Pyrometallurgical recovery of metals from Lithium-Ion batteries

From waste to resources. What does recycling really mean?

Ambitious recovery targets and growing demand for lithium and critical raw materials pose the question of how challenging the recycling of lithium-ion batteries (LIB) is today. The answer lies in how we define the "recycling". If we consult the dictionary, "recycling" refers to the process or action of recovering reusable products from waste, which is true. However, this definition doesn't fully capture the meaning of what recycling has become today. To convey its complete meaning the term lacks the inclusion of "sustainability". Modern lithium-ion battery recycling must rely on environmentally friendly, sustainable technologies and meet high recovery targets. Simply converting waste into raw materials is no longer enough; there must be minimal to no loss throughout the recycling chain, without posing major risks to the environment.

So what does recycling really mean in today's context? A comprehensive definition might be: "A process or method to sustainably convert waste into raw materials and meet recovery targets in the recovered products, facilitating their reuse in other industries or directly in LIB production." It sounds complex, doesn't it? We thought so too. However, complex problems often spark innovative solutions.

The COMET Module FuLIBatteR (Future Lithium-Ion Battery Recycling for Recovery of Critical Raw Materials) addresses this challenge by aiming to convert waste into valuable raw materials sustainably and meet recycling targets. The recycling initiatives, split into three projects, aim to recover critical raw materials and valuable metals from LIBs using sustainable methods. In the previous newsletter, we explained how graphite is recovered from active material via the flotation process in Project 1. Project 2, "Pyrometallurgical processing of LIBs and black matter", focuses on the high-temperature recovery of metals from LIBs. Now, what comes to your mind when you hear "pyrometallurgical"? Perhaps you imagine high temperatures and something not so environmentally friendly? But rest assured, pyrometallurgical processes do not always have to be so.

Figure 1 depicts the InduRed reactor, the core element of the so-called RecoPhos process. Developed at the Chair of Thermal Processing Technology at the University of Leoben (Montanuniversitaet Leoben), this innovative reactor operates under a reducing atmosphere and is heated inductively, utilizing renewable energy. A bed of graphite cubes acts as susceptor material to the magnetic field and provides the necessary heat for the pyrometallurgical process. Upon introduction of active material from the upper part of the reactor, it undergoes a reduction process, followed by the separation of lithium via the gas phase and other metals (Co, Ni, Mn, and Fe) as an alloy – yielding high-quality, valuable products. What distinguishes this process from other pyrometallurgical recycling methods? Separating lithium via the gas phase avoids Li-slagging (refers to the loss of lithium in the slag without any economic value) and meets the recycling targets – providing a significant advantage.

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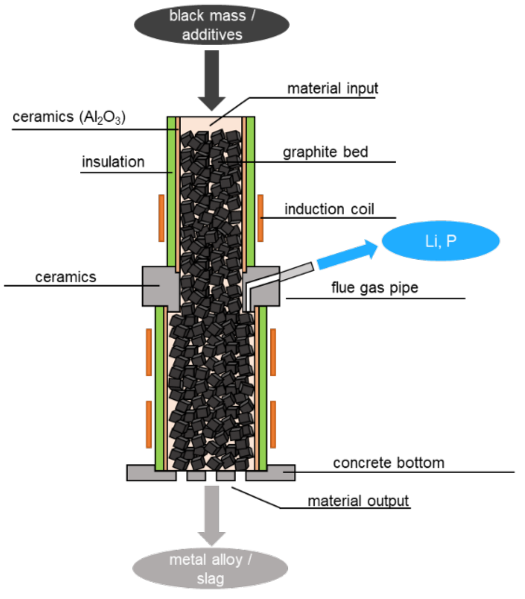

Figure 1: InduRed reactor. Source: Ponak, C. et al. 2019, Recovery of Manganese, Chromium, Iron and Phosphorus from Basic Oxygen Furnace Slags. In GDMB (Ed.): European Metallurgical Conference 2019. Optimum utilization of esources lausthal-Zellerfeld: GDMB Verlag GmbH, 1311 – 1319.

The team is currently enhancing the functionality and recycling efficiencies of the reactor through several focused initiatives. Additionally, a lot of effort is put into the scale-up of the reactor by advancing the Technology Readiness Level (TRL) with key developments in automation and continuous feed experiments, as well as improving off-gas treatment and recycling for a sustainable solution. A critical area of research has been identifying the optimal crucible material to maximize reactor efficiency, where the results will be published in Elsevier Ceramics shortly.

Additionally, innovative crucible designs are explored to reduce lithium diffusion. These designs are crucial for increasing the recovery yield, ensuring that the processes are not only more efficient but also more sustainable. This commitment to advancements underscores the dedication to scaling up and optimizing the reactor concept, presenting a compelling alternative to state-of-the-art technologies. First results have already shown high recovery yields of higher than 90 % for lithium and phosphorous via the gas phase and up to 98 % for nickel, cobalt, manganese, copper and other elements.

Apart from our research efforts, the FuLIBatteR team actively engages with a broader audience at the international level. K1-MET was assigned as an associated partner in the IPCEI (Important Projects of Common European Interest) Eu-BatIn together with FuLIBatteR contributing to the "Recycling and Sustainability" workstream. The team's activities were presented at the Workshop (EU Battery Convention Days), which took place in Bologna, Italy, 14 – 15 March 2024 and on the 8th Green & Sustainable Chemistry Conference, 13 – 15 May 2024 in Dresden, Germany (contribution from P3). On a national level, K1-MET participated in "automotive.2024 – Austrian Roads to Excellence" on 6 June 2024, in Linz (voestalpine Stahlwelt), where FuLIBatteR was prominently featured. Additionally, we aim to showcase FuLIBatteR at various conferences:

- 11th International Conference on Sustainable Solid Waste Management, 19 – 22 June 2024, Rhodos, Greece (contribution from P3)
- European Congress on Biotechnology, 30 June – 3 July 2024, Rotterdam, The Netherlands (2 contributions from P3)
- 29th International Congress for Battery Recycling ICBR 2024, 10 – 12 September 2024, Basel, Switzerland (contribution from P2)

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