✓ problem only at labscale

Mo crucible

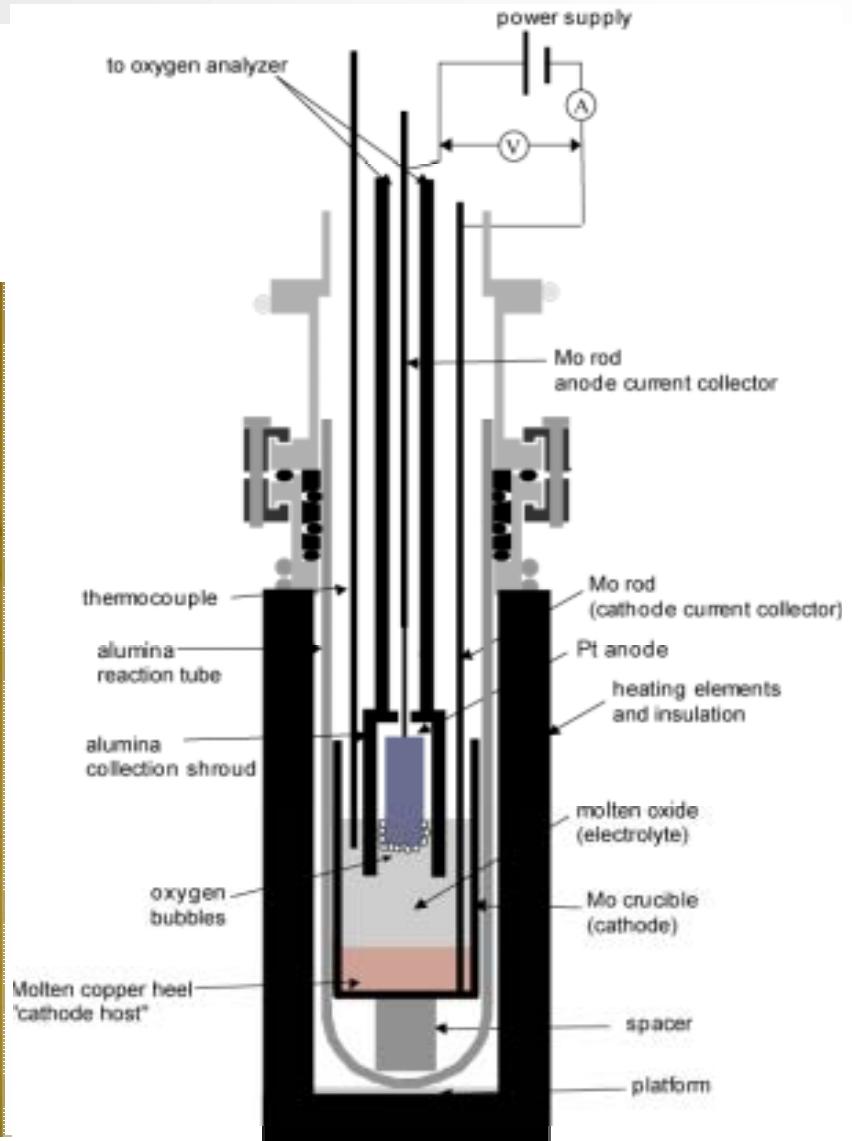
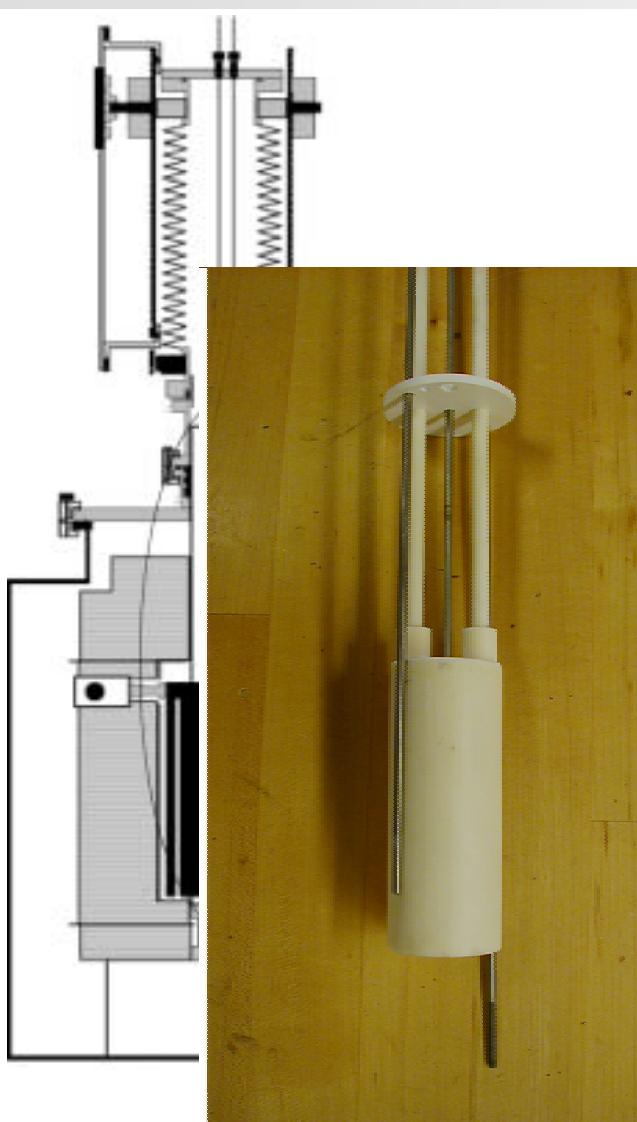
- **oxygen carrying apparatus**

