Master's theses topics 2022-2023. 4MAT Department

Rare earth combined with electricity production in a fuel cell

Rare earth elements (REEs) are considered to be critical metals by the EU due to risks associated with supply chain and increasing demand from clean-tech applications. More than 20% of REEs produced are consumed for producing NdFeB permanent magnets. Thus, end of life products containing rare-earth permanent magnets such as NdFeBs are important secondary resources from which REEs can be recycled.
Several processes – pyrometallurgical, hydrometallurgical and electrochemical, have been successfully demonstrated to recover critical metals from the magnets. This project aims to recover REEs from NdFeB magnets inside a configuration of a fuel cell. Such a process a) can be carried out at room temperature b) Does not consume acid and can thus be a closed loop process consistent with green chemistry principles c) Can also produce energy. The researcher will undertake the exciting and challenging task of constructing the REE-FC which will not only involve reactor construction but also working on finding thermodynamically the appropriate cathodic and anodic reactions to ensure the result of a spontaneous reaction with a reasonable cell voltage. The influence of several parameters – pH, concentration of ions, the chosen cathodic reaction, solution ionic strength on key outcomes such as power density, current efficiency and percentage of metal extraction will be systematically investigated.

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References

1. Prototype of a scaled-up microbial fuel cell for copper recovery, Journal of Chemical and Biotechnology, Volume92, Issue11 November 2017, 2817-2824
2. Selective electrochemical extraction of REEs from NdFeB magnet waste at room temperature, Green Chem., 2018,20, 1065-1073

An acid free closed-loop recycling of Lithium batteries

The imperative to decarbonize has propelled a massive push in the manufacture of electric vehicles. Recycling end of life batteries and incorporating recycled content into battery production are essential components of forging a sustainable and circular battery manufacturing. Various recycling processes based on the principles of pyro and hydrometallurgy have been developed hitherto to process end-of-life Li ion batteries. Hydrometallurgical processes are preferred over pyrometallurgical processes as they are less energy intensive. One of the key challenges in hydrometallurgical recovery of battery waste is to avoid excessive consumption of non-recyclable chemicals such as inorganic acid, reducing agents and precipitating agents.
The objective of this work is to create redox-mediated process in which the reagent used for extraction of metals from the battery waste would be recovered back in an electrochemical reactor. Simultaneously, the researcher will also work towards designing a reactor in which the extracted metals can be precipitated as metal hydroxides using membrane electrolysis. Using electrons as green reagents, the researcher will work towards developing a holistic closed-loop process for battery recycling. However, the chemistry developed in this flowsheet can be

widely applicable for metal extraction towards various waste streams. Thus, a significant portion of the research will also be dedicated towards understanding the reaction mechanisms.

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References

1. Recycling lithium-ion batteries from electric vehicles, Nature 575(7781) (2019) 75-86.
2. Hydrometallurgical Processes for Recycling Spent Lithium-Ion Batteries: A Critical Review. ACS Sustainable Chemistry & Engineering 2018, 6 (11), 13611-13627

Leaching and Electrowinning of Tin from waste and by-products (Industrial collaboration with JGI Hydrometal):

JGI Hydrometal is processing waste and by-products to recover non-ferrous metals among with tin. Tin oxide and hydroxide coming out hydrometallurgical processes are usually reduced using carbothermal process to produce metallic tin. Carbothermal reduction is done at a temperature above 1000°C. It consumes a lot of energy and emit CO_2. JGI would like to evaluate the feasibility to reduce the tin oxide and hydroxide using an electrolysis process. The metallic tin obtained could be further purified in the electrorefining plant located in Engis (Hydrometal). Hydrometal produces a very high purity tin (99,999%) for the electronic industry. The student will work on the leaching and the electrolysis process to evaluate the feasibility.
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Recycling critical metals from samarium cobalt magnet waste

Samarium cobalt magnets (SmCo) are resistive to corrosion, have excellent thermal stability and are increasingly used in consumer electronics, aerospace and medical technology. Recycling SmCo magnets can result not only in recovery of valuable critical metals but also lower the environmental footprint of primary mining. In this project, students will focus on designing an environmentally friendly hydrometallurgical recycling process that can selectively recover critical metals from the SmCo waste in a *closed-loop* manner. They will be trained to apply principles of green chemistry and will investigate leaching processes, followed by selective electrowinning of cobalt from the waste. The project will focus on recovering samarium in a high purity oxide form via precipitation and in investigating the fundamentals of cobalt electrodeposition and the role of impurities.
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Iron metal production by direct electroreduction of iron ore

The direct electroreduction of iron oxide to produce metallic iron (ULCOS project) is truly a fascinating field of research and offers a breakthrough alternative to the existing status quo of blast furnace based iron production. The reaction happens in alkaline media and the mechanism of electroreduction -ie, solid state direct reduction is yet to explored in detail. Furthermore, a lot of other sources such as bauxite residue can be directly used to produce metallic iron via this method. The students will work on firstly understanding the fundamental reaction mechanism of direct electroreduction of iron from iron oxide in alkaline media.

