

THE PRODUCTION OF LIQUID TITANIUM BY MOLTEN OXIDE ELECTROLYSIS

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ELECTROLYTIC PRODUCTION OF TITANIUM

“It might, however, be fair to say, that titanium will be made competitively by fusion electrolysis within the next 5 to 10 years”

W. J. Kroll-1959 at American Institute of Mining,
Metallurgy & Petroleum Engineers

ADVANTAGES OF HIGH TEMPERATURE ELECTROLYSIS

- Production of molten titanium results in complete physical separation of metal and electrolyte
- Electrolysis is continuous in contrast to batch nature metallothermic reduction
- Possibility of major cost reductions

ELECTROLYTIC REDUCTION OF TiO₂ IN OXIDE MELTS

- direct use of beneficiated ores
 - ⇒ avoiding halide metallurgy
 - ⇒ environmental advantages
- higher solubility of TiO₂ ⇒ higher throughput
- possibility of
$$2\text{O}^- \rightarrow \text{O}_2 + 2\text{e}^-$$
 on an inert anode

MATERIALS CHALLENGES IN ULTRA-HIGH-TEMPERATURE ELECTROCHEMISTRY

special conditions:

- high melting point of titanium (1675°C)
- aggressive solubilizing power of oxide melts

special needs:

- chemical and electrochemical stability
- electronic conductivity

HOST ELECTROLYTE

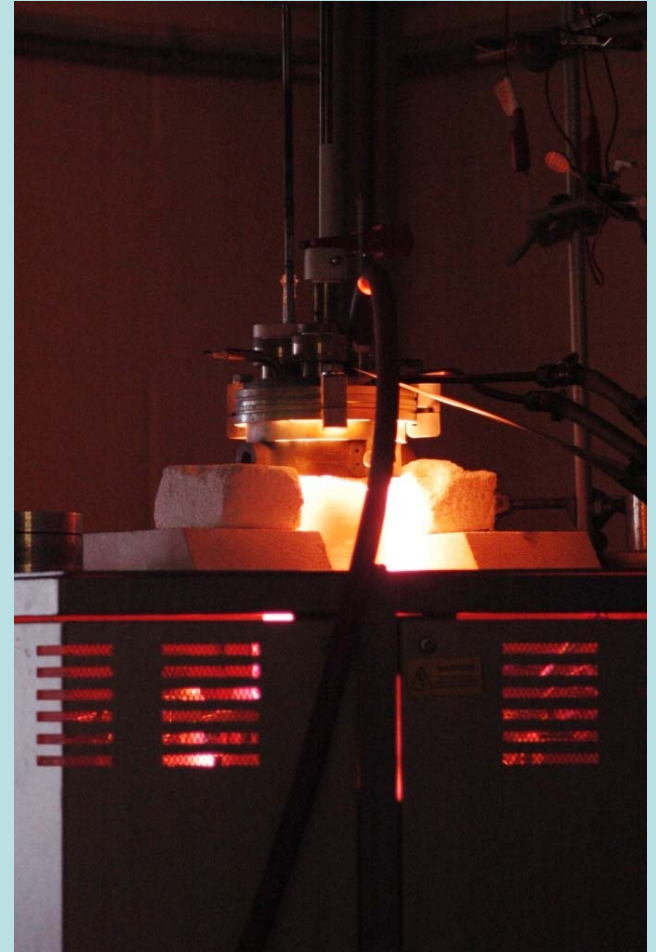
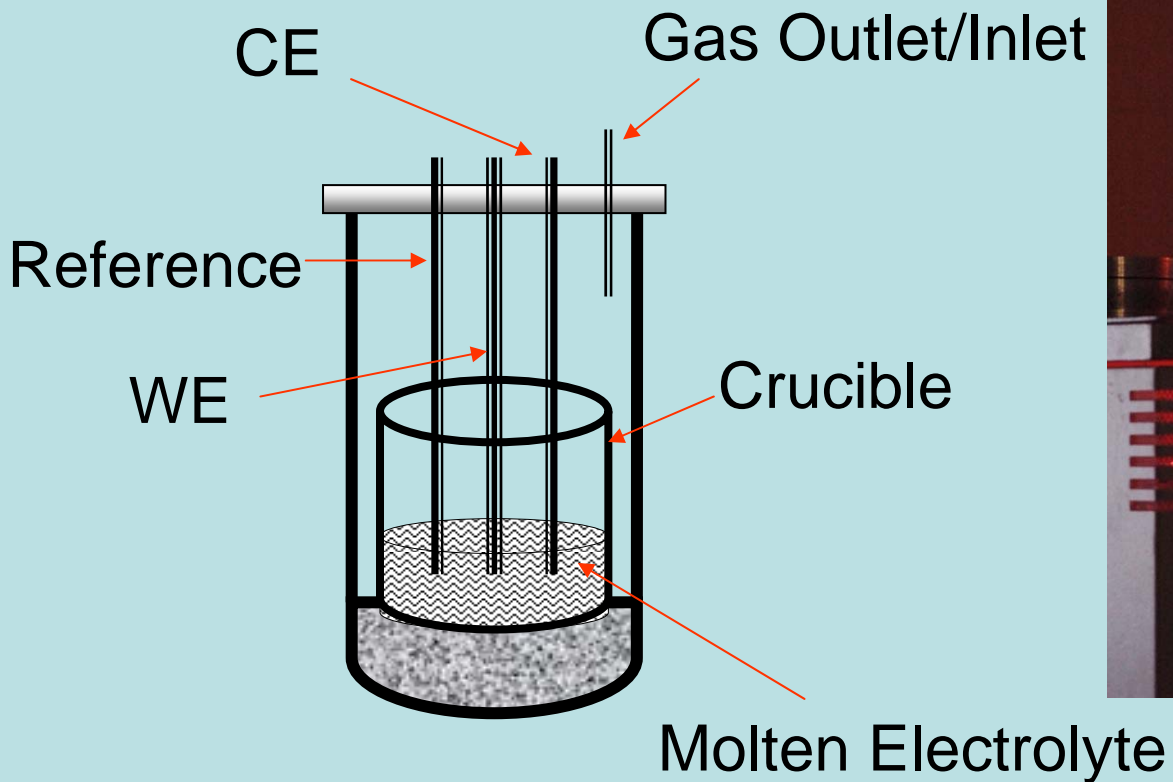
- Low melting temperature
- Wide potential window
- Good ionic conductivity
- Electronically insulating
- Capable of dissolving TiO_2



