Impact Objective

- Develop sustainable rare earth and magnesium recovery technologies to produce low-cost magnesium-rare earth element alloys

Reinventing Magnesium Alloys

__Blanca Araujo Perez__ and __Dr Federica Forte__, part of __Remaghic__ project investigating rare earth element recovery, are helping develop new, high performance magnesium alloys that offer low cost, sustainable alternatives to existing materials

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Can you tell us a little about the Remaghic project?

BA: Remaghic is focused on producing magnesium alloys with rare earth content from secondary sources. Magnesium is very lightweight, offering useful design properties. However, its sinusoidal price curve, poor corrosion and creep properties hinder its market penetration. To solve these issues, magnesium is alloyed with rare earth elements (REEs). To solve the price problem, Remaghic aims to enable magnesium foundries to recycle their own scrap while improving the performance of their alloys by demonstrating that secondary REEs can be used to obtain better performance from secondary sources. Remaghic also aims to contribute to improving Europe's sustainability by reducing its dependence on non-EU raw material. Some materials, such as light alloys and some REEs, will be absolutely necessary in the near future and Europe must improve its recyclability to be competitive and sustainable.

What are REE-magnesium alloys and what is their significance?

FF: REEs are a group of 17 elements that include the 15 lanthanides (a group of metallic elements) plus scandium and yttrium (Y). REEs are crucial as they are used in many applications, including permanent magnets, such as those used in electric vehicles and direct-drive wind turbines, and lamp phosphors, used in energy-saving lamps, alloys and rechargeable batteries. In the 2017 European Commission report on critical raw materials (CRMs), REEs are once more considered the most CRMs, taking into account both their economic importance and high supply risk.

BA: REEs provide specific and improved properties to the base metal properties in REE-magnesium alloys. However, both these materials and the development of new alloys are costly, leading to the alloys commanding very high prices, thus making them competitive only in very specific niche applications. Ensuring a cost-effective, sustainable supply of magnesium would improve the market penetration of these alloys, allowing many sectors to benefit from the useful properties they offer.

How are the techniques developed by Remaghic superior to existing methods of recovery?

FF: Our techniques offer 'closed-loop' solutions for the treatment of the selected waste streams by valorising the whole waste fraction. For example, in the case of fluorescent lamp powder, Y and europium (Eu) are recovered as pure oxides, and the residual waste is also valorised and terbium – a valuable element – is recovered as well. This offers added value to the whole treatment process.

Waste is currently processed by disassembly, mechanical treatment (shredding of the plastic casings) and magnetic/eddy current separation for base metal isolation. The most valuable fractions, such as the fluorescent powder contained in the fluorescent lamps, are currently disposed of. Plants that process this waste can enhance their global recovery efficiency by targeting these fractions to close the loop. In the HydroWEEE process, the fluorescent powder is treated in a hydrometallurgical process, resulting in a mixed Y-Eu oxide. This process might be further improved by the addition of an extra step aimed at Y-Eu separation to obtain pure rare earth oxides.

What challenges did you face and how did you overcome them?

FF: One of the main challenges was to upscale processes such as REE separation techniques tested at a lab scale to a higher technology readiness level (TRL). This was achieved as part of a specific task dedicated to developing basic engineering calculations for the final selected recovery route. In magnesium recycling, the challenge is to find a good trade-off between yields and costs and scaling laboratory procedures to a facility that can run at 250 kg/h in full production. This was solved by integrating technical and economic information in a business model and life cycle analysis models that helped the project decision-making mechanisms.

A greener future for alloy production

*The **Remaghic** project, the work of a consortium of leading universities, research institutions and private companies, seeks to develop new recovery processes to produce high-performance, low-cost rare earth-magnesium alloys*

Technology such as aircraft, bicycles, laptops and cell phones are ubiquitous and are used by an ever-growing number of people worldwide. However, unbeknownst to many, this technology would not exist without magnesium. A strong, readily-available element, magnesium is an excellent choice for many engineering applications. More specifically, magnesium alloys, or magnesium metals made by combining two or more metallic elements, are the go-to building materials when strength and weight are critical design elements. However, creating magnesium alloys that are lightweight, durable, cost effective and sustainable is a huge feat, so with this in mind, the question for engineers and scientists remains: what type of magnesium alloys are most effective for future engineering? Can these alloys be effectively mined and recycled in an eco-friendly manner?

These are exactly the questions that the Remaghic project is trying to answer. Originally founded by Grupo Antolin, one of the largest players in the car interiors market, and Cidaut, a transport and energy R&D centre, the Remaghic project is a three-year-long investigation into developing high-performing, low-cost magnesium alloys. Blanca Araujo Perez coordinates the project that melds the efforts of a consortium of world-class research and education organisations, as well as design and engineering firms, to recycle magnesium metals from industrial waste, combining them with rare earth elements (REEs) to create high-performance alloys. This work may be key in improving Europe's sustainability to reduce its dependence on raw materials, supporting a closed economy model of reusing and recycling rather than treating these resources in a disposable manner.

