Zero-Emissions Magnesium Process Debuts

A process designed to lower the cost of magnesium metal, making it competitive with aluminum, has been an industry goal for over a century. Magnesium's density is the lowest of structural metals (35% lower than that of aluminum), and its bending-stiffness-to-weight and strength-to-weight ratios are the highest of all metals. Although magnesium metal makes up millions of today's lightweight cell phone and laptop cases, its persistently high cost (twice that of aluminum today) has impeded broad, high-volume use in other areas, including the automobile industry.

This could soon change, thanks to researchers at INFINIUM, based in Natick, MA, who have developed a low-cost, energy-efficient, zero-emissions process for making this lightweight, strong metal.

The process could be a boon to the auto industry. According to the U.S. Automotive Materials Partnership, replacing steel and aluminum vehicle parts that account for 19% of vehicle weight with magnesium parts, which weigh about half as much, could increase vehicle gas mileage by 6%. And, to meet the new U.S. EPA fuel economy standards (35.5 mpg in 2016, and 54.5 mpg in 2025), automakers envision going much further than just parts substitution, replacing half of the automobile body with magnesium alloy components.

Most magnesium is now made by one of two processes. The first, which is used in China to produce 85% of the world's magnesium, involves reducing magnesium oxide (MgO) with ferrosilicon. This process is four times more energy intensive than today's aluminum production process. The remaining 15% of the world's magnesium metal is produced via electrolysis of anhydrous magnesium chloride, a raw material that costs more than twice that of magnesium oxide per ton of produced metal. This electrolysis process, which is practiced at a single plant in the U.S. and at plants in Israel and Russia, emits harmful chlorine, polychlorinated biphenyls (PCBs), and other contaminants; the U.S. facility has been declared a Superfund site.

INFINIUM's process, called MagGen, is a low-cost modular approach to magnesium production. It involves the electrolysis of MgO dissolved in a pool of molten magnesium and calcium fluoride salts.

Even though the MagGen process is similar to the dominant Hall-Héroult (H-H) electrolysis process for aluminum production, key innovations eliminate shortcomings associated with the H-H method. For example, unlike the carbon anode used in the H-H process, the zirconia anode used in the MagGen process is very oxygen-selective, which blocks harmful gases such as hydrofluoric acid from entering the anode gas stream and prevents the formation of perfluorocarbons — both of which are perennial problems in the aluminum industry. This feature also results in a high-purity oxygen byproduct. The zirconia anode prevents undesired reactions between metal produced at the cathode and gas produced at the anode, which is a problem that lowers efficiency in the H-H process. The MagGen process operates above magnesium's 1,090°C boiling point, enabling inline distillation to produce high-purity metal from commercial-purity oxide. And, it operates in an inexpensive, well-insulated, welded steel crucible, with much lower heat loss than that from the H-H cell.

The MgO raw material is abundant and cheap. Millions of tons are produced every year, primarily for water softening and agricultural use, mainly by magnesium hydroxide precipitation from brines or seawater.

Without the need for pollution abatement equipment and permits, the modular MagGen process can be scaled to magnesium mini-mills operating at MgO production plants or customer sites, cutting shipping costs and energy usage dramatically. INFINIUM CTO Adam Powell says, "MagGen, with its distributed mini-mill production capability and pure oxygen gas co-product, creates more value for a mill operator and transforms the environmental and economic landscape for magnesium production. We're looking to make magnesium cost-effective for a new generation of ultra-lightweight vehicles."

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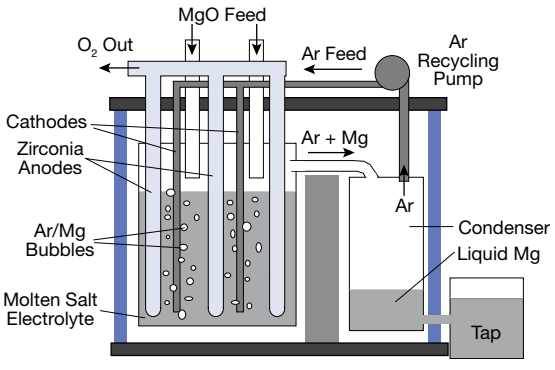

▶ In the MagGen process, MgO is fed into the electrolysis cell, where it dissolves in molten salt to form Mg^{2+} and O^{2-} ions. The O^{2-} ions migrate through the salt and zirconia tubes and form high-purity oxygen gas at the anodes, and Mg^{2+} ions form magnesium metal vapor at the cathodes. Argon dilutes the Mg metal vapor to prevent it from reacting with zirconia. The argon travels with the Mg metal vapor to the condenser and is recycled in a closed loop. Liquid magnesium can be drawn from the condenser. Image courtesy of INFINIUM.

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