Ultrahigh-Efficiency Aluminum Production Cells

Saving Energy and Reducing Carbon Emissions with Cell Redesign and Novel Electrolytes

This project will develop a multipolar aluminum electrolysis cell technology with an inert anode, a wetted cathode design, a novel low-temperature electrolyte, and advanced sensors and controls. These advancements will save energy, reduce greenhouse gas emissions, cut aluminum production costs, and increase productivity.

Introduction

Aluminum is an indispensable metal in modern manufacturing. Its lightweight, low density, corrosion resistance, and easy processing possibilities, coupled with its suitability for recycling, strengthen its position as the material of choice for many applications, from spacecraft components to beverage cans.

Primary aluminum (as opposed to secondary, recycled aluminum) is one of the most energy-intensive mass-produced materials. Roughly one-third of the cost to produce aluminum from ore is associated with the use of energy and associated environmental compliance. In 2003, the aluminum industry consumed more than 45 billion kilowatt-hours of electricity or 1.2% of U.S. electricity consumption. This is equivalent to the electricity used by more than 5.2 million U.S. households.[1]

Primary aluminum production also generates significant greenhouse gas emissions, contributing about 20% of the annual non-combustion carbon dioxide (CO_2) generated by U.S. industry. This is a byproduct of the consumable anodes used for electrolysis in the Hall-Héroult process, the standard means of aluminum production.

Inert anodes and wetted cathodes have significant potential advantages over the classic Hall-Héroult cells used today. Replacing consumable carbon anodes with inert anodes will drastically reduce the emission of greenhouse gases associated with the production of primary aluminum and the manufacture of carbon anodes. Wetted cathodes allow for decreased anode-cathode distances, accompanied by reduced cell voltage, temperature, and energy consumption.

The combination of these technology improvements has the potential to produce a transformational improvement in aluminum manufacturing efficiency and a similar reduction in emissions and production costs.

Laboratory-scale ultrahigh-efficiency aluminum production cell, showing the arrangement of a central metal anode and wetted cathodes.

Photo courtesy of Argonne National Laboratory.

Benefits for Our Industry and Our Nation

The development of high-efficiency aluminum production technology will produce environmental, energy, and economic benefits.

- Displace a large portion of the aluminum industry's greenhouse gas emissions
- Eliminate of the principal quantifiable source of perfluorocarbon emissions in the United States
- Reduce aluminum production costs and increase productivity

Applications in Our Nation's Industry

Improvements in aluminum production technology will benefit both U.S. aluminum manufacturers and consumers.

The aluminum industry employs more than 145,000 people in the United States.[1] Reduced electricity consumption costs will improve the industry's competitiveness in the face of increased foreign aluminum production.

The United States is the world's largest consumer of aluminum, using the metal in applications across automobiles, aircraft, boats, electronics, construction materials, packaging, electricity transmission lines, and more. Cheaper aluminum supplies could potentially reduce the costs and increase the competitiveness of U.S. manufacturing.

Project Description

The project goal is to develop a commercially-viable, multi-polar inert anode aluminum electrolysis cell technology. Accompanying enabling technologies will also be developed, including a wetted cathode design and a novel low-temperature electrolyte.

Barriers

- The impact that sodium fluoride (NaF) accumulation in the electrolyte melt has on cell efficiency, cell performance and anode stability
- Scaling successful 100-hour, 100-ampere trials of a novel low-temperature electrolyte and metallic inert anode to a new, larger 1–3 kiloampere (kA) test cell

Pathways

The project will be structured in three phases of research and development, with each new phase building on the advances of the previous phase.

In Phase 1, bench-scale research will be undertaken to determine the impact of NaF concentration on cell performance and anode stability. Phase 1 results will also provide preliminary design criteria and expected operating conditions for a later 1–3 kA test cell.

To execute Phase 2, an automated alumina feeding and aluminum tapping system will be designed. The results from Phase 1 will guide two 100 A, 500 hr continuous trials. Other laboratory work will explore the impact of electrolyte additives on anode stability and on the use of alloying elements to maintain anode stability.

After successfully completing Phase 2, the initial specifications and design of a 1–3 kA cell will be developed, followed by the construction and manufacturing of the cell. Further optimization of electrolysis conditions will continue as needed to support the cell's successful operation.

Milestones

- Technical development & preliminary economic analysis
  - Preliminary capital economics analysis (Completed)
  - 1–2-amp tests
- Scalability testing & continued economic analysis
  - 100-amp, 500-hour tests
  - Wetted cathode development
  - Anode film characterization
- Pilot scale development
  - Cell design

Commercialization

Inert anodes and wetted cathodes can be retrofitted to existing cells with minor changes to the potline infrastructure. The aluminum industry will be able to implement this technology as cells are rebuilt, rather than having to fully shut down production or prematurely replace operational capital equipment. Metal inert anodes and wetted cathodes using commercially available alloys can be produced by existing infrastructure metal fabrication shops.

Project partner Noranda produces both primary aluminum and value-added downstream products such as aluminum foil and light gauge sheet. The company is fully qualified to provide commercial perspective to the development, design, and implementation plans and to commercialize the technology once it is successfully developed.

Project Partners

Argonne National Laboratory
Argonne, IL
Principal Investigator: John N. Hryn
E-mail: jhryn@anl.gov

Kingston Process Metallurgy
Kingston, Ontario, Canada

Noranda Aluminum, Inc.
New Madrid, MO

For additional information, please contact

Glenn Strahs
Technology Manager
U.S. Department of Energy
Industrial Technologies Program
Phone: (202) 586-2305
E-mail: glenn.strahs@hq.doe.gov

(endnotes)

[1] Department of Energy Industrial Technologies Program. U.S. Energy Requirements for Aluminum Production: Historical Perspective, Theoretical Limits, and Current Practices. 2007. http://www1.eere.energy.gov/industry/aluminum/pdfs/al_theoretical.pdf

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
eere.energy.gov/informationcenter

DOE/EE-0468 • May 2011

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.