EMF SERIES AT 1700°C(V)

| | |
|-------------------------|------|
| TiO_2 | 1.53 |
| Al_2O_3 | 1.80 |
| MgO | 1.98 |
| CaO | 2.18 |

EXPERIMENTAL SETUP

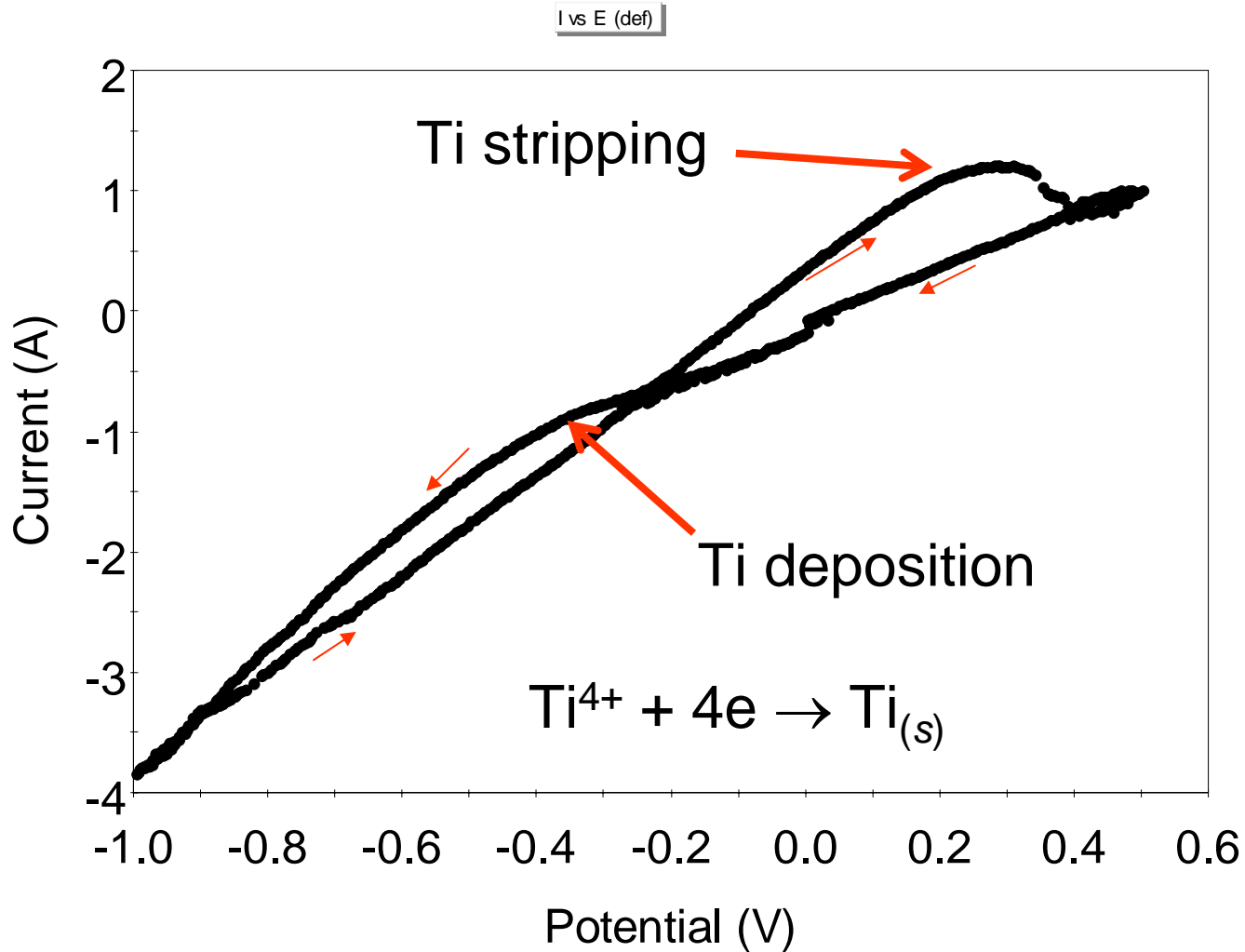


Learn to crawl

