Recycling of valuable metals from spent Li-ion battery

Summary

The main objective of this Ph. D. project is to recycle spent Li-ion batteries (SLIBs) cathode component and extract various valuable metals (Li, Co, Ni, Mn etc.). As LIBs production keeps increasing, the amount of SLIBs is also growing rapidly. SLIBs are classified as dangerous waste. If they are not properly treated, they will cause damage to the environment and may as well cause harm to animals and human health. Nonetheless, SLIBs have a high economic value, as they contain a significant amount of valuable metals. Therefore, SLIBs recycling could have environmental and economic benefits, but to take the full advantage of the recycling potential, there is a great need for finding new recycling pathways. In this project various metal extraction possibilities will be studied and optimized based on the chemical composition of different SLIBs. The final goal is to develop cost-effective recycling methods for SLIB cathode and re-use extracted metal-oxides for the synthesis of valuable catalyst material for metal-air battery and low-temperature fuel cell applications.

Research field:	Chemical and Materials Technology
Supervisors:	Ivar Kruusenberg Kerli Liivand
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Offered by:	National Institute Of Chemical Physics And Biophysics
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Description

Lithium-ion batteries (LIBs) show excellent electrochemical performance and this is the reason they are extensively used in different applications, such as portable electronics and electric vehicles. As the production keeps increasing, the amount of spent LIBs (SLIBs) is also growing rapidly. According to statistics, the lifetime of LIBs in digital products is only one to three years, and in power vehicles it is five to eight years. LIBs consist of cathode, anode, electrolyte, and separator. The cathode is an aluminium plate coated with a mixture of active cathode material (LiNiO2, LiMn2O4, LiCoO2, LiFePO4, LiNixCoyMn1-x-yO2, etc.), binder polyvinylidene fluoride (PVDF), and additives. The anode is a copper plate coated with a mixture of graphite and PVDF binder. The electrolyte of a LIB usually includes solvents (mixtures of one or more of the reagents DMSO, PC, and DEC, etc.) and solutes (LiClO4, LiPF6, LiBF4, etc.). LIB separators are usually a single layer or multi-layer of polyethylene or polypropylene. Materials used in LIBs, such as heavy metals and toxic electrolytes, pose a special threat to ecosystems and human health. If the SLIB is disposed of by landfilling the pollution of underground waterbodies can arise. As well, if the SLIB is burned considerable amount of poisonous gases (like HF) emerge, thereby polluting the environment and atmosphere occurs if traditional waste management procedures are applied. In addition, SLIBs have a high economic value because they contain a significant amount of valuable metals. SLIBs usually contain 5%–20% cobalt (Co), 5%–10% nickel (Ni), 5%–7% lithium (Li), 5%–10% other metals (copper (Cu), aluminium (Al), iron (Fe), etc.), 15% organic compounds, and 7% plastic, although their compositions differ depending on the manufacturers. Valuable metals such as Li, Co, Ni, and Mn from SLIBs bring significant economic benefits if they can be recycled.

State-of-the-art processes for metal recycling from SLIBs can be divided into three types of processes: pre-treatment processes, metal-extraction processes, and product preparation processes. Metal-extraction process focuses on changing the solid metals in SLIBs into their alloy form or solution state, which facilitates the subsequent separation and recovery of metal components. The common approaches include hydrometallurgy and pyrometallurgy. Hydrometallurgical method involves leaching, which dissolves the metallic fraction and recycled metal solutions for subsequent separation and recovery. Pyrometallurgical method involves high-temperature smelting reduction, where valuable metals are reduced and then recovered in the form of alloys. At the last stage of a battery recycling process, the valuable metals from SLIBs are transferred into other substances, such as alloys, slags, solutions and precipitates. Metal salts can be recovered if the valuable metals are separated and then respectively recovered by solvent extraction, chemical precipitation, and crystallization. Based on the literature, various recycling processes aiming to recover the valuable metals from SLIBs have been developed. However, an ideal recycling process that is capable of recovering all valuable components of SLIBs with low energy consumption and minimum environmental pollution is still unachieved. Therefore, many efforts are still needed for the development of more suitable recycling options and more knowledge needs to be gained to complete the circular economy aspect.

Additionally, during this project extracted and recovered metals will be re-used for synthesis of electrocatalytically active catalyst materials that can be applied in energy conversion systems (fuel cells and metal-air batteries). Fuel cells are recognized as highly desirable energy-conversion devices and power sources for many applications – including automobiles and backup power. In the current state of technology, the most practical electrocatalysts for fuel cells are Pt based materials which are not only rare but also very expensive. To reduce catalyst cost, two strategies have been explored during the last three decades. One is to reduce the Pt loading, and the other is to replace Pt-based catalysts with non-noble metal catalysts. Among the non-noble metal catalysts explored, transition metal macrocyclic (TMM) complexes and their pyrolyzed materials have attracted the most attention worldwide for fuel cell applications. For forming TMM catalysts for use in oxygen reduction reactions (ORRs), various non-noble TMs can been used, like Co, Mn, Ni and Cu, which can be recycled and extracted from SLIBs.

Therefore, this project has **two main objectives:**

- The extraction of highly valuable metals such as Li, Co, Ni, and Mn from SLIB cathode layer
- Synthesis of electrocatalytically active catalyst materials by using the materials extracted from SLIB

Responsibilities and tasks:

- Pre-treatment of SLIBs
- Metal extraction from SLIB by hydrometallurgical method
- Metal extraction from SLIB by pyrometallurgical method
- Metal extraction from SLIB by combining hydrometallurgical and pyrometallurgical methods
- Physical characterization of the extracted materials
- Synthesis of electrocatalytically active catalyst materials by re-using SLIB recycled components
- Electrochemical testing of synthesised catalyst materials
- Publishing of the results and reporting activities, evaluation of the results

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