Banking on Better Black Mass

Investigating the use of different physical separation techniques to increase the value of black mass from spent Li-ion batteries

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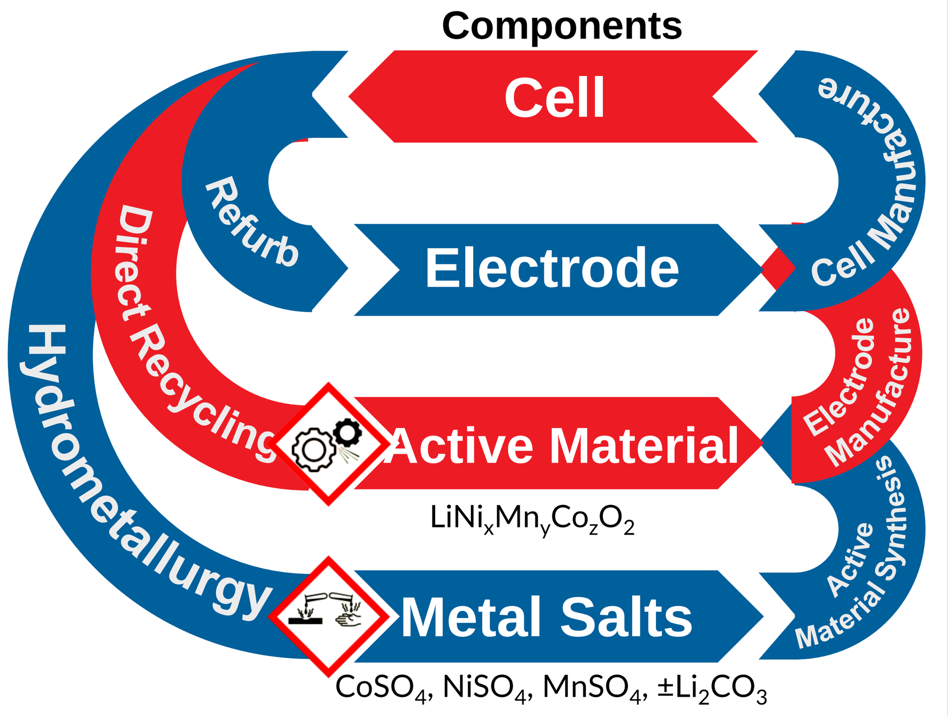
ABSTRACT

- This study employed size and magnetic separation methods to enhance nickel and cobalt content in black mass.
- Increased the value of black mass for hydrometallurgy.
- Wet high-intensity magnetic separation (WHIMS) effectively separated Ni/Co from graphite.
- Promising results suggest potential for improved recycling strategies.



MOTIVATION

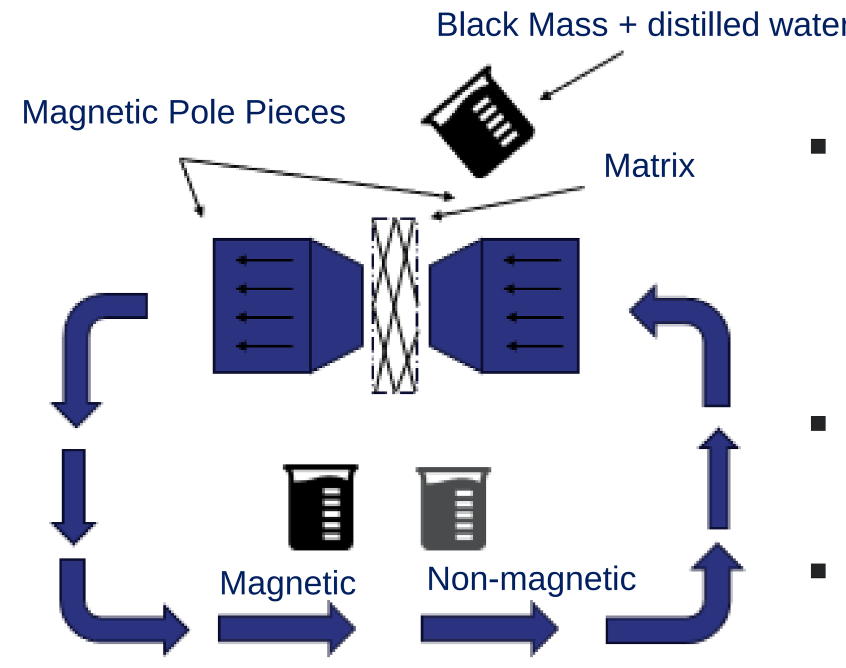
Black mass: Key intermediate product in Li-ion battery recycling.

