Titanium Electrowinning Process

Case Western Reserve University (PI: Rohan Akolkar)

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METALS Annual Meeting

Proposed Electrowinning Process

\[ \text{Cl}_2 + \text{TiO}_2 \xrightarrow{C} \text{CO}_2 + \text{TiCl}_4 \]

electrolysis
Outline

- Team Intro
- Technical Concept
- Technical Progress to date
- TEA Highlights
- Future Goals
- Q&A
Case Western Reserve University

- Case Western Reserve University Team Members:
  - **PI:** Rohan Akolkar
  - **Personnel:** Dai Shen, Stephen Banik, Mirko Antloga, Craig Virnelson, Uziel Landau, Mark DeGuire, David Zeng

- Goals of the ARPA-E METALS Project:
  - To develop a novel electrowinning process for low-cost extraction of titanium metal from ore, and
  - Demonstrate stable, energy-efficient extraction of high-purity Ti powder

Proposed Electrowinning Process

\[
\text{Cl}_2 + \text{TiO}_2 + \text{C} \rightarrow \text{CO}_2 + \text{TiCl}_4
\]

Proposed Electrowinning Cell Design

- Segmented Diaphragm Design Enables Ti Electrowinning
- Ti Electrowinning
- Cl₂ Evolution

Cl₂ Evolution!
Technical Concept

PROBLEM STATEMENT

Problem with diaphragm-less cell:
Redox shuttling of titanium ions causes low current efficiency

PROPOSED SOLUTION

Use a stack of thin diaphragms

Design Rule: $\Delta \phi = \frac{il'}{\kappa} < \Delta E$

Ensures diaphragm & cell stability
Increases electrowinning efficiency
Technical Progress (Phase-I)

Molten-salt electrowinning reactor was constructed and operated.

Ti sponge was deposited, isolated and then characterized.

Thin diaphragms enabled stable cell voltage at industrial plating rates.

n>3 diaphragms provide efficient Ti electrowinning.
Technical Progress (Phase-II)

Molten-salt electrowinning reactor was relocated inside a glove-box for controlled environment studies.

EDS analysis shows up to 5 wt.% oxygen contamination in the electrowon Ti deposits.

~100 mg Ti deposits were collected and analyzed for purity using EDS.
TEA Highlights

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<tr>
<th>Metric</th>
<th>ARPA-E METALS GOALS</th>
<th>Proposed Technology (Ti Electrowinning)</th>
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<tbody>
<tr>
<td>Cost of Ti Sponge</td>
<td>&lt; $4 / kg</td>
<td>$4-5 / kg</td>
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<tr>
<td>Energy Consumption</td>
<td>&lt; 35 kWhr / kg</td>
<td>25-30 kWhr / kg</td>
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<tr>
<td>CO₂ emissions</td>
<td>&lt; 11 kg-CO₂ / kg</td>
<td>12-15 kg-CO₂ / kg</td>
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- Cost reduction primarily driven by energy-efficiency and process simplicity (elimination of the sacrificial Mg recycling as needed in conventional Kroll process)
Future Goals

- **Purity improvements:**
  - Currently, oxygen contamination of Ti product is a technology risk. To address this risk, we are designing an efficient vacuum distillation unit to purify the Ti product with the goal of achieving >99% purity.

- **Q2 2016:** Basic feasibility of Ti electrowinning demonstrated
- **Q3-Q4 2016:** Immediate focus is on improving Ti purity by lowering oxygen contamination via distillation
- **Q3-Q4 2016:** Detailed TEA for Ti powder electrowinning underway – will likely pivot process towards powder (vs. sponge)
- **2017:** Seeking additional federal and/or industrial funding for developing a Ti powder production process

**Industry Collaborator:** ATI (ATI in kind support: personnel, analytics, TEA)
QUESTIONS?