REVOLUTIONIZING BATTERY RECYCLING:

THE INDURED REACTOR AND SUSTAINABLE PYROMETALLURGICAL PROCESSES

Ensuring economic independence as well as developing efficient recycling methods are pivotal to retaining valuable metals and securing the raw material market in Europe. However, the versatility of lithium-ion batteries (LIBs) presents challenges for efficient waste management and recycling due to their fluctuating chemical compositions. Current recycling technologies face significant hurdles in achieving targeted recycling rates.

While several state-of-the-art recycling technologies are available to recover valuable metals from LIBs, each of these methods has its limitations. For instance, the hydrometallurgical recycling approaches have achieved impressive recycling efficiencies, but they are highly sensitive to the diverse nature of input materials. The fluctuating cathode chemistry used in batteries results in a waste stream that varies significantly, posing challenges for the recycling. In contrast, pyrometallurgical recycling methods exhibit greater resilience to varying input materials. However, they encounter the issue of lithium slagging, hindering efficient recovery and not being able to fulfill mandatory recycling targets. Moreover, the conventional energy-intensive nature of pyrometallurgical methods, relying on sources like oil and gas, renders them ecologically unfavorable.

To address these challenges, researchers in the COMET module FuLIBatteR (Future Lithium-Ion Battery Recycling for Recovery of Critical Raw Materials) in Project 2 (Pyrometallurgical processing of LIBs and black matter) are focusing on developing a sustainable recovery of lithium and other metals from LIBs.

The Chair of Thermal Processing Technology at the Montanuniversitaet Leoben has pioneered the InduRed reactor, a novel pyrometallurgical recycling concept. This innovative approach utilizes an inductively heated carbon bed, providing a large reaction surface and enabling highly reducing conditions. The primary objective of the InduRed reactor is to simultaneously recover nickel, cobalt, and manganese as an alloy, while the elements phosphorus and lithium are expected to be separated via the gas phase. The InduMelt reactor, which is a discontinuous lab-scale prototype based on the InduRed concept, has shown promise in initial experiments for lithium recovery and the production of a metal alloy comprising nickel, cobalt and manganese.

The ongoing research activities of the project team involve investigating the behavior of commonly used pure cathode materials like NCA, NMC, LCO and LFP as well as active material from the battery pre-processing step, under high temperatures and reducing conditions. Various analyses, including heating microscope experiments, thermo-gravimetric, and differential calorimetry analyses, are being conducted to gain insights into the reaction mechanisms.

Moreover, the team is actively engaged in developing a mathematical model to describe the thermal deactivation process of LIBs. This attempt aims to enhance our understanding of their thermal behavior, gas evolution, and, importantly, predict potential instances of thermal runaway. To gather the necessary data, the team is conducting thermal deactivation tests, commonly referred to as "box tests". The collected data from these tests will be incorporated into the mathematical model, thus enabling us to refine its accuracy and predictive capabilities.

In conclusion, the ongoing research demonstrates promising results, particularly in terms of lithium removal rates. The future investigations will focus on understanding the energy demands of the reactions and the necessary modifications of the active material to meet the requirements of the desired recycling process. The InduMelt reactor, with its innovative design and capabilities offers a promising solution for the recycling of LIBs. It contributes to the recovery of valuable metals and reduces the environmental impact of battery waste, advancing the cause of sustainability.

The results of FuLIBatteR – Project 2 were / will be disseminated at the following events:

- Copper Cobalt Africa 2023, Victoria Falls Livingstone, Sambia, 12 – 16 June 2023; "Influences of Pre-treatment Steps and Contaminants in a Pyrometallurgical Recycling Process for NCA (LiNi0.8Co0.15Al0.05O2) Lithium-Ion Battery Material"
- ICBR 2023, Valencia, 6 – 8 September 2023; "Pyrometallurgical recycling of lithium-ion battery cathode material: The impact of slag formers on meltability and lithium slagging potential"
- AABC 2023, San Diego, 11 – 14 December 2023; "Evaluating Refractory Material Performance in Pyrometallurgical Recycling of Lithium-Ion Batteries under a reducing atmosphere."

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