Carlo Burkhardt (Lead author)

REProMag – Resource Efficient Production of Magnets

Manufacturing processes for complex structures and geometries of magnets with efficient use of material – closing the gap between technology and market

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Steinbeis-Edition

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Imprint

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Abbreviations

AM	Additive manufacturing
EOL	End-of-life
FeCo	Cobalt Iron
H	Magnetic field strength
HPMS	Hydrogen processing of magnetic scrap
IEC	International Electrotechnical Committee
J	Magnetic polarisation
LCA	Life cycle assessment
LCC	Life cycle cost
LMM	Lithography-based metal manufacturing
ME	Material extrusion
MIM	Metal injection moulding
NdFeB	Neodymium (Nd) Iron (Fe) Boron (B)
PFM	Pulsed field magnetometer
RE	Rare Earth
SDS	Shaping, debinding and sintering
SEM	Scanning electron microscopy
STA	Simultaneous thermal analysis
WEEE	Waste of electric and electronic equipment

Executive Summary

Magnets are one of the most crucial materials necessary for modern Europe, as they are integral to energy conversion across the renewable energy and electric mobility sectors. Unfortunately, even though the alloying constituents of NdFeB magnets have been classified as EU Critical Raw Materials and 90 % are produced outside of the EU, there is still no circular economy to reuse and capture value for these type of materials. With the predicted need for Rare Earth (RE) magnets doubling in the next 10 years, this problem becomes ever more urgent.

In this context, the REProMag project developed and validated an innovative, resource-efficient manufacturing route for RE magnets that allows for the economically efficient production of net-shape magnetic parts with complex structures and geometries, while being waste-free along the whole manufacturing chain. Being based on the use of recycled material e. g. from end-of-life (EOL) electronic devices, REProMag's results enable an extremely resource-efficient closed material loop for a RE magnetic materials.

REProMag's new Shaping, Debinding and Sintering (SDS) process for RE magnets is an innovative automated manufacturing route to realise complex parts; resulting in a significant increase in the material efficiency during manufacturing; while at the same time allowing additional geometrical features and structural optimisations or the joint-free realisation of e. g. fins or fixtures that are either not possible with conventional manufacturing technologies or would lead to a significant additional increase of waste material during machining.

Even without such additional features, the SDS process allows a new level of sustainability in production, as the energy efficiency along the whole manufacturing chain can be significantly increased when compared to conventional production routes. Moreover, the used raw material is completely recycled and can be recycled again in the same way at the end of the lifetime of the products.

In short, the innovative REProMag SDS process has the potential to manufacture complex structures of high quality and productivity with minimum use of material and energy when compared to conventional manufacturing.

This handbook was developed within the framework of the European project REProMag, coordinated by the OBE Ohnmacht & Baumgärtner GmbH & Co. KG, Germany in collaboration with 13 partners from five European countries (FOTEC Forschungs- und Technologietransfer GmbH, Austria; PT+A GmbH Powder Technologies + Additives, Germany; HAGE Sondermaschinenbau GmbH & Co. KG, Austria; Lithoz GmbH, Austria; TEKS SARL Ltd., United Kingdom; Siemens AG, Germany; Sennheiser Electronic GmbH & Co. KG, Germany; Technische Universität Wien, Austria; University of Birmingham, United Kingdom; Montanuniversität Leoben, Austria; Institut Jozef Stefan, Slovenia; NPL Management Ltd., United Kingdom and Steinbeis 2i GmbH, Germany.

It presents the vision, challenges, research and innovation priorities for a circular economy for RE magnets, as well as the impact and deployment of the SDS process in two application domains. The document aims at giving support to the European Commission in structuring the future critical raw materials related research programme, as well as at giving researchers in the field and decision-makers from industry, academia, and policy making of the related domains a broad perspective on developments and implementations in the field of complexly shaped high performance RE magnets.

1 Introduction

Rare Earth (RE) magnets based upon the chemical elements neodymium (Nd), iron (Fe) and boron (B) – the so-called NdFeB-magnets – play a fundamental role in the shift from fossil fuels to a clean energy future. They are used in wind turbine generators, in electric vehicles and across other sectors. RE magnets underpin an industry worth in excess of $1 trillion worldwide (2015)[1], but in recent years the supply of the light RE like Nd and the heavy RE – mainly Dysprosium (Dy) used to increase temperature stability in NdFeB magnets – has come under considerable threat. Driven by increased adoption of electric vehicles and green technologies, the global demand for NdFeB magnets (~80,000 t / a 2017) could grow at 15–20 % / annum for the next decade[2]. The ability of European companies to participate fully in these markets is restricted by the near-monopoly supply of RE materials in China, which currently produces over 90 % of the world's REs[3]. As a result, a large amount of other producers were priced out of the market. Chinese mining and production of REs is significantly cheaper than competitors due to less stringent environmental and health and safety concerns. Less costly mining techniques, together with government subsidies for Chinese magnet producers and tax cuts for buying REs within China have led to a decline in non-Chinese RE producers globally. More recently, this reduction in RE production outside China has led to supply issues. As China's internal demand for these materials continues to increase, export quotas were gradually reduced, starting in 2006. 2010 saw the largest change in export quotas so far, with a reduction of 40 %[4], which caused significant disruption to the global RE market, resulting in a volatility of the material prices. The European Commission carries out regular criticality assessments on raw materials, where supply risk and economic importance are taken into account to determine the materials that are most critical. Figure 1 shows these critical materials, with their supply risk plotted against economic importance. It can be observed that the REs, both light and heavy appear at the top of the list, in terms of supply risk.

1 Kooroshy, J. / Tiess, G., / Tukker, A. / Walton, A. (2015).
2 Kooroshy, J. / Tiess, G., / Tukker, A. / Walton, A. (2015).
3 Binnemans, K. et al. (2013).
4 Hatch, G.P. (2012).