STAR 2015

Growing role seen for rare earths as world pushes ahead on 'green' technology agenda; supply constraints, recycling issues remain key challenges

The Japanese rightly called them 'the seeds of technology'; while in US it is the 'technology metals'. Unknown to most lay persons, these elements make possible the high-tech world we take for granted today – from electronics, medical technologies and novel 'green' energy solutions, to supporting a myriad of essential telecommunications and defence systems. These elements have come to be recognised as the vital cog in the world of technology owing to their unique magnetic, phosphorescent and catalytic properties. Even though the amount of these elements used in these high tech equipment is nominal, almost always it is critical to the unit's performance.

These elements – incongruously termed the 'rare earths' – are a set of 17 elements in the periodic table, specifically the 15 lanthanides plus scandium and yttrium, since they tend to occur in the same ore deposits as the lanthanides and exhibit similar chemical properties. Rare earths are in fact not that rare, and are relatively abundant in the Earth's crust. However, it is quite rare to find them in quantities significant enough to support economic mineral development.

Dominance of China

The mining, separation and processing of rare earths is expensive and rarely eco-friendly. The high costs and damaging techniques pushed most rare earth mines out of business in the early 1990s. Aided by a lax environmental regulatory regime, China kept its mines going, positioning itself for the ensuing high-tech boom, and is now both the dominant supplier and leading consumer of rare earths ahead of Japan and the US. In 2010 and 2011, China, controlling 97% of global rare earths production, clamped down on trade by imposing export restrictions and raising tariffs as it sought higher prices to help cover the environmental costs of production and tried to encourage the growth of domestic industries that use rare earths. The average price of rare earths – including terbium and europium, used in fluorescent bulbs; and neodymium, used in the powerful magnets that help to drive wind turbines and electric engines – shot up by as much as 750% in a year.

This resulted in global consumers scrabbling for supplies and with it came uncertainty in the market place and significant price volatility. Concerns were partly addressed last month, when China removed some restrictions on rare earths exports following an order by the World Trade Organisation (WTO).

All these developments managed to drag the rare earths out of relative obscurity and right into the vision statements and future planning policies of governments around the world. But the threat of future supply problems for rare earths still looms.

It was perhaps fitting that the state

Prof. Alex King

of Kerala – known for its rich reserves of rare earth elements – recently hosted an eclectic gathering of leading scientists, industry experts, businessmen, academicians, research students and others working in the field of rare earths. The occasion was the 'International Conference on Science, Technology and Applications of Rare Earths – 2015 (ICSTAR 2015)' organised by the Rare Earth Association of India (REAI) at Kovalam, Thiruvananthapuram. Presentations made at the conference covered the entire gamut of the value chain – from extraction, separation, recovery & recycling to applications in nanomaterials & pigments, light emitting diodes (LED), magnetic materials, etc.

Lessons from the past

Speaking about the crisis in the availability of rare earths and the huge dependency on a single supply source, Prof. Alex King, Director of the Critical Materials Institute, The Ames Laboratory, USA, in his keynote address, explained how we could learn from such instances in the past.

"Several times since the beginning of the industrial revolution, there have been instances when certain materials have fallen into short supply. The reasons for such high supply risk have been the concentration of production of these materials in just a few countries, low recycling rates and poor substitutability," he said. The Bronze Age, around 2,000 years ago, caused copper supplies to run dry. In response, Prof. King pointed out, the ancients recycled bronze, looked for new mines, and spent 200 years optimising the more-available but less-ideal alternative – iron – to do the same job.

"We need to anticipate which materials will become critical and not just respond to the shortage when it happens. We need to look for suitable replacements and the time lines are not 200 years anymore," said Prof. King.

"While it took 200 years to replace copper with iron, now in 2000, it takes about 20 years to replace a metal in applications," pointed out Mr. R.N. Patra, President of REAI and Chairman & Managing Director, Indian Rare Earths Ltd.

Impact on green technologies

Given that the rare earths have such a vital role to play in the global push to reduce greenhouse gas emissions and enhance energy efficiency, the shortage of rare earths used in 'green' technology solutions like electric car batteries, solar panels and wind turbines, is hampering the growth of renewable energy technologies. Experts at the conference highlighted current research in finding alternatives to these critical elements, new sources or better ways to recycle them.

