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ALUMINUM PURIFICATION AND MAGNESIUM RECOVERY FROM MAGNESIUM-ALUMINUM SCRAP

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PROJECT ID: MAT166

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OVERVIEW SLIDE

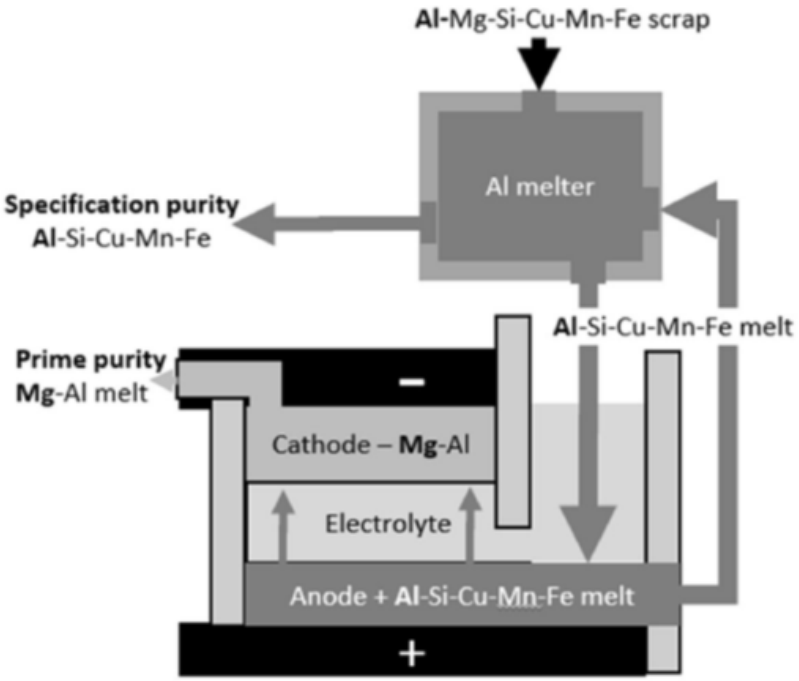
- Timeline:
  - Project start date: Oct 1, 2019; CRADA signed Dec 14, 2019
  - Project end date: June 14, 2020 (CRADA close-out)
  - Percent complete: 99%
- Budget:
  - $150,000 DOE (TCF Topic 1); $150,000 industry in-kind
- Barriers:
  - Currently there are few domestic primary magnesium production facilities and the processes used are often energy intensive and carry environmental penalties. In order to effectively take advantage of the weight reduction potential offered by magnesium, there is a need for environmentally clean, low-cost production capacity in North America.
  - Higher material cost is a barrier to the increased use of aluminum. De-magging, a process to reduce the Mg content of aluminum melted scrap by chlorination, contributes to this cost.
- Partners:
  - Phinix, LLC: cost-sharing partner
  - Kingston Process Metallurgy: collaborator
  - Real Alloy: aluminum recycling industry advisor

RELEVANCE

- Aluminum scrap, such as UBC (used beverage cans), contains a significant amount of alloyed Mg
- During scrap melting, the Mg content in the melted Al-Mg scrap is usually higher than desired
- De-magging with chlorine gas injection removes the excess Mg
  - produces a salt waste that must be landfilled
  - about 50kT/yr Mg is lost through de-magging by chlorination
- The U.S. imports about 50 kT/yr of Mg annually, mostly as an alloying additive to aluminum
- UBC are a potential abundant US supply of Mg, which can be recovered in decentralized locations
- Al-Mg electrorefining cells offer a solution for the recovery of Mg from Al-Mg scrap like UBC
- Products are Mg-rich layer and Mg-depleted Al melt
- **Objective:** Demonstrate that molten salt electrorefining technology can form the basis for a technically and economically viable process for recovering Mg from Al-Mg scrap leading to a low-cost domestic supply of Mg
- **Impact:** This environmentally friendly, low-cost domestic Mg production technology will enable greater use of magnesium in vehicles, and will reduce the cost of recycled aluminum, further increasing the use of aluminum in vehicles.

CONCEPT

- Three-layer electrorefining cell has a bottom Al-Mg molten metal layer (anode), a less dense electrolyte layer, and an Mg metal top layer (cathode) layer
  - Magnesium (density 1.7 g/cm^3)
  - Electrolyte (density 1.85-2.1 g/cm^3)
  - Aluminum scrap (density 2.3 g/cm^3)
- Operates with a secondary aluminum smelter
  - Al-Mg melt (anode) is circulated through the secondary Al smelter until purified
  - Mg-rich product (cathode) is removed from the top/side of the electrorefining cell



