Challenges in Metal Recycling

Introduction

Metals are, in principle, infinitely recyclable. In reality, metal recycling is generally inefficient and in many cases non-existent. This is due to a number of factors ranging from social behaviour to recycling technology. Product design considerations and the issues involved in the separation of alloys are other major contributors. The metric used in this report to measure recycling rates is the EOL-RR (End of Life Recycling Rate). EOL-RR can be defined as the "fraction of metal in discarded products that is reused in such a way as to retain its functional properties". The materials used in the design of new products are becoming increasingly diverse. Currently, "virtually every stable element in the periodic table is used so as to take advantage of its unique physical and chemical properties". The special characteristics of the materials are being exploited for improved performance by designers. The unintended consequence of this is that this makes recycling the materials a much more complicated task. There is a huge disparity between the recycling rates of different metals (measured using EOL-RR). The "base metals." such as iron, copper and titanium are at one end of the spectrum with recycling rates of over 50%. These metals are very commonly used, generally in large quantities. At the other end of the spectrum are metals such as lithium, gallium and indium with recycling rates of less than 1%. These materials are used extensively in the electronics industry but only in small amounts. This paper discusses the current status of metal recycling, current recycling/recovery technology and the steps to improve this situation.

3 Important Findings

Figure 1 in this report (which is included in the Appendix below) is the source of one of the most important findings of this report. This figure shows a periodic table with 60 metals or metalloids selected and their estimated recycling rates. An important finding is the sheer number of metals that are essentially not recycled at all. The majority of the metals discussed, 35 out of the 60 or 58.3%, have recycling rates of less than 1%. As it is put in the report, we are faced with the "bizarre situation of spending large amounts of technology, time, energy and money to acquire scarce materials from mines and then throwing them away after a single use". With these specialty metals the recycling process can be so technologically and economically difficult that an attempt is rarely made. Even with metals that are comparatively easy to recycle, such as the “base metals” referred to in the introduction, the recycling rate is hovering around the 50% mark. This is startling that even metals that are relatively easy to recycle (be it due to quantities used, thermodynamic efficiencies or other factors) still roughly half are used once and thrown away. As far as can be discerned, the main factor contributing to the high recycling rates in “base metals” is that the quantities used allow the development of "economies of scale".

From an energy efficiency (and thus, with the right research, an economic) point of view, developing closed loop materials systems makes sense. Recycling metal is much more efficient than mining. In fact, "Depending on the metal and the form of scrap, recycling can save as much as a factor of 10 or 20 in energy consumption.” This potential saving highlights the issues with the current state of recycling processes and technologies. From an engineering perspective it is natural to think that the bottle neck in improvement lies with the advances, or lack thereof, in recycling technology. In some respects this is true, but social and behavioural issues surrounding collection rates are perhaps more important. Collection efficiencies are related to government and social factors while sorting and separation are technological factors. WEEE collection rates, 25% - 40% in Europe, are poor despite legislation to support the process. This implies a lack of enforcement and social behaviours limiting collection rates. The rest is discarded, exported as used/scrap or otherwise lost. Even when collected, pre-processing limitations are evident. Advanced sense and sort machinery is expensive and it is difficult to justify the expense with little monetary return. Issues of scale are very important here.

Thermodynamics of separation is the "ultimate limitation" of the final processing stage. Most metals are used in alloys or other mixtures, seldom in pure forms. Some metals will be reprocessed to their elemental form (e.g. copper) but many must be reprocessed as an alloy. If the metals in an alloy have similar thermodynamic properties, then separation is either very energy intensive or not possible at all. This means that some metals may never be returned to their original, useful state. This post-processing stage shows the importance of efficient pre-processing.

Low Recycling Rates of Specialty Metals

A number of reasons account for the low recycling rates of specialty metals, several of which have been briefly mentioned above. Specialty metals are generally used in high tech designs, in very small amounts. The metals are often mixed to combine desirable properties. Due to their specialised usage and the small quantities used per design, they are exceedingly difficult technologically to recycle making it difficult to justify economically. Increasingly these products have a shorter life span, meaning more materials are used which is exacerbating the issue. Another major factor is that current legislation favours "base metals" and essentially ignores specialty metals. Although future revisions to this legislation seems likely. Designers often do not take recyclability into account as a result. With performance a priority, taking advantage of specific materials to maximize performance is the obvious course to take.