before you learn to run

- *D.R. Sadoway*

CYCLIC VOLTAMMETRY AT 1550 °C

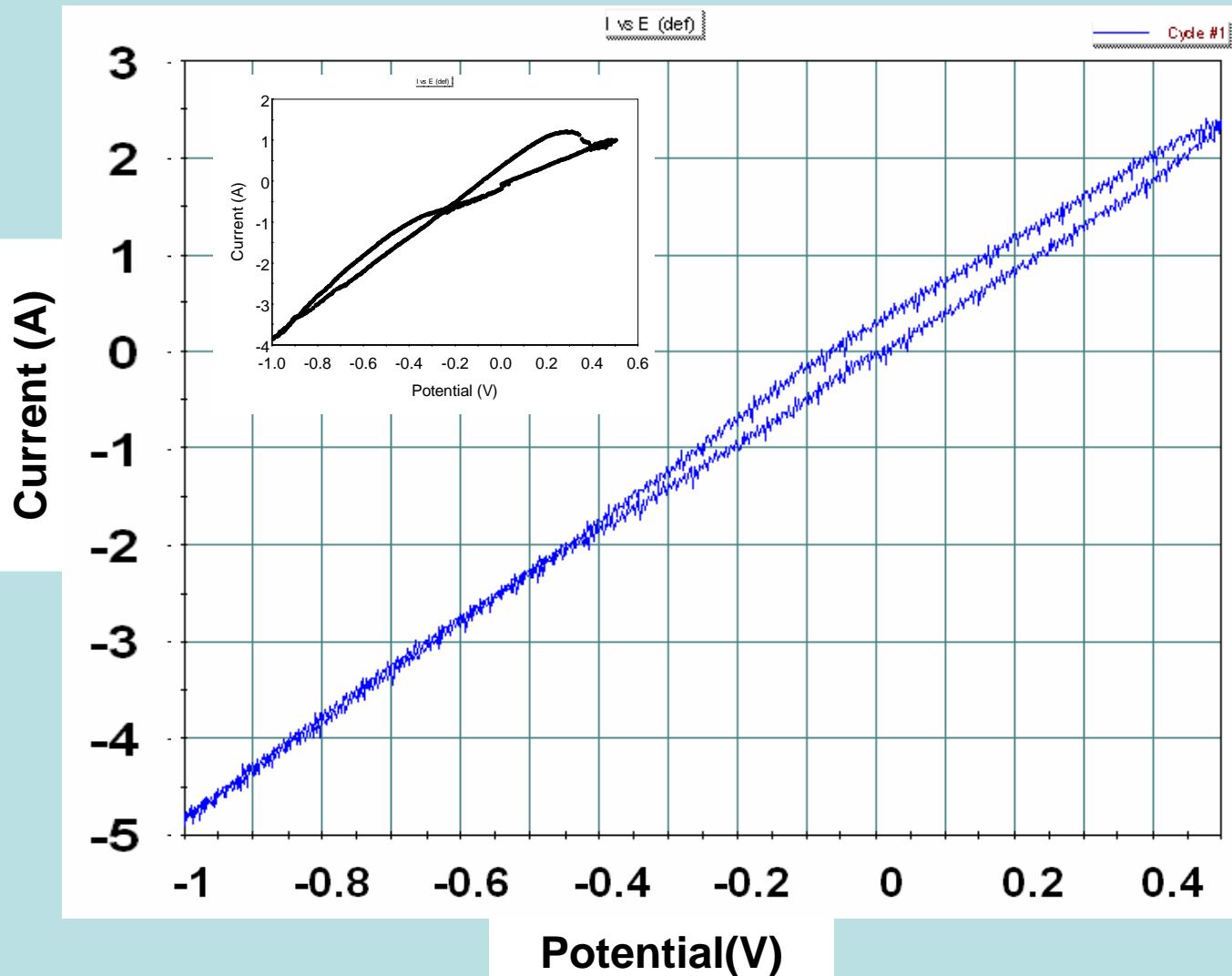


WE: Mo

RE: Ti

CE: Mo

CYCLIC VOLTAMMETRY OF THE ELECTROLYTE

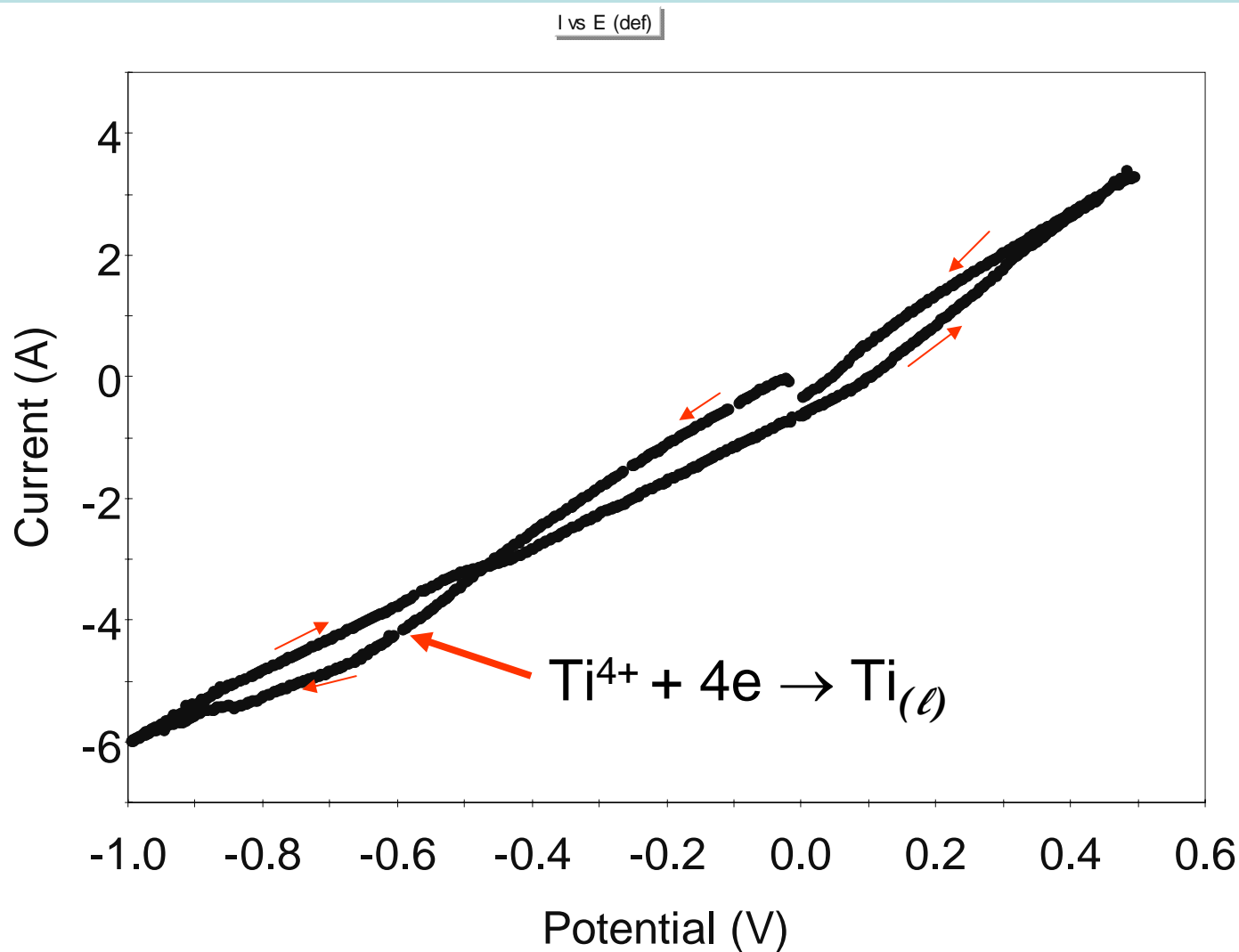


