A Technical Feasibility Study of Steelmaking by Molten Oxide Electrolysis

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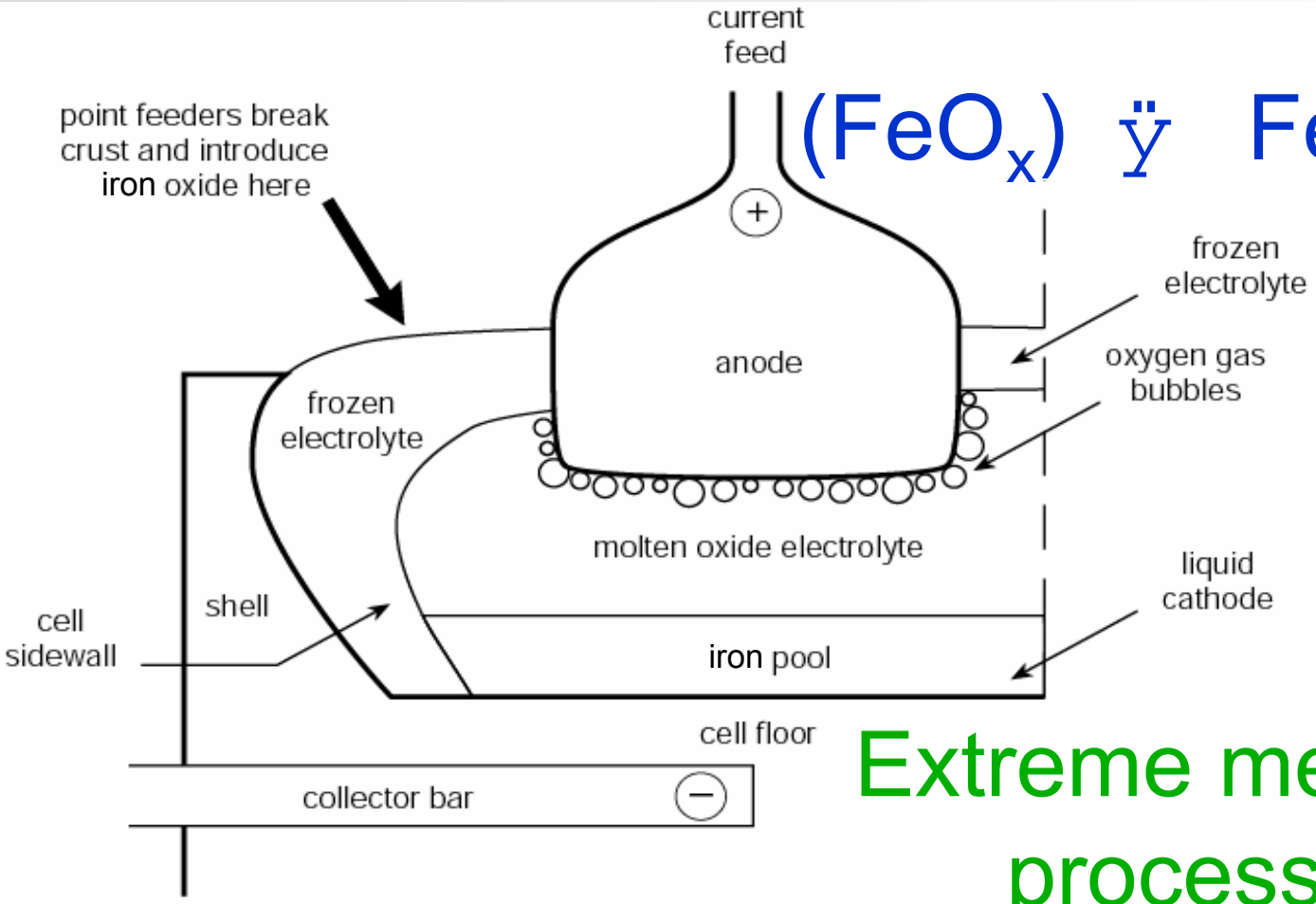
goal of the research