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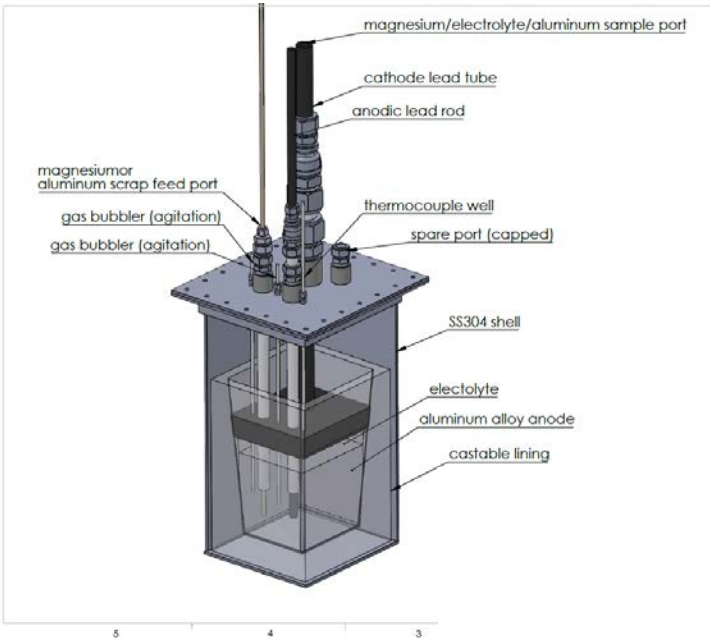
APPROACH

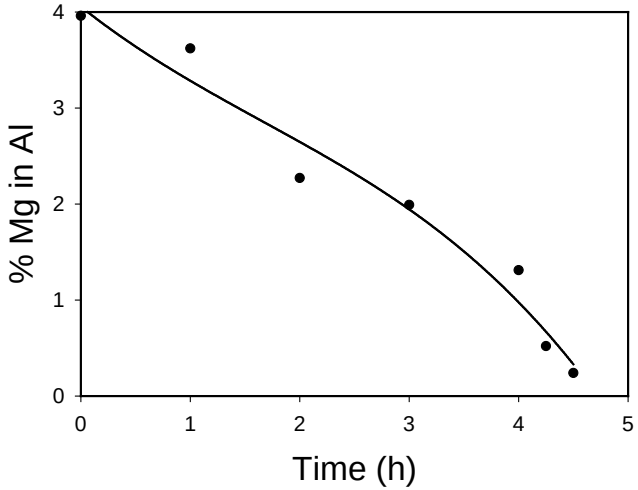
- Identify suitable electrolyte
  - Molten salt: chloride vs fluoride based
- Identify suitable materials of construction
  - Anode, cathode, container
- Design electrorefining cell
  - Up to 300A; 1.5A/cm2
- Confirm concept
  - Mg content reduction in Al-Mg melt at anode (bottom)
  - Mg-rich product recovery at cathode (top)

TECHNICAL ACCOMPLISHMENTS

- Multiple chloride and fluoride electrolyte compositions evaluated
  - Chloride-based electrolyte selected:
  - 8.1wt%$MgCl_2$-2.3MgF_2-44.5$CaCl_2$-45.1NaCl
  - Primary considerations: pre-treatment, cost, container compatibility
- Construction materials evaluated, selected:
  - Carbon/graphite anode, castable refractory side wall, iron/steel cathode
- Cell designs evaluated: three generations
- Electrorefining tests: up to 75A at 760C; 1.5A/cm^2
  - Decrease of Mg content in Al-Mg melt (bottom)
  - High purity Mg recovered at cathode (top)



TECHNICAL ACCOMPLISHMENTS



- Excellent Mg separation and purity (98.5wt%);
- ~20% of expected Mg was physically recovered from solidified cell

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COLLABORATION WITH OTHER INSTITUTIONS

- Phinix LLC
  - Inventor of original RM-12 process evaluated in ARPA-E award
  - Participated in Small Business Voucher program with Argonne
  - Cost-sharing partner in TCF project, co-inventor of revised technology
- Kingston Process Metallurgy
  - Cell materials evaluation
  - Collaborator in TCF project, co-inventor of revised technology
- Real Alloy
  - Aluminum recycling industry advisor

PROPOSED FUTURE RESEARCH

- Run multiple tests at 300A-1000A scale (pre-pilot scale)
  - Confirm and quantify operational parameters
    - Composition change at anode (depleted Mg) and cathode (purity of Mg product)
  - Stability of electrolyte during sustain operation
  - Stability of materials of construction (anode, cathode, container)
  - Recovery of Mg product
- Design, construct, and operate pilot-scale furnace (10kA)
  - Lab environment
  - Industry environment
- Design/operate prototype 300kA furnace, transfer technology to industry
  - Successful prototype demonstration will lead to establishment of a domestic low-cost Mg production industry that is integrated into existing aluminum recycling operations, and decreased aluminum cost that will enable further vehicle lightweighting
- Any proposed future work is subject to change based on funding levels

SUMMARY SLIDE

- Accomplishments
  - Process is scalable
  - No exotic materials in cell components or cell construction
  - Produces high quality magnesium that can be recovered for re-use
- Impact
  - Creates a virtual Mg smelter with no associated emissions and a decentralized low-cost on-demand domestic Mg supply
  - Enable further lightweighting of vehicles
- Future
  - Propose to proceed to pilot-scale (10kA) technology evaluation