ISSN 2063-5346

RECOVERY OF RARE EARTH ELEMENTS FROM ELECTRONICS WASTE ITEMS & ENVIRONMENTAL FOOT PRINTS: A REVIEW

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Abstract:

Rare earth elements (REEs) are used in a various industrial product. The demand for rare earth elements is growing at a rate of 3.7–8.6% annually. Yttrium (Y), europium (Eu), cerium (Ce), lanthanum (La), and terbium (Tb) rare earths are used for fluorescent lamps (FLs). In this review paper various techniques associated with the recycling and recovery of REEs in phosphors from waste FLs& other electronics items & their environmental impact is discussed. (Binneman’s et al,2013) Demands for rare earth elements (REEs) has been increased due to fast technological development such as permanent magnet, green energy, defence related applications, efficient fuel vehicles, and fluorescent lamps, etc. There is need to develop alternative routes for rare earth production and supply. As the demand of rare earth is increasing day by day in various industrial products eg permanent magnets, lamp phosphors, rechargeable Ni-MH batteries and catalysts

Keywords: Reculing, Rare earths, waste, Industrial Products

1. Introduction:

Rare earth elements are classified into two groups one is light rare earth elements (LREEs) and another one is heavy rare earth elements (HREEs). This classification is based on their electron defined as the heavy rare earth elements. (Cox. et al. 2004) All the heavy rare earth elements have 'paired' configuration. Lanthanum through gadolinium, as atomic number 57 to 71 is defined as light rare earth elements. Terbium through lutetium, atomic number 65 to 71, and also yttrium (atomic number 39) are electrons whereas the light rare earth elements have unpaired electrons, from 0 to 7. Yttrium is lighter than the light rare earths, but it is (lanthanide series) in the HREEs group because of its similar ionic radius, chemical properties and physical associations with heavy rare earths in natural deposits. The HREEs are available in nature in trace amount but more valuable **(**Agarwala et al. 1996**)**. Cerium, the most abundant rare earth then promethium which is virtually unknown in ore deposits because it undergoes radioactive decay. One intriguing aspect of the lanthanides is that the odd-numbered elements are less common than the even numbered ones. Various physical properties of rare earth hardness, density and melting point increases from cerium to lutetium. (Gour et al. 2014) China accounts for 36% of world ‘s reserves of rare earths and producer of over 95% of world output of rare earth minerals. The United States is one of the largest consumers and importer of rare earths.

The unfilled 4f electronic structure of rare earth elements exhibit unusual luminescence, magnetism, and electronics capabilities that might be utilised to generate numerous novel materials. (Nash et al. 1993)

2. Applications of Rare Earth

In country like USA and Japan they are used rare earth in almost all guided missile systems, advanced sonar, secure communication systems, advanced jet aircraft engines, advanced Armor, advanced radar, stealth technologies targeting and triggering systems. Furthermore, rare earth metals are essential alloying elements in steels. Electric and hybrid cars can contain 20-25 pounds of rare earths, which is double that found in a standard gasoline vehicle (Kennedy,2009). The battery itself is made from several pounds of rare earth compounds. REEs are also employed in electric traction motors and regenerative braking systems. The motors are powered by neodymium and dysprosium magnets. The motors consist of powerful magnets made from neodymium and dysprosium. REEs are also used to make high-capacity wind turbines, advanced solar panels, high efficiency lighting, petroleum and pollution control catalysts for automobiles and high-speed rails (Mei et al. 2009). Rare earths are also useful in refrigeration and cooling applications which can help reduce fossil fuel consumption by 15%. They are also extensively useful in fibre optics, advanced electric motors, lasers and X-ray equipment and common modern gadgets like cell phones, computer hard drives, and colour televisions. Europium and yttrium, for example, provides red phosphor for televisions and computer monitors. Cerium is used in the glass-polishing industry. it is essential to possess secure supply chains for rare earth elements.

