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Critical raw materials: A perspective from the materials science community

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Abstract

Functional materials are crucial to meet today's societal challenges and needs, such as the transition towards low carbon energy production to reduce climate change, renewable energies and green economy, clean mobility and improved communication. In order to fulfill specific functions, many of these materials require a variety of specific metallic elements whose total reserves in primary deposits on the planet are limited in quantity and unevenly distributed, respectively require significant efforts for exploration and investments in their exploitation. Furthermore, the extraction and processing of the corresponding metallic minerals can be sometimes related to a high environmental burden as well as frequently negative social impacts. While in contrast to fossil fuels mineral materials can be principally recycled and hence kept as resources, closing the materials loop especially for many specialty metals today is often hampered by dissipation as well as by physical and economic challenges. These metallic elements are also listed under “critical raw materials” which have been receiving increased attention in scientific and policy-related debates over the last decade and years. In this paper, we introduce the topic of materials criticality for the special issue of *Sustainable Materials and Technologies* and observe how the criticality of raw materials is perceived and handled within Materials Science. For this, we (i) present examples of critical raw materials in advanced technologies, (ii) summarize some definitions of criticality, (iii) outline the topic of critical raw materials in the Material Scientist community by highlighting relevant outcomes of a survey on critical raw materials for materials scientists, and (iv) conduct a literature research on “Critical Raw Materials” and “Criticality” in search engines commonly used by materials scientists. The results show that material scientists seem frequently not concerned with the criticality of raw materials in their work, and that the relevant terms appear for a broader scientific community mainly in the fields of environmental science, chemistry-related processing and environmental and resource management. The paper presents and discusses these results and suggests to advance the implementation of the concept of materials criticality in materials research and development.

Section snippets

The importance of critical raw materials to advanced technologies

The present materials paradigm is based on a linear 19th and 20th Century model conceived for a significant smaller world population and implicitly ignoring the limits of earth resources and the impact of resource consumption on our climate. It is overdue to introduce a new paradigm to maximize the circularity of existing materials uses and to explore novel approaches for smarter renewable materials, taking at the same time the limited availability of some materials into consideration: the…

Definitions of criticality

What does the term “critical elements” or “critical (raw) materials” mean and what makes materials critical? The existing overviews of methodologies on criticality assessment and reviews on existing publications are manifold; a few examples are[9,[24], [25], [26],35,[40], [41], [42],[48], [49], [50], [51]],59, and [61].[2]…

Perceptions on critical raw materials by the materials science community

Material scientists are used to describing materials on the level of their microstructure. Metallic alloys e.g. consisting of a mixture of two or more metallic elements or a mixture of metallic and non-metallic ones. From the point of view of a material scientist, it is important that the composition of a material, together with the manufacturing process, leads to the desired properties and functions in a component and thus to a superior performance of the end product, which is why we also…

Perspective on the literature

As mentioned before, there are numerous comprehensive reviews on existing criticality studies, conducted from a variety of perspectives, general ones (see “Definitions of criticality”), but also e.g. focusing on international comparison [41], technological sectors [52] and other selected aspects. The research conducted in this paper aims at a) providing an overview on the development of publications in the area of CRM as recorded in two databases commonly used by materials scientists and…

Conclusions and outlook

Today, we relate the term “critical raw material” not only to questions of geology but also to other areas such as politics, geopolitics, economy, environmental and social considerations as well as to various disciplines in basic research, science and engineering. The European Commission and the Parliament discuss “societal challenges” which include fundamental current topics such as climate action, food security and efficient energy [45]. Besides being listed as a societal challenge on its…

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“Towards a World Forum on Raw Materials” (FORAM), that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nr:730127….

References (63)

J.J. Meier *et al.*
Google scholar's coverage of the engineering literature: an empirical study
J. Acad. Librariansh. (2008)

J. Dewulf *et al.*
Criticality on the international scene: Quo vadis?
Resour. Policy (2016)

D. Humphreys
The great metals boom: a retrospective
Resour. Policy (2010)

A.R. Chakhmouradian *et al.*
From ‘strategic’ tungsten to ‘green’ neodymium: a century of critical metals at a glance
Ore Geol. Rev. (2015)

C. Helbig *et al.*
Benefits of resource strategy for sustainable materials research and development
Sustain. Mater. Technol. (2017)

D. Peck *et al.*
Critical materials from a product design perspective
Mater. Des. (January 2015)

J. Dewulf *et al.*
Criticality on the international scene: Quo vadis?
Resour. Policy (2016)

B. Achzet *et al.*
How to evaluate raw material supply risks-an overview
Resour. Policy (2013)

X.T. Li *et al.*
Large batch recycling of waste NdeFeeB magnets to manufacture sintered magnets with improved magnetic properties
J. Alloys Compd. (2015)

M. Zakotnik *et al.*
Commercial-scale recycling of NdFeB-type magnets with grain boundary modification yields products with ‘designer properties’ that exceed those of starting materials
Waste Manag. (2015)

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