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E-SCRAP NEWS

Rare earth well done

By Alex King and Eric Peterson

With China moving to reduce exports of rare earth materials, recovery of those metals in old electronics has become a growing business. Our authors offer an overview on which materials are being targeted and what methods are creating the most enticing opportunities in the sector.

The Critical Materials Institute, a U.S. Department of Energy Innovation Hub, is pursuing energy- and cost-efficient rare-earth recycling processes, and is exploring new ways to recover the rare-earth metals neodymium and dysprosium through the recycling of e-scrap – particularly hard disk drives.

But that's not necessarily easy. The challenges of e-scrap recycling, or "urban mining," are different and, in some ways, more difficult than mining these materials straight out of the ground.

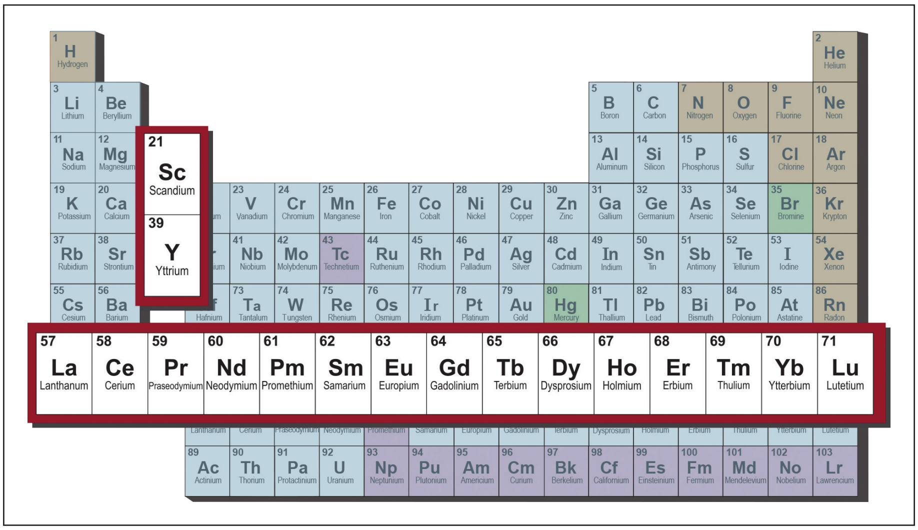
At CMI, we are working on removing the barriers to recycling by developing new processes and technologies to simplify the extraction of neodymium and dysprosium and make the process more cost-effective.

When rare earths became critical materials

Critical materials are elements or compounds essential for the manufacture of a particular device or technology that are not easily replaceable with other materials and have supply chains that are vulnerable to disruption. The rare earths are the poster children for critical materials.

If you had not heard of rare earths before 2010, that would not have been too surprising. But when prices for these exotic metals rose by as much as 2,500 percent, these materials were suddenly the center of attention. While prices have declined to just three or four times what they were before 2010, there is still great concern about the supplies of some of these materials because the limited number of sources still leaves us with vulnerable supply chains. Even with the opening of mines at Mountain Pass, California and Mount Weld, Australia, more than 80 percent of the world's supply comes from China.

The rare earths, or rare earth elements, are 17 chemical elements that include scandium, yttrium, and all of the lanthanide series.



The periodic table with the 17 rare earths highlighted

The materials are commonly discussed as a group because they have very similar chemical properties, and are usually found together in geological resources. Although they have similar chemical properties, the elements have a wide range of physical properties, which make them important in specific applications. Neodymium, sometimes in combination with dysprosium, is alloyed with iron and boron to make the strongest permanent magnets available today. Those magnets show up in applications where high-field magnetic strength and low weight are desirable – such as electric motors in cars, loudspeakers, microphones, earbud headphones and generators in some wind turbines. Rare earths also exist in every hard disk drive, in the spindle motor that turns the disk itself, and in the voice-coil motor that positions the read/write head.

In fact, the biggest single use of rare-earth permanent magnets today is in disk drives – though the magnets in each drive are relatively small, the world consumes about 550 million new units every year and discards correspondingly large numbers, too.

Hard disk drives contain rare earths in their spindle and voice-coil motors.

Recovery process has many steps

Developing new sources of materials can be a slow process – it usually takes more than a decade to bring a new mine online. Inventing alternative materials is historically even slower – it takes about two decades to invent a new material and get it qualified for use in a product. By comparison, improving on the use of existing resources can have a much quicker impact. This is why Japan's first approach to remedying the criticality of the rare earths was a program of "urban mining," or recycling.

CMI is researching the recovery of neodymium and dysprosium through recycling of hard disk drives. Targets for recycling include the spindle motor and the voice-coil motor in the hard disk drive, but the primary focus is on the voice-coil motor, since this is larger, more accessible, and easier to extract in one piece.

What is the Critical Materials Institute?

The Critical Materials Institute is a scientific research powerhouse that resulted from the U.S. government's growing concerns about narrowing global supply and increasing demand for rare-earth and other elements, ones key to clean energy technologies as well as to consumer electronics.

These are elements that most people might only vaguely remember from high school chemistry and the periodic table, but they are everywhere. They exist in wind turbines, vehicles, lighting, cell phones, computers and televisions. Unstable supplies of these materials have the potential to threaten our energy security and disrupt our economy.

In response, the Critical Materials Institute was launched in 2013 with the goal of finding new technologies that will reduce our reliance on these elements through a variety of approaches: improving manufacturing and recycling methods, developing substitutes, and diversifying existing supplies.