3. Recovery of Rare Earth Metals in Industrial Waste

Disposal of industrial waste containing rare metals is not subject to the above laws, but must be disposed of in accordance with the Industrial Waste Disposal Law. Large amounts of rare metals have been discarded as process waste by many manufacturing companies, and most of them have been landfilled except in special cases for recycling. First, we collect general waste and industrial waste containing rare metals from consumers and businesses. Voluntary activities by citizens and organized activities by local governments play an important role in increasing the collection rate of rare metals in electronic waste. Also, the incentive to increase resource recycling rates allows manufacturers to recover more rare metals from their own industrial waste. Collected waste is dismantled and crushed at an intermediate processing plant. Manual sorting can sometimes be better than machine sorting (Wanget et al. 2011) This initial separation process is very important as it determines the subsequent recycling path for each rare metal component K.H Radeke (1998) In fact, post-separation of mixed waste in a high entropy state requires a lot of energy and costs, increasing the environmental burden for recycling. (Jha et al. 2008)

The next step in recycling is the more precise separation and enrichment of rare metals in the pre-treated waste by mechanical or physical treatment. Many types of shredding, cutting, crushing, mixing, or crushing equipment are used as mechanical treatments, and the release of multiphase waste into each component is a key technology in recent advances. Rare metal enrichment is also done by physical treatments such as vibration separation, gravity separation, buoyancy separation, magnetic separation and eddy current separation. Some processing is incorporated into the traditional mining process (Shimizu et al. 2005) R. Others have recently been developed to concentrate rare metals in urban mines. The final stage of rare metal recycling is smelting or chemical processing for mine extraction and refining. As a

ISSN 2063-5346

dry method, we are developing advanced technology by roast halide evaporation melting and molten salt treatment. (Granite, et al. 2012) Wet processes include mechanochemical treatment, hydrothermal treatment, ion exchange, solvent extraction, filtration, electrodeposition, and bio separation. Rare metals obtained through the above processes can be supplied to manufacturing companies as recycled raw materials with quality comparable to virgin raw materials. (Xu et al. 2009) Increasing the recycling rate and efficient recovery of low-cost, low-environmental-impact rare metals is still the goal of research and development. (Bunus et al. 2000)
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3.1 Phosphors from Waste Florescent Lamps Fixtures

Fluorescent lamp phosphors are a rich source of heavy rare earth elements such as europium, terbium, and yttrium. The current state of technology for extracting rare earths from lamp phosphors is limited to big fluorescent lamps. Compact fluorescent lamps and cathode ray tubes (Takahashi et al. 1996).

There are three different approaches possible in relation to the recovery of REEs. The first is the direct re-use of lamp phosphors in new lamps, the second is the recycling of individual phosphor components using physicochemical separation methods, and the third is chemical attack on the phosphors to recover their REE content (Takahashi et al. 1999).
REE recovery technologies can be divided into three general categories: concentration of metal by physical beneficiation, hydrometallurgical leaching and precipitation as well as potential electrometallurgical/pyrometallurgical processing. There is need to research on the recovery of rare earths from tiny fluorescent lamps used in LCD backlights or Phosphors used in white LEDs (Takahashi. 2003).

In the future, new technologies for scandium recovery, such as selective leaching and solvent extraction, might be developed. (Rabahetal et al. 2008). The volume of waste electrical and electronic equipment (WEEE) on a worldwide scale is vast, estimated to be approximately 50 million tonnes per year.

3.2 REEs from permanent magnets

Most common REE magnets in cars are based on Neodymium-Iron-Boron (NdFeB) alloy. Dysprosium is often added to magnets to increase temperature resistance to demagnetization, and the dysprosium content in NdFeB magnets varies greatly depending on the application (Binnemans, 2013).
In general, there are some established separation methods for metals, but these are often not suitable for his REE of magnets due to their properties and the use of coatings. The literature presents a decomposition technique developed by Hitachi to recover his NdFeB magnets from his HDD and air conditioner compressors. A typical permanent magnet contains 72 wt.% Fe, which cannot be recycled into saleable products by many proposed REE recovery processes. (Bi) In many cases, extensive pre-treatment is required to extract fractions from which REEs can be efficiently recovered. (Lawrence et al. 2010)