- ✓ need for collection

alumina



# prototype electrolysis cell

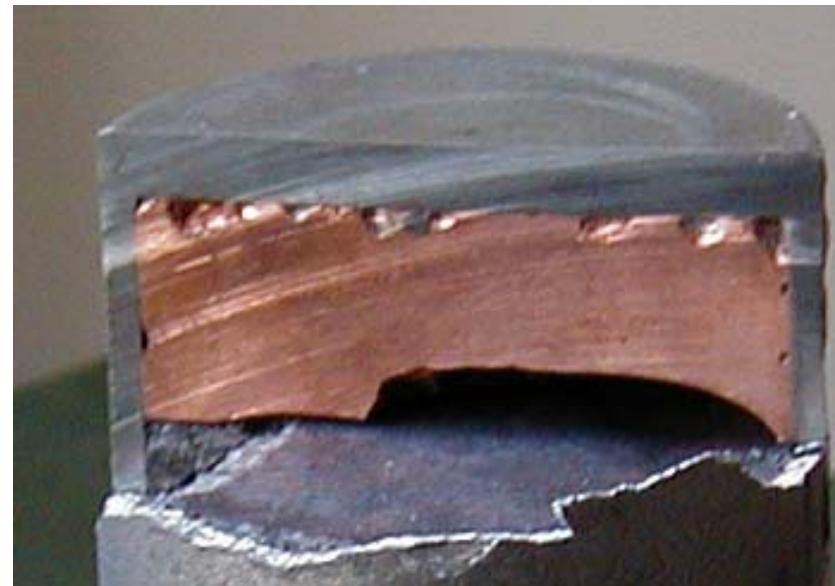
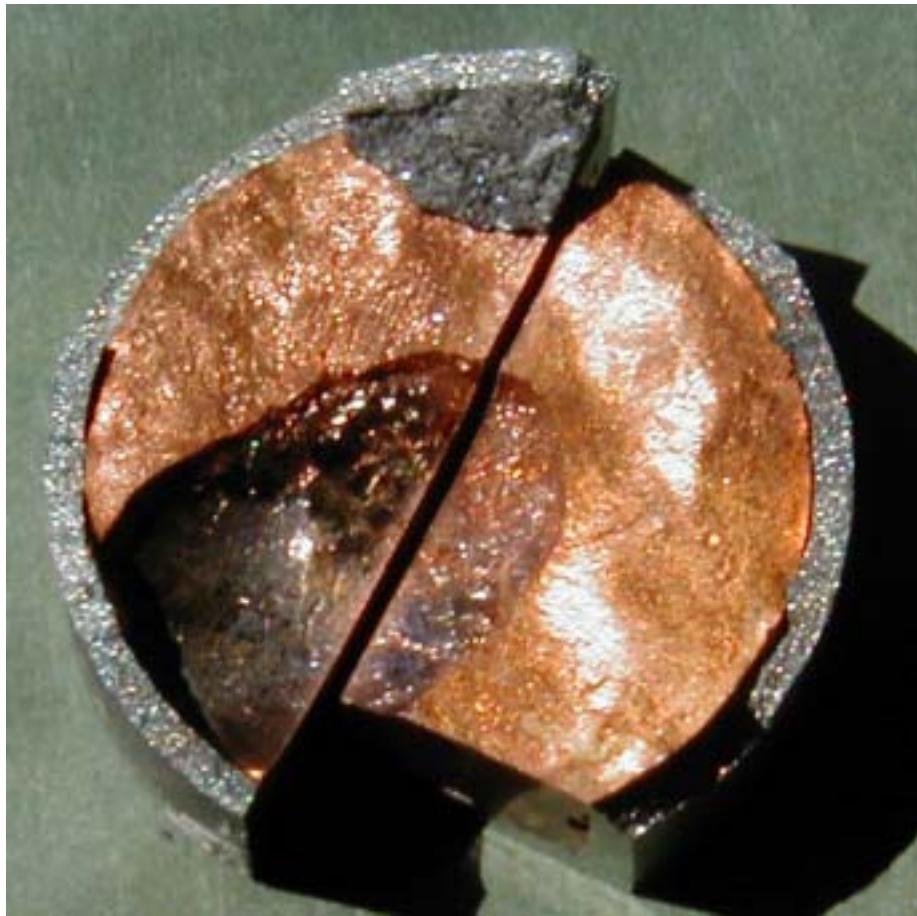


# Observations

- electrolysis products
  - ✓ anode : oxygen
  - ✓ cathode : iron
- Faradaic efficiency
  - measured value 39%
  - theoretical limit 85% ( $t_e$ )



# Observations



# applicability to oxygen generation:

## **lunar/martian electrolysis cell**

daily oxygen requirement = 2.75 kg

Faradaic efficiency = 85% (based on  $t_{\text{ionic}}$ )

current = 452 A

cell voltage = 2 V ( $2.5 \times \Delta H_{\text{FeO}}$ )

power supply = 904 W

current density = 5 A cm<sup>-2</sup>

electrode area = 90 cm<sup>2</sup>



# ... in closing

- ✓ high-accuracy electrical conductivity and transference number measurements in molten oxides at extreme temperatures
- ✓ electrolytic production of breathable oxygen & propellant not viable



# ... in closing

- ✓ implications for fluxes and slags,  
e.g., welding, refining, &  
metallothermic reduction
- ✓ nothing to preclude adaptation to  
electrolytic production of steel & Ti

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