WE: Mo

RE: Ti

CE: Mo

CYCLIC VOLTAMMETRY AT 1700 °C



WE: Mo

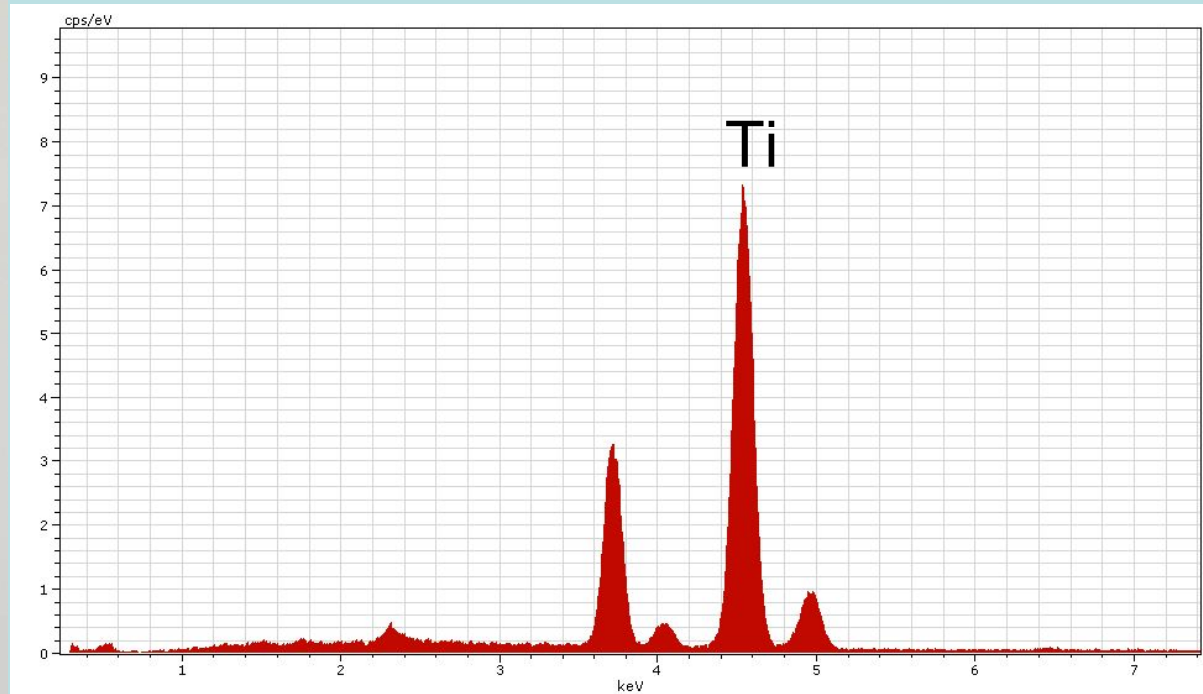
RE: Mo

CE: Mo

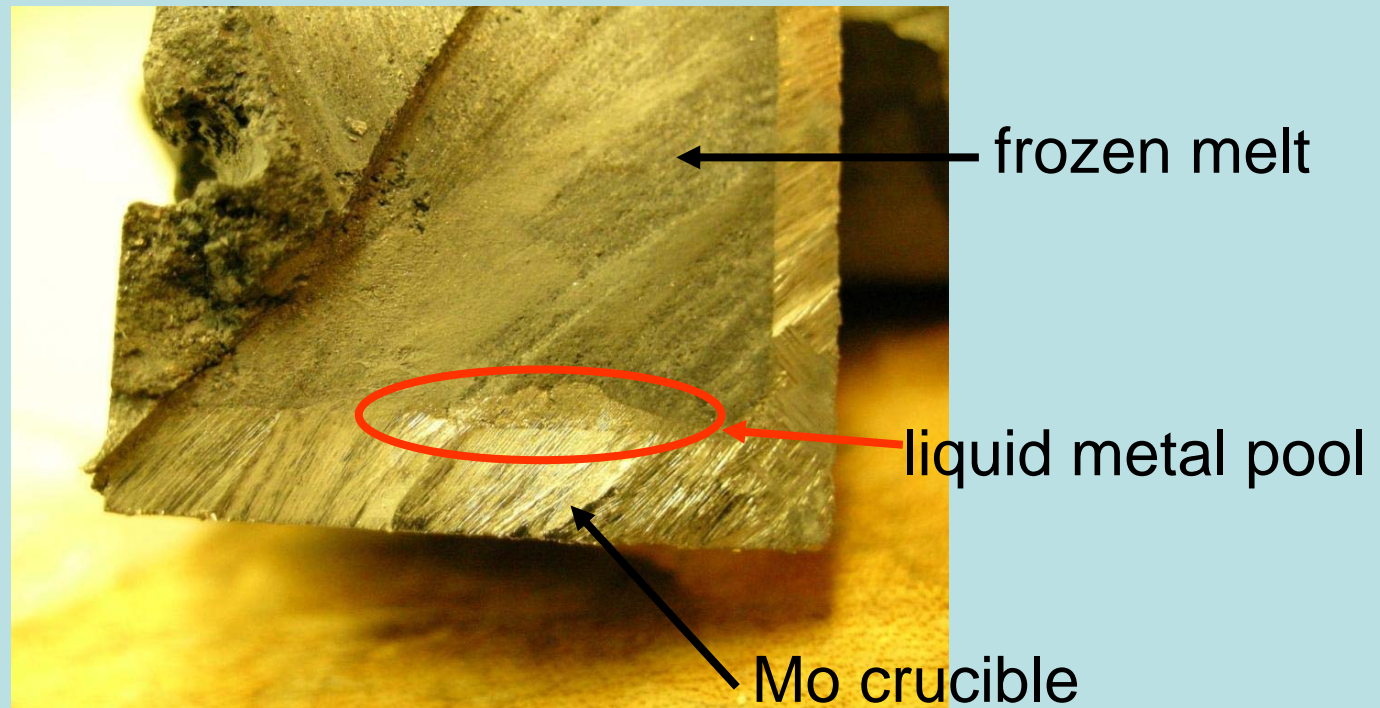
ELECTROLYTIC PRODUCTION OF SOLID TITANIUM



Cathode: Mo
