Iowa lab gets critical materials research center

The DOE hub is set to be the largest R&D effort toward alleviating the global shortage of rare earth metals.

The newly created Critical Materials Institute at the Ames Laboratory has the goals of expanding the supply and minimizing the use of rare earth metals and other scarce elements. The CMI, whose participants include three other Department of Energy labs, US universities, and suppliers and end users of the elements, was selected from among proposals submitted in response to a 2012 DOE solicitation (see PHYSICS TODAY, July 2012, page 28).

Located at Iowa State University, the DOE-owned Ames Laboratory has a history of materials R&D and a particular specialty in rare-earth elements. The fifth of DOE's "energy innovation hubs," the CMI is scheduled to receive $120 million in federal funding over five years.

Rare-earth metals and other critical elements, such as germanium, tellurium, and platinum, are essential in a wide variety of electronic, energy, environmental, and military applications. In recent years consumption of the materials has grown rapidly along with demand for items such as flat-panel displays, hybrid vehicles, and clean-energy technologies. Supply from outside China has been slow to respond, due largely to the lack of investment and long lead times to bring new mines into production. The result is that China has gained a near-monopoly on the supply of rare-earth metals (see PHYSICS TODAY, May 2010, page 22).

In a 2011 report, DOE identified five rare-earth elements whose supply could affect clean-energy-technology deployment in the coming years: neodymium, dysprosium, terbium, europium, and yttrium.

Alex King, director of Ames and the new institute, says that one of the CMI's objectives is "to make mining a viable option no matter where alternative resources exist. We want to get away from having just a single source of any material, including rare earths, and mines must be able to survive on a straightforward economic basis, under whatever constraints they have to operate." He notes that Molycorp, a CMI member and operator of the only US rare-earth mine, must function under California's very strict environmental requirements. Part of the Ames center's mission will be to help mines and material processors meet regulatory requirements at the lowest cost.

Switching magnets

The CMI also will be looking for substitute materials that don't require rare earths or that minimize their use. King cautions that finding replacements with the desired properties won't be easy, but he cites one instance in which substitution notably succeeded: Today's neodymium iron boron permanent magnets, used in hybrid electric vehicle motors, computer hard drives, wind turbines, and other applications, were first developed in response to a near cutoff in the world supply of cobalt in the 1970s following a revolt in what was then Zaire. "We were able to substitute [NdFeB] to take the place of samarium cobalt, which was then the best magnet in the world," King says. "We're trying to do that trick once again, invent a new material that will take the place of [NdFeB] and have equivalent properties."

If a magnet made without NdFeB doesn't perform as well, other components will have to be redesigned around that magnet, King says. "If it is in a motor, the motor needs to be redesigned. If it's in a loudspeaker, the loudspeaker has to be redesigned."

General Electric, a CMI member, uses rare earths in its lighting, healthcare, energy-generation, wind-turbine, nuclear-fuel, and other products, says Steven Duclos, senior scientist at GE Global Research. The company uses 72 of the first 82 elements of the periodic table, he notes, and rare earths are "very high on our list of materials that exhibited a lack of availability."

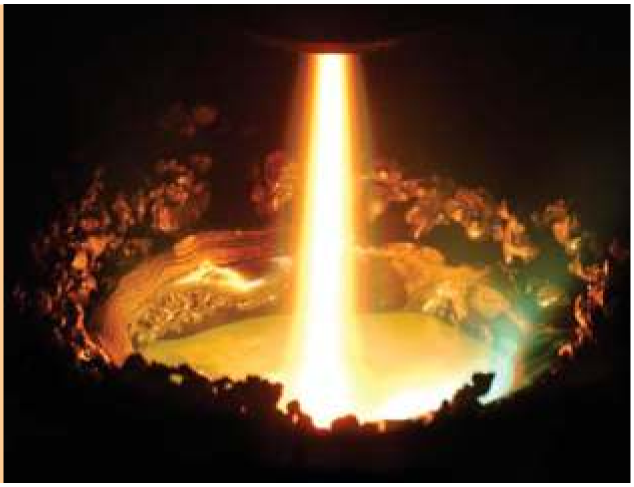
For materials recognized as being at risk, mitigating measures include "manufacturing more efficiently, making sure we have the capability of recycling materials out of the product at end of life, ensuring we have more avenues for doing substitutions, and working with the sources we have for these materials," Duclos says.

