Unlocking Aluminum: Scientists Gain a New Perspective in Understanding the Chemistry Behind Aluminum

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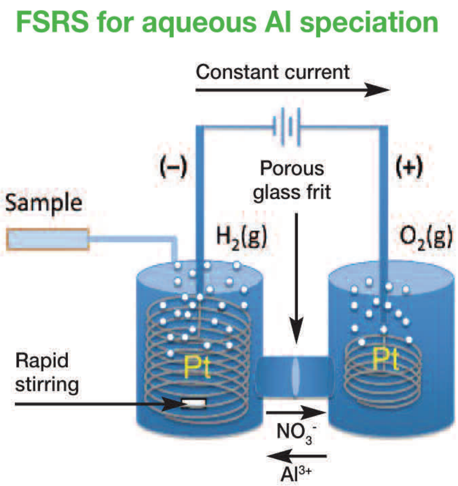

Cell for $Al(NO_3)_3$ (aq) electrolysis.

If it works, go with it—but why? Why does a material work the way it does, in this case, aluminum. A detailed understanding of this metal's water-based forms proved elusive until recently, when researchers unlocked a new world of potential for this ductile material. Now, the metal complex can be studies at a molecular level, creating possibilities for advances in numerous industries.

After more than 100 years of commercial use without a breakdown of aluminum at a molecular level, this latest breakthrough is significant. "Suddenly we have this solution-based, bottom-up approach starting from the molecular-level construct and that's how cool this is—scientists have developed these protocols to preform targeted synthesis of aluminum hydroxide clusters (Al_{13}) in water, which can be readily used as a 'green' solution precursor for large-scale preparation of aluminum oxide thin films and nanoparticles for electronics, catalysis, photovoltaics and corrosion prevention," says **Chong Fang**, assistant professor at Oregon State University's Department of Chemistry. Oregon State, The University of Oregon and the Center for Sustainable Materials Chemistry, have combined efforts to work on the metal's breakdown.

Fang is one of nine researchers involved in the collaborative report, "Electrolytic synthesis of aqueous aluminum nanoclusters and in situ characterization by femtosecond Raman spectroscopy and computations." Published in *Proceedings of the National Academy of Sciences*, the report lays out how a new electrolysis method is used to control precisely during aqueous cluster synthesis without steep pH gradients commonly associated with base titrations.

Bottom-up approach

Until now, there has been no effective way to study aluminum. "Before, researchers used a limited arsenal of tools to characterize certain types of aluminum species, but usually with limited access to detailed molecular-level structure and dynamics," Fang says.

After silicon, aluminum is the second most abundant metallic element in the Earth's crust, according to the U.S. Geological Survey. While plentiful in supply, it has only been produced for commercial use for a little more than 100 years. At one point in the mid-1800s, aluminum was harder to find and considered more valuable than gold. Today, however, aluminum is produced on a massive scale, with five companies operating 10 primary aluminum smelters in the U.S. The USGS reported the value of primary domestic metal production in 2012 was $4.32 billion.

Aluminum is obtained from bauxite, which contains a mixture of hydrous aluminum oxides difficult to extract from ore because of its high reactivity and high melting point. Producing aluminum is labor and resource intensive. Four tons of bauxite are required to produce two tons of alumina, resulting in one ton of aluminum, according to The Aluminum Association. Over the years, aluminum producers have reduced the amount of energy consumption per unit of aluminum by 70 percent. While expensive, this lightweight recyclable metal is used in a wide range of applications. Recycled aluminum is cheaper than aluminum produced from ore and promotes sustainability. It can be recycled over and over again without losing quality, according to The Aluminum Association, which also notes 75 percent of all aluminum ever smelted is still in use today.

Complementary uses

A silicon-based solar cell is typically used when working with aluminum films. Such films are useful in energy applications, particularly within the solar power sector. "It has been demonstrated that coating a thin aluminum-based film on top of a semiconductor can actually increase the light trapping and harvest sunlight more effectively. A good example is that Al_2O_3, thin film has gained popularity as a high-quality surface passivation material, "Fang says.

By uncovering this new approach to aluminum nanoclusters, Fang says the future holds new ways to generate new species of aluminum. "As far as we know, people have not extensively explored this territory using solution-based aluminum speciation, where you easily encounter a variety of complex potentials, different compositions," he says. "Once water goes away after dehydration at an elevated pH, then you're left with versatile metal oxide films. Those are the products that hold transformative impact as society shifts toward more sustainable, greener, cheaper ways of getting and using energy."

FSRS setup that enabled this breakthrough