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Anodic dissolution and electrodeposition of metal oxides/sulfides in deep eutectic solvents

The existing processes such as pyrometallurgy (roasting, smelting) or hydrometallurgy (leaching, solvent extraction and electrowinning) to extract metals from metal ores are often energy intensive, use high concentrations of acids/bases and create excessive amount of tailings and waste. Alternative techniques such as ionometallurgy or solvometallurgy are being investigated as the solvents have low toxicity, wide electrochemical stability and are non-flammable. Deep eutectic solvents (DES) are an exciting class of compounds that are similar to ionic liquids but are cheaper and can be manufactured at a large scale. They have shown to be effective in dissolution and extraction of metals from various end-of-life products and industrial wastes/residues.

The objective of this project is to understand fundamentally the electrochemical dissolution mechanism of metal oxides/sulfides in DES. The first part of the research will focus on gathering insights on the dissolution mechanism using techniques such as cyclic voltammetry, chronopotentiometry and in analyzing the speciation of the metal ions in solution. The second part will focus on applying these insights into bulk electrolysis where both anodic dissolution and cathodic electrodeposition will take place simultaneously. The project will also attempt to answer the challenging question of how complex mixed oxides/sulfides compositions dissolve and will investigate the possibilities of selective dissolution/deposition.

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References:

1. Electrochemical oxidation as alternative for dissolution of metal oxides in deep eutectic solvents, Green Chem., 2020,22, 8360-8368
2. A novel method for screening deep eutectic solvent to recycle cathode of Li-ion batteries, Green Chem., 2020,22, 4473-4482

Development of strengthened industrial glasses by combining chemical tempering and phase separation: making nanostructured glasses.

Traditional window glasses have a homogeneous and fully amorphous structure, which limits the range of their possible properties. In the fields of metal alloys and organic polymers, the combination of different phases enables high functionalization and development of high-performance materials.

By reviewing the phenomenon of phase separation in glasses from a new perspective on the nanometric scale, it is anticipated that superior and/or unique performances compared to traditional glasses can be achieved. Specifically, this master thesis will investigate the effect of chemical tempering on those heterogeneous, phase separated glasses. The preferential partitioning of elements in the different phases of the microstructure, should lead to an enhanced ion-exchange during the tempering process and therefore give additional strength to the glass that exceeds that of a tempered glass with a homogeneous microstructure.

This final year project will be carried out in close cooperation with the boundary-pushing Technovation Centre of AGC Glass Europe. Moreover, it is proposed to link this topic to an industrial internship at the AGC Research Center.

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Industrial partner: AGC Glass Europe

Developing the windshields of the cars of the future. When technology development meets fundamental understanding. Collaborations AGC/4MAT with a possible internship.

Today's cars contain more and more onboard technologies aimed at improving both the security and comfort of its users. Recently, this trend has accelerated as the market slowly shifts towards more autonomous cars. The number of cameras and detectors coupled to the windshield is therefore expected to increase heavily, inherently increasing the value of said windshield and therefore making its replacement more costly when an impact occurs.
In this context, the trend in the automotive industry has been directed towards the development of windshields with greater impact resistance, leading to smaller cracks and glass chips (repairable) and less propagation of said crack.
As a global leader in the flat glass industry, AGC Glass Europe (European branch of the AGC Group (Asahi Glass Co., Ltd) is directing its focus on a deeper understanding of crack initiation and propagation mechanisms in glass.
What glass properties influence these mechanisms? How is the microstructure involved in these phenomena? How do you ensure a particular crack mechanism? How do you quantify it?
In the context of this master thesis, you will receive the opportunity to collaborate with the research teams of AGC.
The Technovation Center of AGC is situated in Gosselies and regroups 280 employees collaborating on projects relating to research and development, engineering and intellectual property.
Will you help us invent the windshield glass of the future?

If you are interested, we are proposing an internship linked to this topic

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Additive manufacturing of soft-magnetic alloys for electrical cars

The development of electrical cars calls for the development of environmentally and yet efficient magnetic materials to work in an alternative field. Fe—Si alloys are great candidates. Nevertheless, the geometry of the devices as to be optimized together with its crystals orientation in order to maximize its magnetic properties. In this framework, additive manufacturing is essential to develop optimized macroscopic geometries while ensuring during or via popst-treatment an optimized microstructure. In close collaboration with the Sirris research center, we will study the properties of an Fe-6%Si alloy printed by laser powder bed fusion. This Master's thesis can be coupled to an industrial internship at Sirris.

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Synthesis of a “liquid” electrode.

Traditionally electrodes are made of a bulk piece of conductive materials. A high concentration nanoparticle suspension of conductive materials can behave like an electrode if the percolation threshold is reached.
This project will explore the preparation of the nanoparticles, their characterization and formation of the suspension. This “liquid” electrode will be characterized in terms of stability, homogeneity, and electrochemical behavior. The percolation threshold will be determined.
The nanoparticles will be produced by sono-electrochemistry, characterized by TEM and THEED.

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