CREATING MARKETABLE MAGNESIUM ALLOYS

To succeed at this goal, the Remaghic project is divided into seven work packages (WPs), each of which is led by one of the consortium's partner companies. Ranging in theme from the recovery of REEs from industrial waste residues to technology upscaling and managing the alloying process, researchers working on the project are able to harness the knowledge and experience of partner companies to fulfil their project objectives.

By working with companies including Relight, Grupo Antolin, Tecnalia and Fraunhofer, researchers involved in WP1 and WP2 have been investigating and developing techniques for the recovery of REEs and magnesium respectively, reclaiming these useful elements from industrial waste residues, dross and scrap piles.

This work will then feed into WP3, which focuses on the alloying process between magnesium and REEs. Researchers have been investigating the influence of REEs on the behaviour and microstructure of magnesium, as well as the impact of the recycling process on the REEs. WP4 targets industrial scaling and the focus is on ensuring that the methodologies developed in previous WPs can be used to produce industrially-viable quantities of materials. This work will take place during the last months of the project, which is still in progress. This process allows for the identification of the final operational and manufacturing issues to confirm that the technology is fit for market. The objective of WP5 is to quantify the economic and environmental benefits of the recovery and alloying processes and includes data collection for the economic and environmental assessment. Life cycle cost analyses and cost benefit assessments must also be completed to determine the most cost-effective option for recovering and alloying magnesium and REEs.

Increasing the scientific community's awareness of the project is the focus of WP6, which aims to disseminate, exploit and communicate the results derived from Remaghic. Project partners involved in this WP are also dealing with any intellectual property rights relating to the project, as well as ensuring that efficient communication is used throughout the study. Any business plan and blueprint work for post-project market introduction also falls within the remit of this WP.

In combination with other projects sharing similar recycling targets, this work will contribute to the future creation of scraps classification, to the implementation of policies that foster recycled materials, and to the development of a recycling culture in the European society

Overarching the entire project, the objective of WP7 is to manage the whole process and ensure that all project goals are met. Running in parallel with the other WPs, this final strand keeps overall targets lined up across WPs and provides continuity, efficient cost and resource allocation, and cohesion across the entire project.

As a result of the combined efforts of the teams working on the seven WPs, Remaghic offers a 'closed-loop' solution for magnesium alloy production. As Araujo describes, this will allow the team to, 'safely preheat and melt magnesium scrap and to alloy REEs with minimum loss and maximum homogeneity.'

A MORE APPLICABLE MAGNESIUM

Remaghic is scheduled to complete its work in August 2018, and many of its action points are now complete. Much of this progress has been extensive and time-consuming, but, as Araujo notes, the results have been promising: 'Remaghic has designed an integrated process to recover REEs and allow a future integration of these elements in magnesium production'. This project has proved that it is possible to improve the performance of recycled magnesium alloys by adding REEs – a discovery that is new to the field of magnesium alloy production. Additionally, these REEs can positively influence magnesium's mechanical performance (e.g. material strength), corrosion performance and biomedical compatibility (e.g. corrosion of magnesium alloys in *in vitro* metallic materials such as bone screws).

However, these results came with their fair share of challenges. 'In rare earth recovery, the challenge was finding a good trade-off between yields and cost,' postdoctoral researcher Dr Federica Forte explains. This particular issue was solved by the application of technical and economic data, along with a life cycle costing analysis. Moreover, Araujo describes her surprise that the REEs recovered through the procedure, 'did not amount to the quantities needed for magnesium alloying and manufacturing.' The REE recovery process generated oxides rather than metallic elements, and alternative techniques were required to transform these oxides into a state suitable for the alloying process.

DEVELOPING A RECYCLING CULTURE

The Remaghic project has the potential to revolutionise the way in which magnesium alloys are produced, impacting the engineering processes of everything, from cars to medical implants to aircraft. 'Remaghic will show and validate an industrial facility specifically targeted to recycling magnesium alloys, demonstrating as well that there are alternatives to achieving good performance starting from secondary materials,' Araujo explains. With this achievement, the project can influence many companies and foster the implementation of magnesium recycling equipment in factories all over Europe.

Currently, key alloy elements and REEs are simply disposed of, ending up as scrap. With the help of the research and results from the Remaghic project, many organisations can instead enhance their global recovery efficiency by reusing these scraps, closing the loop and creating new sustainability standards. According to Araujo: 'In combination with other projects sharing similar recycling targets, this work will contribute to the future creation of scraps classification, to the implementation of policies that foster recycled materials, and to the development of a recycling culture in the European society'.

Project Insights

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Dr Federica Forte is a postdoctoral researcher in the Department of Chemistry at KU Leuven, Belgium. Her main interests are in the field of hydrometallurgy, ionometallurgy and solvometallurgy. In particular, she has been involved in the development and optimisation of critical raw material (CRM) recovery processes from several types of residues such as fly ash, WEEE and metallurgical slags.

Blanca Araujo is a senior industrial engineer, and lean project manager. She has more than 10 years of experience in material modelling and simulation. For the last eight years she has worked as a project and innovation manager. Araujo has worked in product design and component development for several OEMs and Tier1 within the transport industry. As Project Manager, she has managed R&D projects related to material development, manufacturing and product development. Araujo serves as Project Coordinator for the Remaghic project.