Dr. Suresh Das, Executive Vice President, Kerala State Council for Science, Technology and Environment (KSCSTE) and Principal Secretary, S&T Department, Govt. of Kerala, emphasised that sustainable development would need greener sources of energy. "Worldwide this is leading to a great deal of interest in development of alternative sources of energy such as wind and solar energy, rechargeable batteries, hybrid cars and LEDs, etc. The success of many of these sustainable energy technologies will depend on the availability of rare earths," he stressed.

A typical hybrid car, for example, would need approximately 500-gm of neodymium for the magnets that drive the engines. And a typical wind turbine will need about 1,000-gm of neodymium, he said. Magnetic refrigeration is a hot new area for energy-efficient technology that can handle cooling and climate control and this technology too needs rare earth components. "With energy becoming a scarce resource, rare earths will only gain in importance in the future and that is why it is sometimes now referred to as the next oil," he said.

According to Prof. King, more reliable wind turbines can be made without the need for fragile gearboxes, but it would require huge amounts of neodymium for use as permanent magnets in the direct-drive wind turbines. Thin, cheap solar panels need tellurium, while high-performance batteries need lithium.

For this shift to 'green' technologies to happen in a truly sustainable manner, the mining of the key resource materials has to be done in a sustainable manner, said Dr. Das. "Without making the sourcing of these materials sustainable, the energy technologies obtained from these cannot be considered as sustainable. Several instances in China and US have shown that uncontrolled mining can lead to some deleterious effect on the environment. The same countries have also shown that with suitable restraints and newer technologies, sustainable mining can indeed be made possible," Dr. Das remarked.

New sources

Meanwhile, the search for new sources of rare earths is gaining momentum around the world – about 450 potential rare earth mines are being looked at around the world, according to experts. Countries like the US, Australia, Brazil and India are ramping up efforts and this is reported to have reduced China's production share from 97% to about 90% in the recent past. According to Prof. Brajendra Mishra, Colorado School of Mines, USA, by the end of the decade, China will have only about 60% share, as other countries work on becoming self-sufficient.

Another unconventional source of rare earth elements is in phosphates dug up for fertilisers. "In rock phosphate there is more rare earths (lanthanum) than uranium. So it makes sense to extract these rare earths along with uranium. India imports about 1-mtpa of rock phosphate. There is the need to look at extracting rare earths as a by-product of uranium from phosphoric acid," said Mr. Patra.

Another place to find more rare earth elements is in tailing heaps – big piles of deposited rock from mines that can contain the elements that are being mined. A good mine will extract 50-60% of the elements from the mine, the other 40-50% will end up in tailing heaps. Rocks in these tailing heaps require more advanced equipment to extract the elements.

Step up recycling

Despite the high cost and high demand of these elements, very little – less than 1% – is recycled, pointed out many speakers.

Prof. B.D. Pandey, CSIR-National Metallurgical Laboratory, Jamshedpur, underlined the urgent need to consider end-of the-life rare earth containing materials as a rich resource and develop appropriate recycling technologies. Major secondary resources include electronic wastes, industrial wastes, spent catalysts & magnets, and phosphors powder.

Recovery of rare earths from electronic waste is an area that requires a lot of research, emphasised Dr. Das. "The huge amount of electronic waste if not properly handled would end up in putting this precious resource mined from the earth at such high economic and environment costs, back into the earth," he added.

However, according to Prof. King, getting these elements out of modern devices is not a simple process, since they are incorporated in tiny amounts into increasingly complex devices. Today's mobile phones contain about 75 elements from the periodic table, compared to 30 in the 2000s.

Despite the relatively high concentrations of rare earths in technology, it is actually chemically easier to separate them from the surrounding material in simple rocks than in complicated phones, he said.

Sustainable use

In the backdrop of supply constraints and difficulties in recycling the minute amounts from end products, there is immense interest in looking for substitutes that are not so critical and expensive. Prof. King talked about how cobalt prices spiked in 1978 as the world was dependent on a single source – Sierra Leone (now Congo). "The prices of cobalt have been unstable ever since. However, it has now been eliminated in many applications," he said. However, he pointed out that finding substitutes for rare earths would not be easy given the almost 'magical' properties of the elements. The key would be to look at replacing the most expensive and rarest of the rare earths.