Activities with Greatest Potential to Improve Metal Recycling

The activity with the greatest potential to improve this situation is collection. This holds with the important findings discussed above. This is crucial for the metals that are used in small quantities but are usually highly mixed. High efficiency when collecting will avoid frustrating the processes later in the life cycle of the material. This requires initiatives and incentives from governments and companies to make it worthwhile and also sharp changes in social attitudes. Similar initiatives are needed to improve the technology used throughout the process. There is a large disparity between the advanced technology used in the manufacturing process and that used in the recycling process. Investment in research and development(R&D) is needed to reap the rewards of an affordable closed loop materials system. A "best of both worlds" approach is needed. Combining low labour costs in developing countries for manual sorting combined with specialised smelters and post processing to make the former worthwhile. Finally, there needs to be feedback between the recycling industry/material scientists and the product designers. This is needed to help design in more sustainable solutions and, in some cases, even replace the materials with those that are easier to recycle and procure. Preferably this would be done with a minimal loss to performance.

Problems for the Technology Industry & Conclusions

Without developments in closed loop materials systems material prices will rise for the technology industry. Even as mining capabilities improve and reserves are therefore expanded, this will forever be governed by the law of diminishing returns. Eventually and inevitably the prices of the materials will have to rise, meaning production costs will rise with all of the associated business implications that entails. That is a longer term problem. In the shorter term, costs may rise in other ways. The international policy to govern legislation surrounding this issue, called for in the report, would have consequences on the industry. Especially as an increasingly eco-friendly public are heard. Legislation that increases taxes on the procurement of virgin ores may be implemented. Simultaneously, incentives to recycle may be introduced. A closed loop materials system (or as close as is possible) would not be subject to the level of uncertainty above. In fact aside from the capital needed for R&D, improved efficiency along with government incentives could lower costs for those in the industry who adopt the policy. This would have a knock on effect for the industry in the future as it would retain the availability of these highly specialised materials. The industry could then continue to "provide society with increasingly innovative and remarkable products". This translates to economic gains for the industry as a whole.

Appendix A

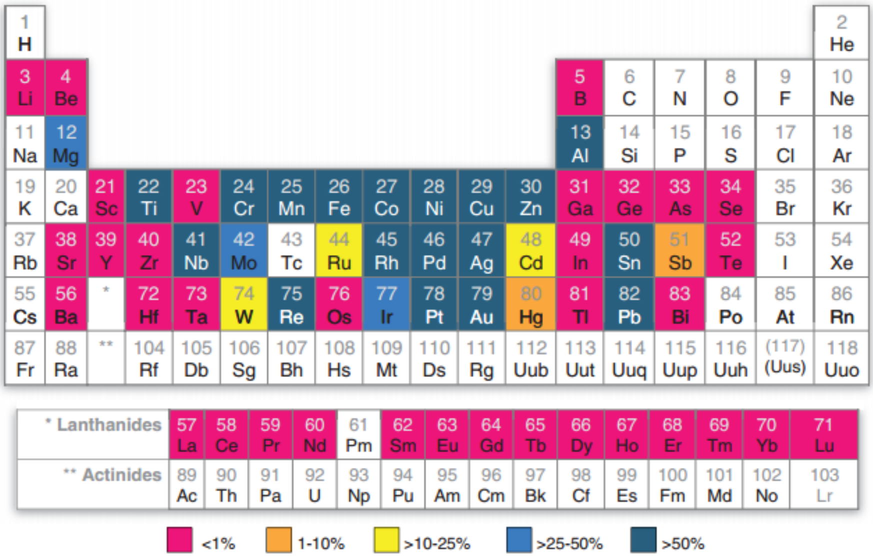

Fig. 1. Global estimates of end-of-life recycling rates for 60 metals and metalloids, circa 2008 [adapted from (*6*)].