2 assess the technical viability of the production of iron by molten oxide electrolysis

What is molten oxide electrolysis?



$$(FeO_x) \xrightarrow{\text{electricity}} Fe_{(\ell)} + \frac{x}{2} O_2$$

Extreme metallurgy: processes emitting only products

Environmental Impact & Energy Savings

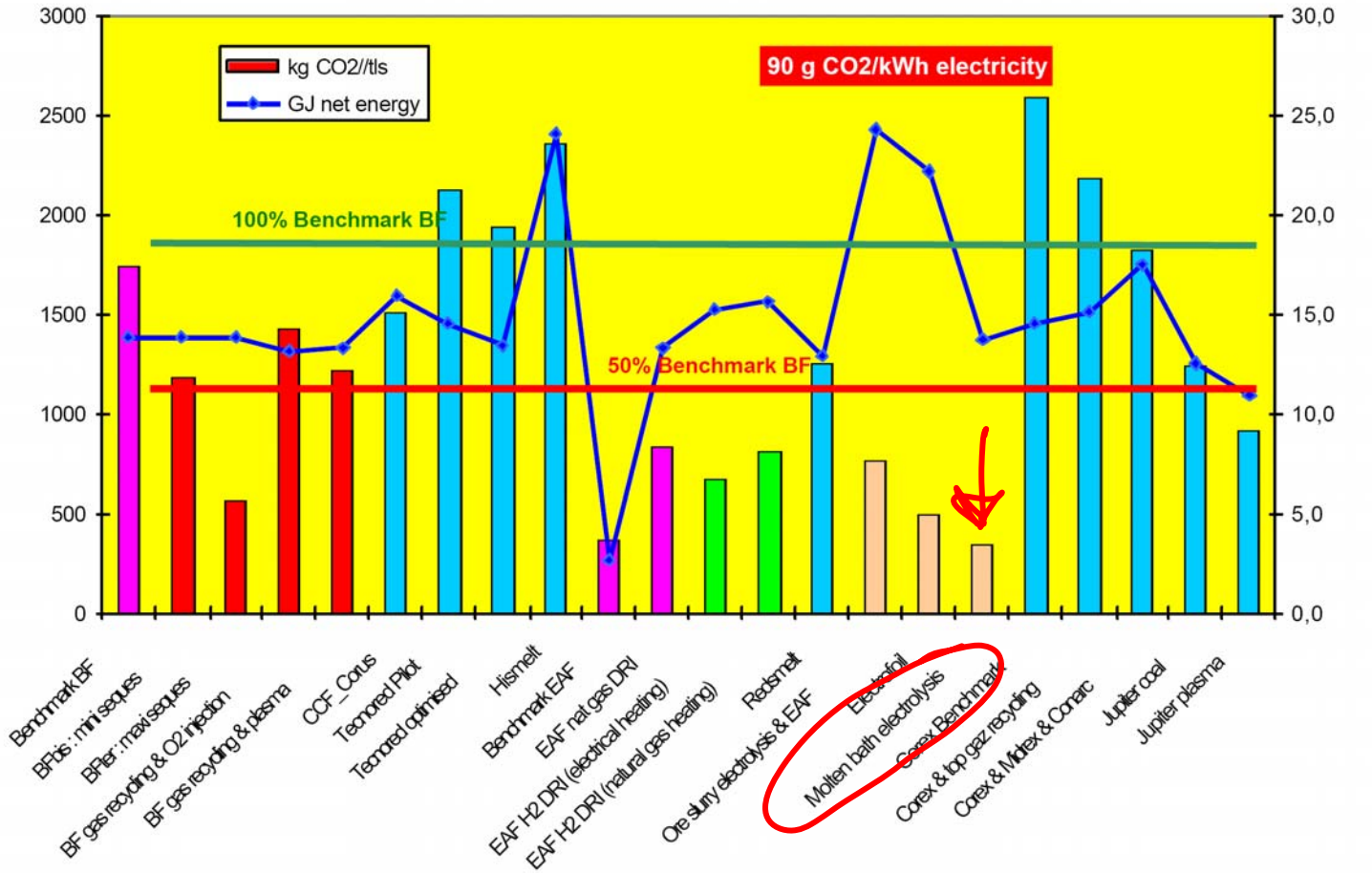


Figure 17 – Comparison of simulations of CO_2 emissions for various steelmaking process routes (per t of liquid steel – process engineering boundaries)