CMI is led by the U.S. Department of Energy's Ames Laboratory in Ames, Iowa, and is a collaboration of four DOE national laboratories, researchers from seven universities, and members of industry. Selected through an open national competition, it is the fifth Energy Innovation Hub established by the Department of Energy since 2010. Energy Innovation Hubs are major integrated research centers that combine basic and applied research with engineering to accelerate scientific discovery in areas crucial to energy independence.

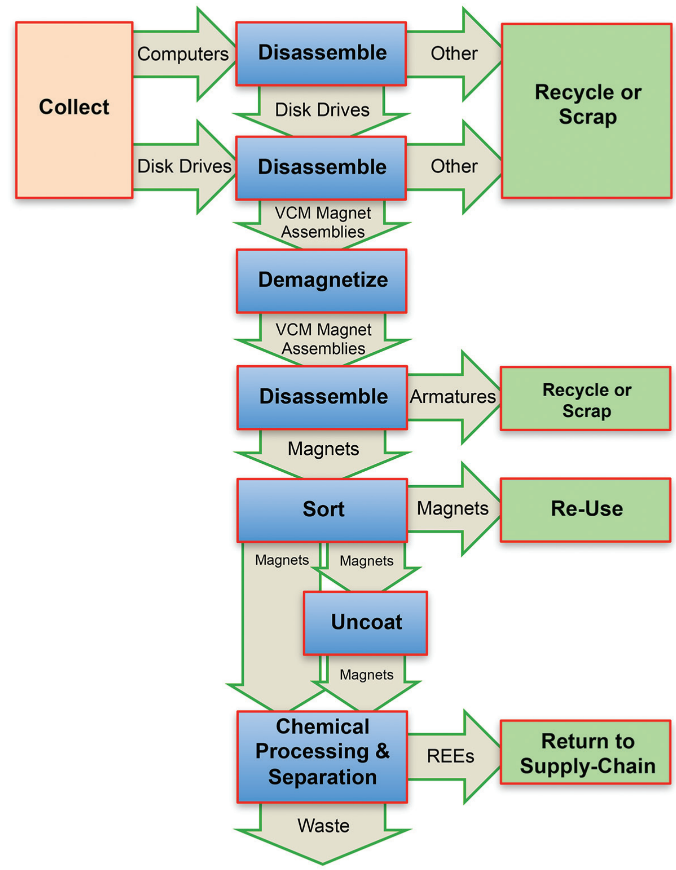
That acceleration is vital to meeting the challenge presented by 21st century rare-earth metals supply and demand, and CMI has recently proven it with 11 invention disclosures in its first year of operation.

Traditionally, the scientific research process can take 10 to 20 years to yield results that can be applied on a commercial scale. The hub concept – with academia, national laboratories, and industry partners working together – can shorten that time considerably.

For more information, visit cmi.ameslab.gov.

Punched out disk and magnet.

Recycling flow chart



Collection of used hard disks is a challenge. It is necessary to assure a good solid supply in order to make the process financially viable. As a guide to the scale of the needs, it would take around a half-million hard disks to provide enough rare earths to make one direct-drive wind turbine. In the interest of data protection, many corporate and governmental users prefer to shred their hard disks rather than offering them to a recycler as whole units. This makes it hard to recover the resulting particles of the magnets, because they stick to the ferrous components of the disk or the shredding device.

The current preferred process involves the collection of whole disk drives, which can be disassembled to collect the printed circuit board (which contains precious metals), and the voice-coil motor magnets.

Once the magnet is out of the disk drive, the printed circuit board can also be recovered, but the magnet has to be demagnetized immediately; these magnets are powerful and they can be quite dangerous around other magnets or ferrous materials. Although it would be safer to demagnetize the magnet before separating it from the disk drive unit, it costs less to demagnetize it afterwards. Demagnetizing is normally achieved by heating these magnets to about 300 degrees Celsius (570 degrees Fahrenheit). Heating a whole disk drive takes significantly more energy than heating only the magnet, and also carries the risk of releasing poisonous gases from decomposing chemicals in the drive.

After the magnet is demagnetized, it has to be separated from its support bracket, to which it is usually glued. At this point, the chemical elements have to be recovered from the magnet but there are more complications.

These magnets are coated to protect them from corrosion, either by painting or by encasing them in nickel, or a layer of copper with a topping layer of nickel; these coatings must be removed. After the coating is dealt with, the process is still not done. These are typically "sintered" magnets, which are easier to deal with than "bonded" ones that contain a lot of glue, but there may be two sintered magnets glued together, and the process would ideally separate the glue to prevent contamination of the magnet materials.

CMI is working on several approaches to this process to simplify it and to reduce recovery costs.

One is a design-for-disassembly approach to reduce the time and cost of disassembling disk drives. Rather than disassemble a drive, we would recommend punching out a disk that contains the voice-coil motor if the location can be identified accurately enough without removing the case.

CMI is also conducting research to determine whether it is optimal to remove the coating before recovering the magnet materials, or to shred the whole unit and separate the copper, nickel or paint by chemical processes.

It's a multi-step process with several choices and options to consider. In its first year CMI has focused on identifying a variety of approaches to managing rare earth metals resources, including recycling techniques, extractive technologies and other processes that can interlock to streamline the recovery process. As CMI looks beyond our beginnings, we are refining our approaches, seeking new ideas and looking for new partners to realize success in this area. ESN

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