3.3 REEs from batteries

Nickel Metal Hybrid (NiMH) Battery contains Lanthanum Cerium Praseodymium and Neodymium. Industrial recycling of nickel-metal hydride batteries consisted of melting the entire battery, with a focus on recovering the nickel used in stainless steel production. Rare earths were lost in the slag. Recent research has developed metallurgical processes for the

ISSN 2063-5346

recovery of nickel, cobalt and rare earths from NiMH batteries. In 2011, Umicore and Rhodia announced that they had developed a process to recycle rare earths from rechargeable nickel metal hydride metal hydride. (Muller et al. 2006)

3.3 REEs From Waste water

Primarily, rare earths can be recovered from effluents produced during the extraction and separation of rare earths. Acid mine effluents (AMD) often contain significant concentrations of rare earths. Several studies have reported the potential recovery of uranium and other metals from AMD by ion-exchange resins or biosorption, but information on the potential recovery of rare earths is limited. (Granite, 2000)
. Therefore, ion exchange resins and chelate resins are preferred. Finally, it should be mentioned that bio-based sorbents such as (chemically modified) chitosan may also be of interest. Although the biosorption of precious metals and uranium by algae fungi bacteria and yeast has been widely explored74-82 up to now relatively little attention has been paid to the biosorption of rare earths (Derevyankin et al. 1991)
Rare earth recovery from ancient mine tailings or industrial water waste streams is still in its infancy. Because the concentrations of rare earths in industrial waste residues are lower than in primary rare-earth ores and recovered End-of-Life consumer goods (WEEE), unique procedures for recovering rare earths from these dilute waste streams must be devised.

4. The Environmental Footprint of These Technologies

Nonetheless, the environmental impact of some REE recycling technologies may be considerable. The majority of the activities outlined above necessitate significant levels of energy consumption, substantial volumes of chemical use, and the formation of waste chemicals and water**.** (Das et al. 2010)
In general, REE recycling has significant advantages over the mining of rare earths including savings in energy, water and chemicals consumption along with a significant reduction of emissions, effluents and solid waste generation resulting from the extraction and processing of rare earth ores. REE recycles do not contain radioactive thorium and uranium unlike the primary mined rare-earth ores. Therefore, radioactive tailing stockpiles and mining health problems can be at least partially avoided. In addition, an increase in demand is expected for certain REEs used in some electronic devices, especially rare earths used in magnets and new energies. (Sintubin et al.2012)

Most of the recycling methods proposed require large amounts of energy and chemicals. Hazardous chemicals such as the strong acids NaOH and HF often have to be used, but these cannot be recovered from the process and end up as chemical waste or contaminants in the wastewater. (Zhao et al.2008)

Increasing demand for magnetic materials by the market. During moulding and manufacturing of magnetic materials, there is material residue and cutting or grinding waste. In addition, since rare earth magnet materials are hard and brittle, waste is likely to be generated during manufacturing. RE-Co based permanent magnet material High consumption of SmCo alloy and RE-Fe based permanent magnet material Nd (PrNd)FeB.

ISSN 2063-5346

5. Conclusion

Rare earth elements are critical due to their importance for a number of applications, including number of green technologies, but primarily, because of high supply risks associated with the dependences on a single source (China). Supply of REEs is expected to exceed demand with the notable exception of a few key REEs (Europium, Terbium, Yttrium, Dysprosium) which are used in the production of Permanent magnets and phosphors. According to a survey of the literature on extant recovery methods of REEs from WEEE, while there has been substantial research, very few of them have advanced to an industrial scale. While the chemistry of metallurgical extraction is well established, the difficulty generally resides in dealing with the impurities that accompany it. To this point, the recovery of REEs from lamp phosphors is the most mature in terms of industrial scale application. However, excessive dilution of rare elements in most types of slag is still a problem and needs further research.

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