Anode: C
Current Density ~ 1A/cm²



ELECTROLYTIC PRODUCTION OF LIQUID TITANIUM

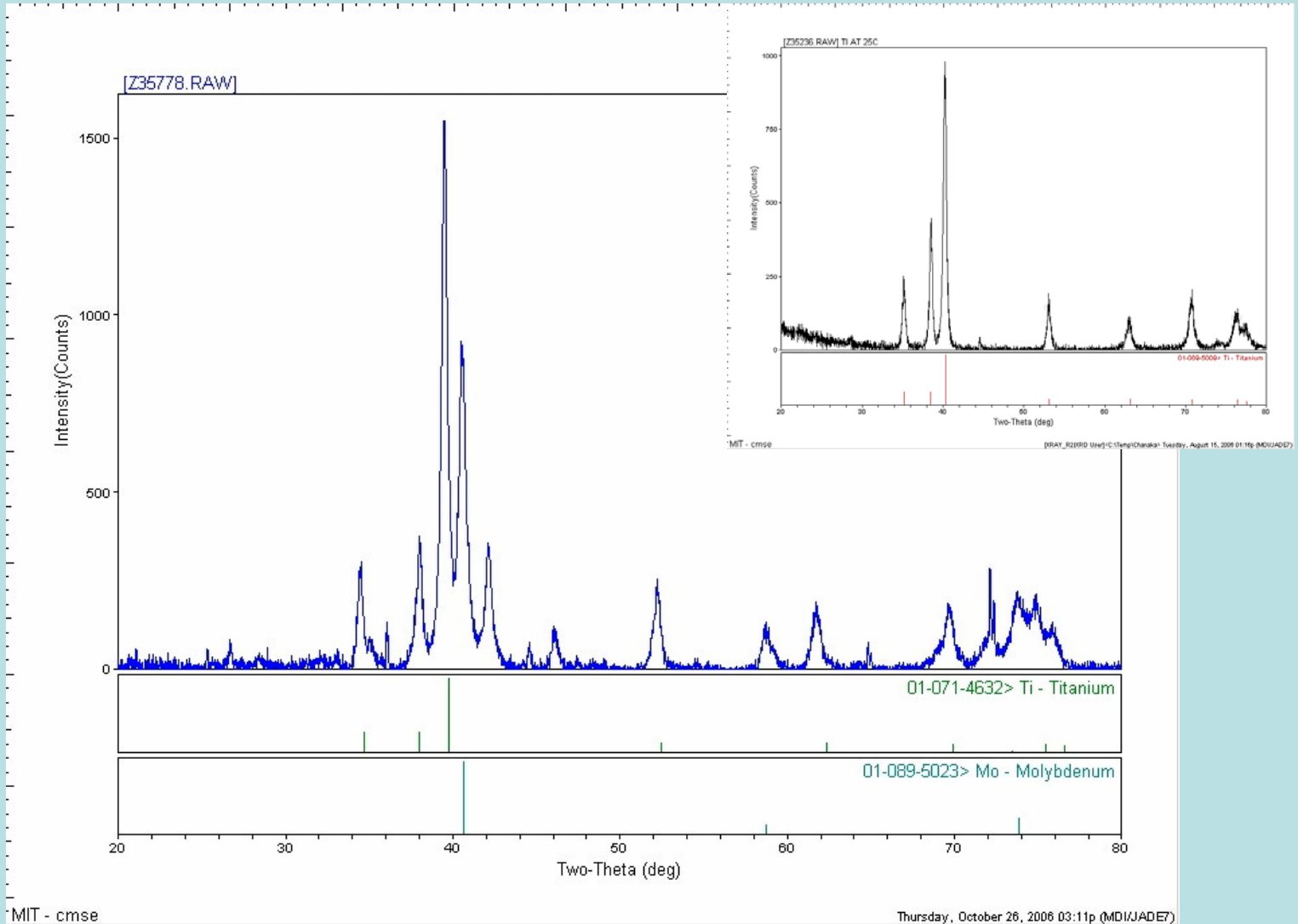


Cathode: Mo

Anode: C

Current Density $\sim 1 \text{ A/cm}^2$

XRD ANALYSIS



SUMMARY

- cyclic voltammetry investigations at white heat
- electrolysis of TiO_2 in oxide solvent melt produces metallic Ti
- current densities as high as $\sim 5 \text{ A/cm}^2$ observed

THE JOURNEY TO ULTRA-HIGH TEMPERATURE