According to the experts, the scientific community and industry should redouble efforts to use rare earth elements in a more sustainable way, including increasing material efficiency in production processes and products, and closing material cycles.

CALL FOR CHANGE

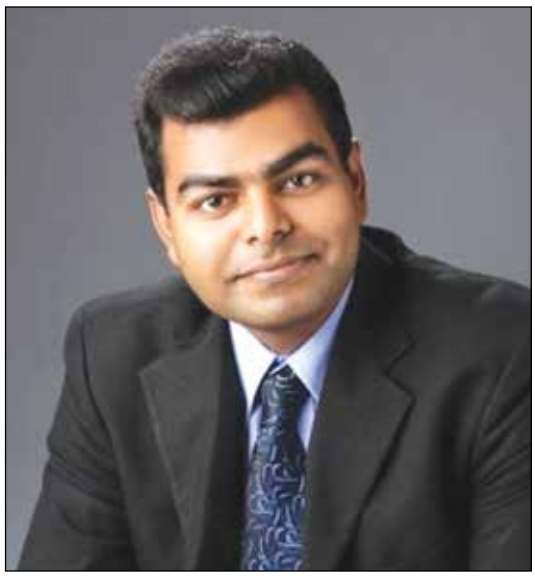
'Allow private players to produce & process monazite to rare earth elements'

Mr. V. Subramanian, Director of Tamil Nadu-based VV Minerals, has called on the government to allow private heavy mineral producers in India to produce monazite and further process the mineral to produce rare earth elements.

Monazite is one of the sources of rare earth elements and as per the latest survey estimates by Geological Survey of India, monazite reserves of India is estimated to be around 11.93-mt, almost half of the identified monazite reserves of the world, informed Mr. Subramanian.

Monazite normally occurs along with other heavy minerals like ilmenite, rutile, zircon, garnet and sillimanite as an associate mineral. Monazite production and processing is restricted to the government sector in India. "Indian Rare Earths Ltd. (IREL) is the only organisation permitted to produce and process monazite. The company had stopped production and processing of monazite from 2004 onwards. Presently, IREL is setting up a facility to process around 10,000-tpa of monazite and the facility is yet to go into operation," said Mr. Subramanian.

This accounts for only 0.1% of the identified reserves in India and there is ample scope for increasing the processing capacity in India, he noted. "The next big step must be to permit other heavy mineral producers in India to produce monazite and further process the mineral to produce rare earth elements; the consequent output of thorium and uranium can be handed over to the government for meeting nuclear fuel requirements. This will enable our country to have a presence in the world market for rare earth elements and also to reduce imports," he added.



Mr. V. Subramanian

Dr. R. Gopalan, International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), noted that the capability in India for exploring the rare earth ore into useful products is still at laboratory level. "In rare earth metal extraction India has expertise at the laboratory level and the potential is yet to be fully explored to meet the magnet technology demand for automotive and aerospace industries," he said.

India ramps up production

Like several countries, India is looking to tap into its rare earths reserves to ensure a steady supply and reduce the monopoly of China. India is the second largest producer of rare earths with an annual production capacity of 2,800-tonnes, much below China's 105,000-tonnes, but ahead of Australia, Brazil and Malaysia.

According to Dr. M.L.P. Reddy, Chief Scientist & Head, Materials Sciences & Technology Division, CSIR-NIIST, Thiruvananthapuram, there is a huge potential for India to increase domestic production and become self-sufficient in the sector. India's reliance on rare earth imports has grown in recent years, partly due to natural calamities in rare earths producing areas, but production is expected to increase in the coming months.

IREL's Odisha monazite plant is expected to be running from October this year. IREL, in collaboration with Japan's Toyota Tsusho Company, is also planning to set up a plant in Visakhapatnam for the production of mixed rare earth materials from uranium and thorium ores, which the Japanese company will use to produce neodymium for electric and hybrid cars, as well as lanthanum, cerium and praseodymium. This will further increase India's rare earths production by about 2,000-tonnes to 2,300-tonnes annually, according to experts.

IREL has also retrofitted its facilities at Aluva (Kerala) to process about 5,000-tpa of mixed rare earth chlorides and to produce separated high purity rare earths. Further, IREL has entered into a MoU with the Bhabha Atomic Research Centre and the Defence Metallurgical Research Laboratory for developing technology to produce rare earth metals and magnets.