Improving the extraction of rare earths from crushed rock will be one of the CMI's focus areas. "We're going to be engaged in some very high-end chemistry, chemical computation, and lab testing techniques to improve the separation of rocks," says King. "Then there are increasingly sophisticated kinds of chemistry involved in separating rare earths from the rocks in which they're embedded."

Beyond rare earths

The CMI hopes to resolve rare-earth issues "in reasonably short order," King says, and move on to other "near-critical materials," such as lithium. Demand for the light metal is expected to soar with the production of lithium-ion batteries for electric vehicles.

Other research efforts around the world address specific critical element challenges. Recovering and recycling precious metals is the focus of an international collaboration of researchers at the University of York, the University of British Columbia, and Yale University. Andrew Hunt, a chemist at York, says the three-year project, funded by the G-8 nations' Research Councils Initiative on Multilateral Research Funding, is exploring



AMES LABORATORY

The plasma torch in the Retech plasma furnace is one tool used in the materials preparation center at the Ames Laboratory to create ultrapure metal alloy samples, particularly of rare-earth metals.

AMES LABORATORY

A vacuum induction furnace at Ames Lab being used to distill a rare-earth metal. The red induction coil surrounds a quartz vacuum tube. The glowing cylinder at the top is the condenser, which collects the metal.

the use of phytoremediation to recover platinum-group metals from in-ground or aqueous waste streams such as mining and electronic wastes, landfills, and wastewater.

The research involves increasing the uptake of metals by plants that are then harvested and converted to a charcoal-like material. The carbonized matter containing the metals is then used directly to catalyze carbon–carbon bond formation employed widely in the pharmaceutical industry. Much of the research is devoted to finding plant species that are fast-growing "hyper-accumulators" of the metals, and investigating the biological routes of metal uptake. Although platinum-group metals and gold are the initial focus, Hunt says that the collaboration also hopes to broaden into the recovery of rare earths.

The development of permanent magnets not containing rare earths is the focus of numerous US and international research collaborations. Several of those focus on the use of manganese composites.

King says Japan has several ongoing efforts. "Early on it created a program that it called urban mining, which is actually a recycling program. They're mining scrap heaps." Japanese appliances like refrigerators and air conditioners have rare-earth magnets in their motors, and recycling those rare earths is part of the program. And Japan's National Institute for Materials Science has created a program for advanced strategic materials that's comparable to some of the research at Ames, he adds.

An opaque market

A critical materials initiative begun last year at Curtin University in Perth, Australia, will focus on advising governments and industrial clients on what lies ahead for the supply and prices for rare earths, says its head, Dudley Kingsnorth, a widely recognized authority on the metals. "We can put a virtual team together which can look at all the steps in the supply chain. Then we can assess the economic and technological barriers for a company to be independent of China in the case of rare earths."

Due to China's dominance of rare earths, little information about supply is publicly available, and the sector can be volatile. China halted rare-earth shipments to Japan in 2011. As a result, prices surged for permanent magnets and electric motors used in hybrids and wind turbines. And the popularity of iPods and mobile tablets created a sudden unforeseen demand for cerium, which is used to polish the high-quality glass screens.

As new mines continue to come on line in the US, Australia, Malaysia, India, and Kazakhstan, China's share of the rare-earth supply will decline from a high of 95–97% in 2010 to 70–75% over the next three or four years, Kingsnorth predicts. Many of the heavier rare-earth elements, notably dysprosium, terbium, europium, and yttrium, are expected to remain scarce and expensive, however, with no new production expected for at least six years. The latter three are used in lighting phosphors. Fluorescent lamps, already segregated from other wastes due to their mercury content, offer a promising opportunity for recovery and recycling.

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