Environmental Impact & Energy Savings

- CO_2 emissions reduced from 1750 kg/tonne liquid steel for benchmark blast furnace technology to 345 kg/tonne liquid steel: a five-fold reduction
- 90 g CO_2/kWh for generation of electric power
- equivalent energy consumption: MOE vs benchmark

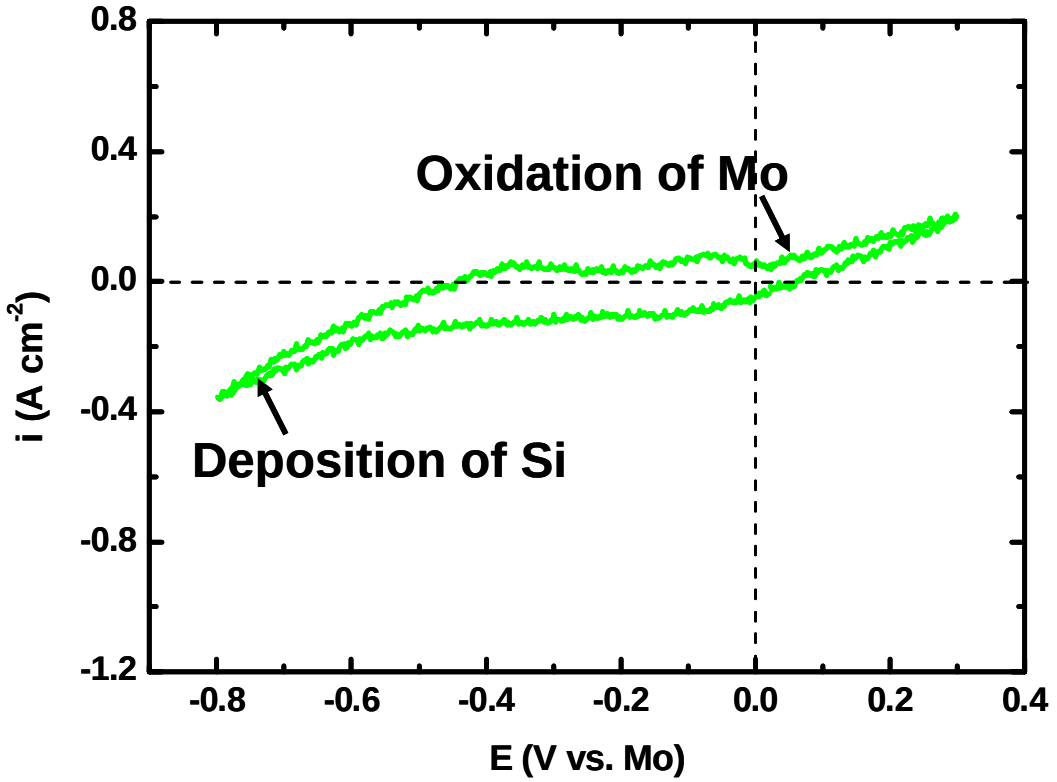
feasibility assessment: issues

- identification of electrolyte chemistries
- selection and testing of electrode materials: inert anode for oxygen gas and stable cathode for molten iron
- performance testing of laboratory-scale cell to set the stage for scale-up

progress to date:

- design, construct, and operate laboratory-scale cell up to 1600ºC
- conduct electrochemical testing on candidate electrolyte melts
- demonstrate production of liquid iron by electrolysis in laboratory-scale cell§
- by first-principles calculations identify candidate electrode materials

electrochemistry at white heat

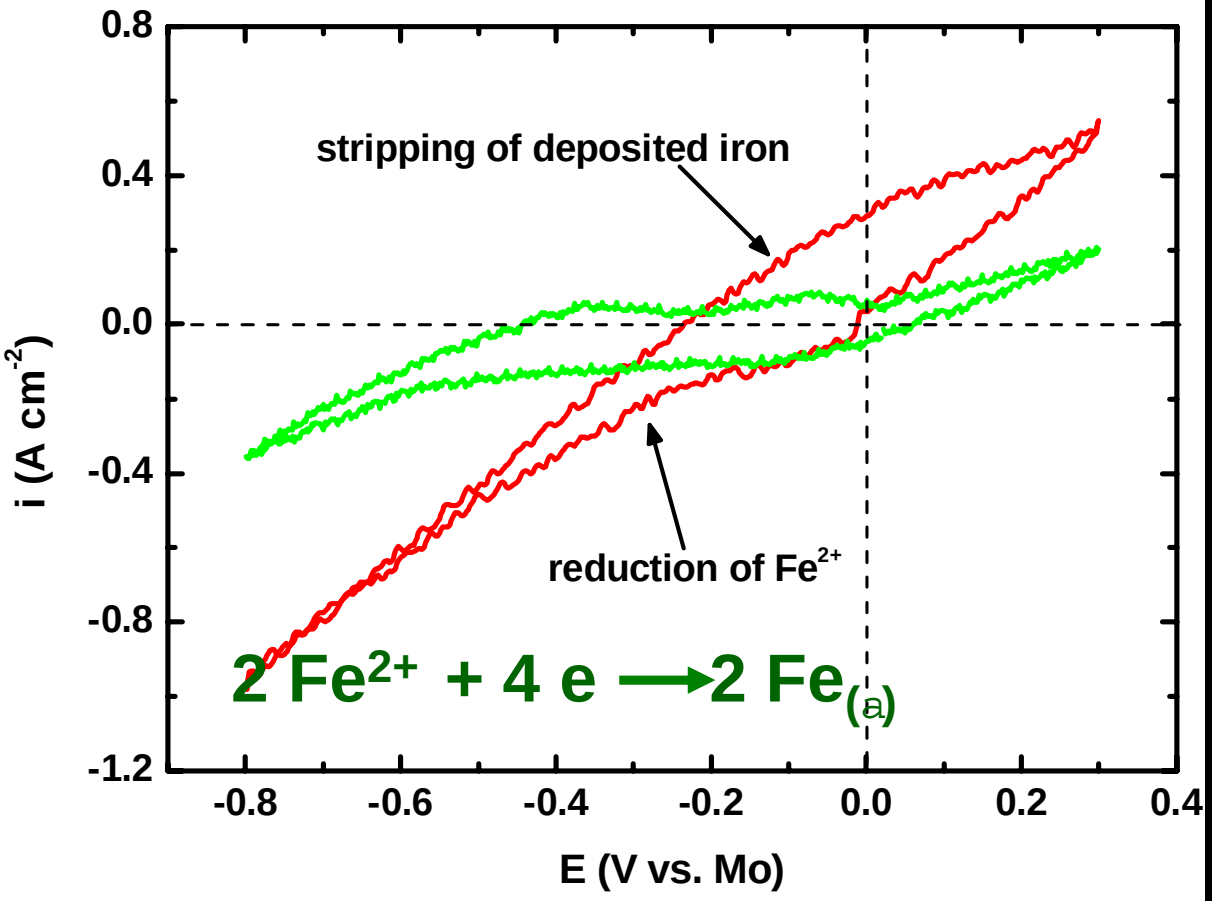


$CaO - MgO - SiO_2$

scan rate = 50 mV s^{-1}

T = 1575°C

electrochemistry at white heat



add 5% FeO to

$CaO - MgO - SiO_2$

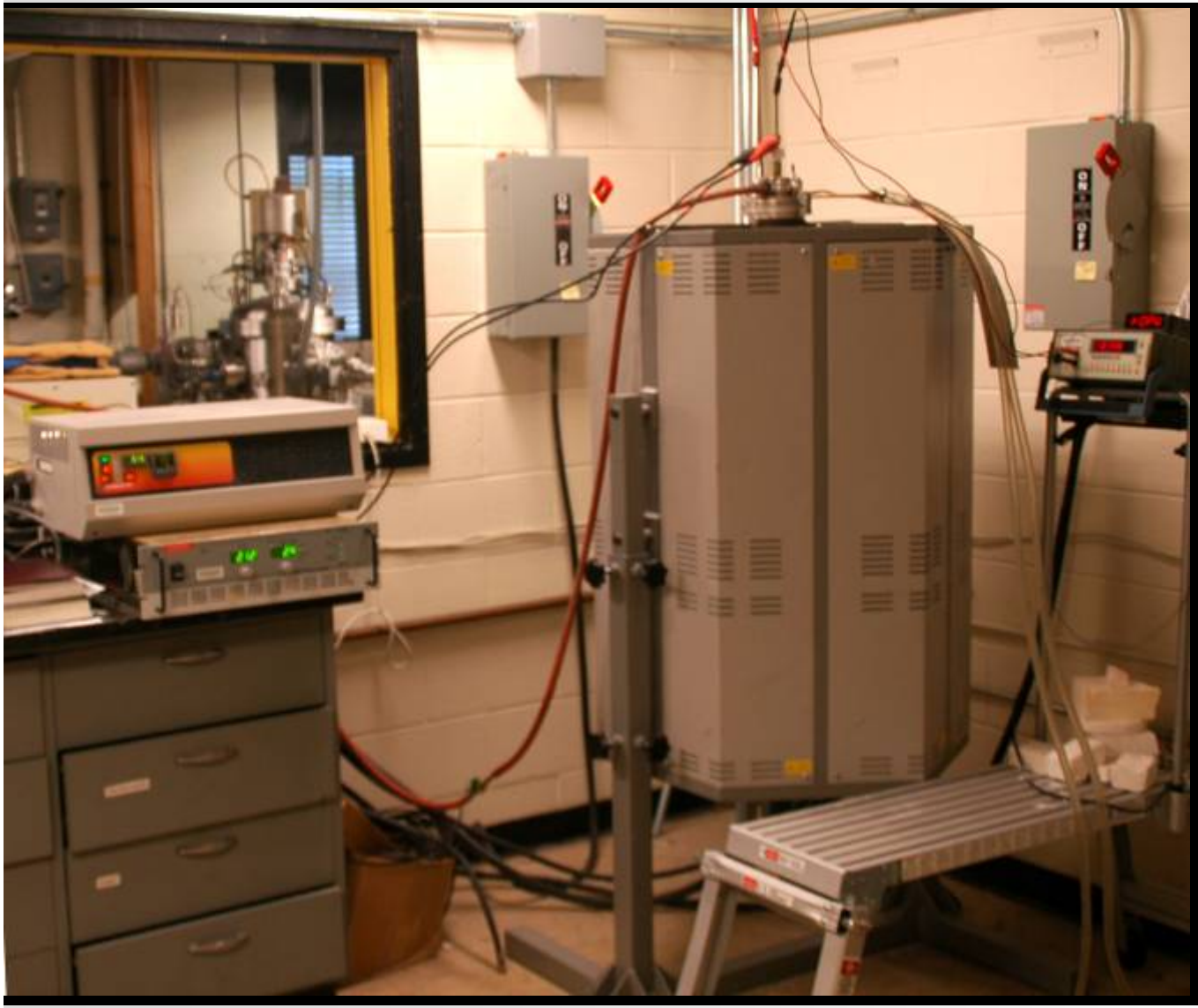
scan rate = 50 mV s^{-1}

T = 1575°C

--- supporting electrolyte

--- 5 wt% FeO

electrolytic production of molten iron:



cathode: Mo

anode: Pt

electrolyte:
$CaO - MgO - SiO_2$

feed: FeO

crucible: Mo

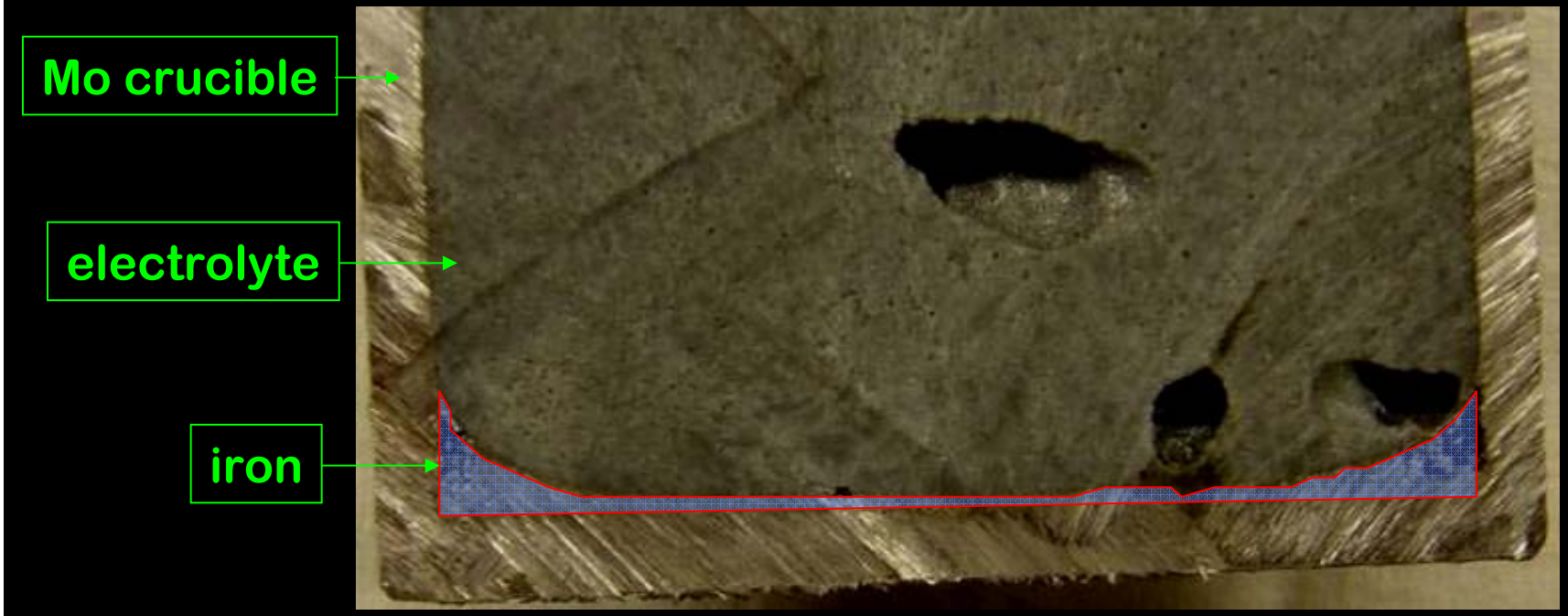
reactor tube: Al_2O_3

constant ***i*** = 3 A

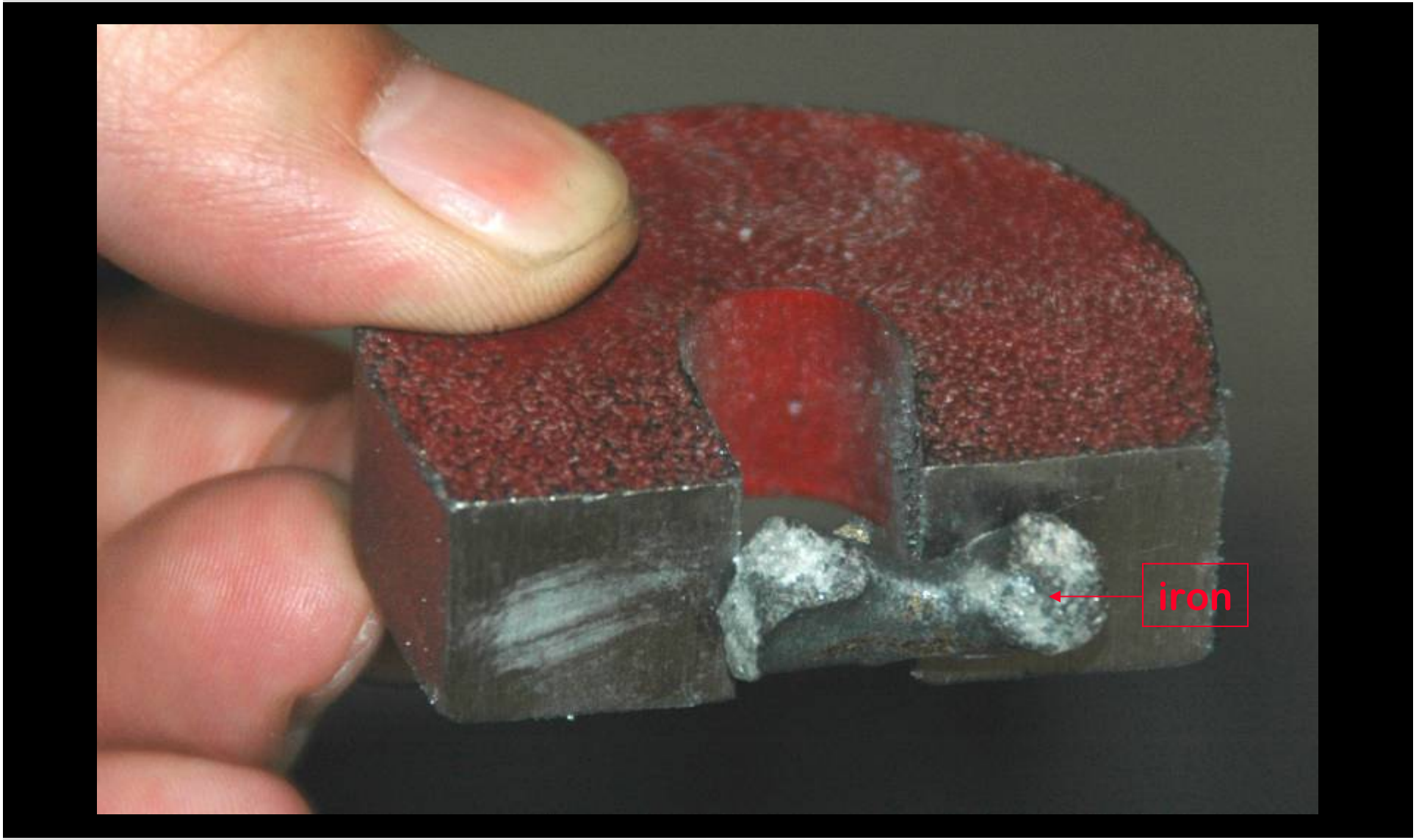
time = 3 h

constant-current electrolysis at 1575°C

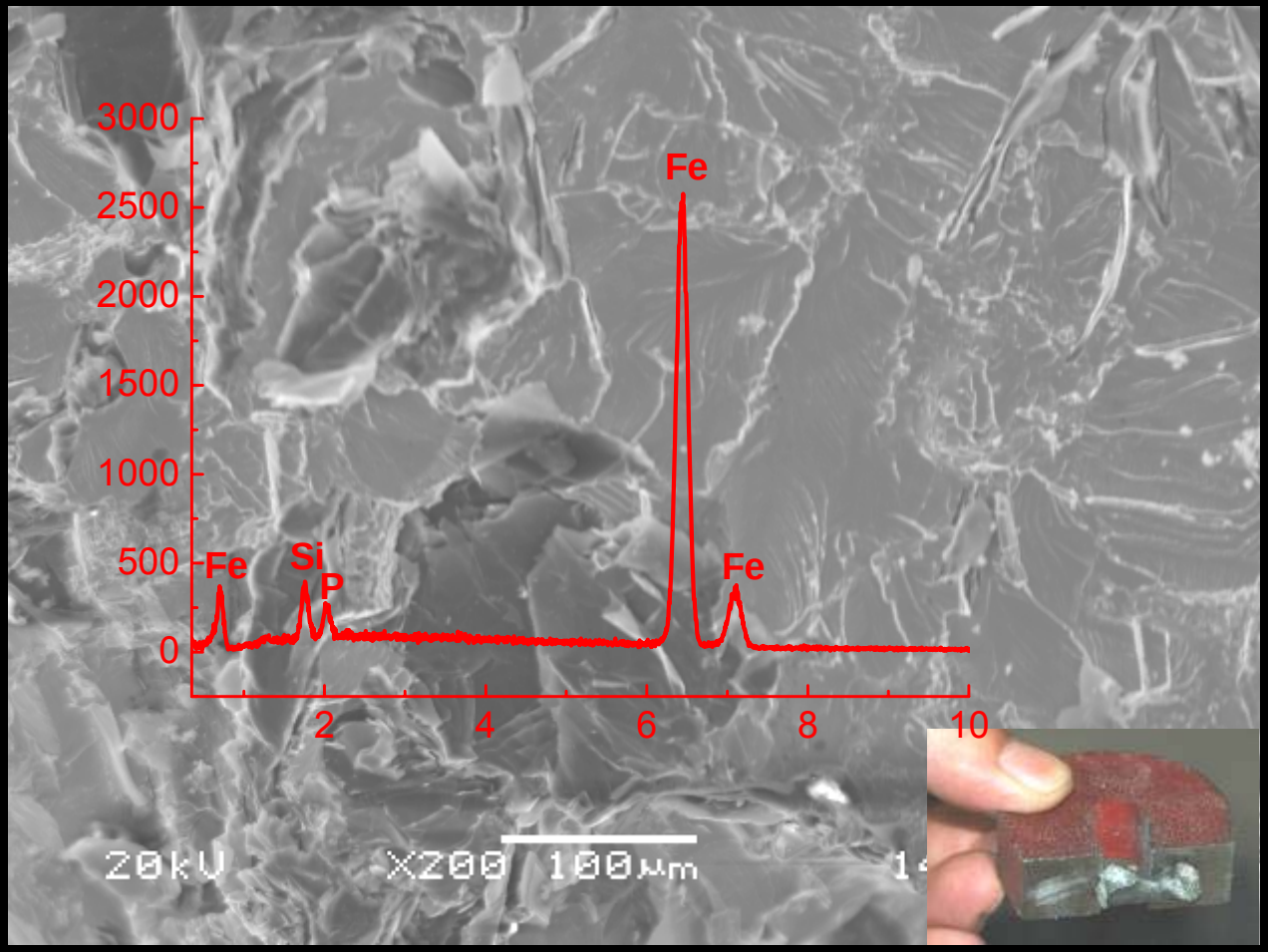
current density: ~1 A cm^{-2}



electrolytic production of molten iron:



SEM and EDX analysis



what have we learned?

- deposition of iron is feasible in these melts
- very high current densities are sustainable
  - 5 A cm^{-2} observed; maybe higher!

    c.f. 0.7 A cm^{-2} in Hall-Héroult cell
  - 15× productivity of aluminum smelting

    ∴ capable of producing tonnage metal

next steps

2 design, build, & operate ***pre-pilot*** cell

- current: 4000 A = 100× today's lab cell
- externally heated
- operating temperature: 1750ºC
- daily productivity: 67 kg Fe & 29 kg O_2

experimental measurements

- cell voltage as a function of current
- cell productivity as a function of current
- metal purity and oxygen yield: mass balance
- electrode wear rates: fate & transport
- energy balance: heat loss vs electrical input

  - cost model
  - design parameters for scale-up to self-heating pilot cell