- Contains valuable cathodic and anodic materials alongside contaminants like current collectors and plastics.
- Potential for reclaiming valuable materials for reuse in batteries or other uses.

METHODS

STEP 1: Size separation

STEP 2: Magnetic separation (WHIMS)



- Slurry was subjected to repeated magnetic separation at a set current until all magnetic material is captured in the matrix.
- The electromagnet was switched off, and the magnetic product rinsed out.
- Non-magnetic material was reprocessed at higher currents (0.2, 0.5, 1, 2, 3, 5, 7.5 A).

RESULTS

STEP 1: Size separation

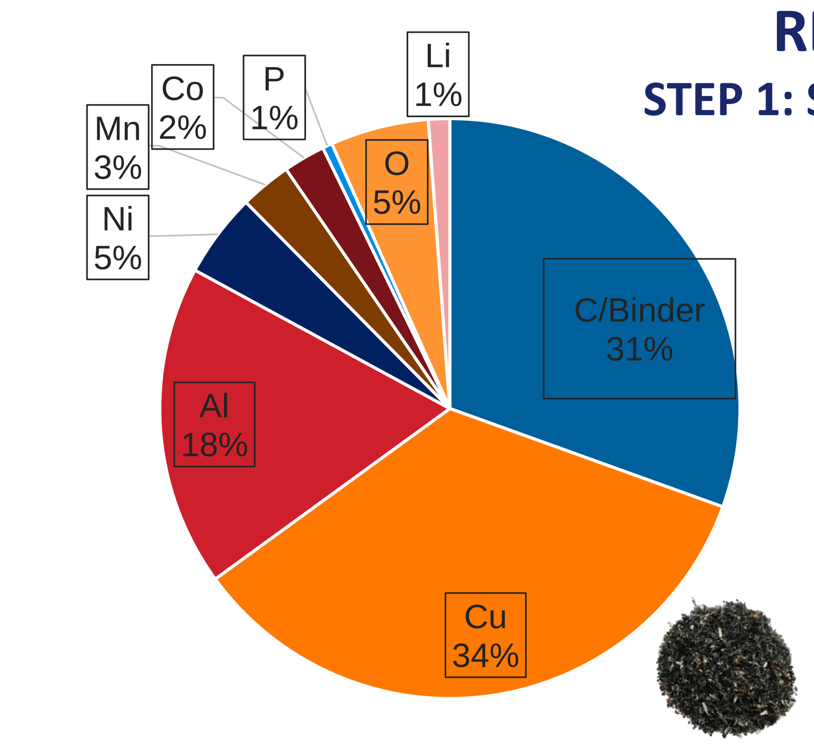


Figure 1. Chemical composition of 1000µm size fraction black mass.

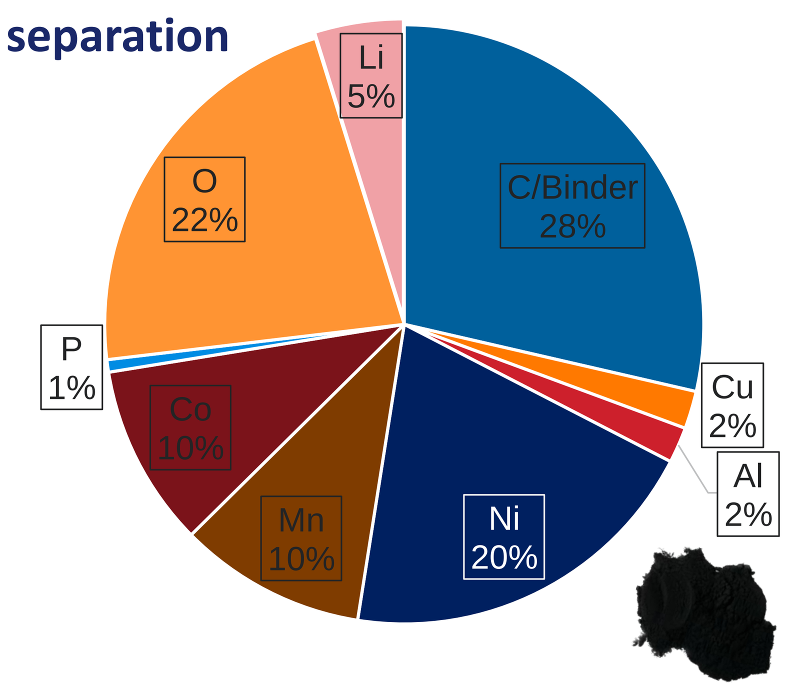


Figure 2. Chemical composition of <40µm size fraction black mass.

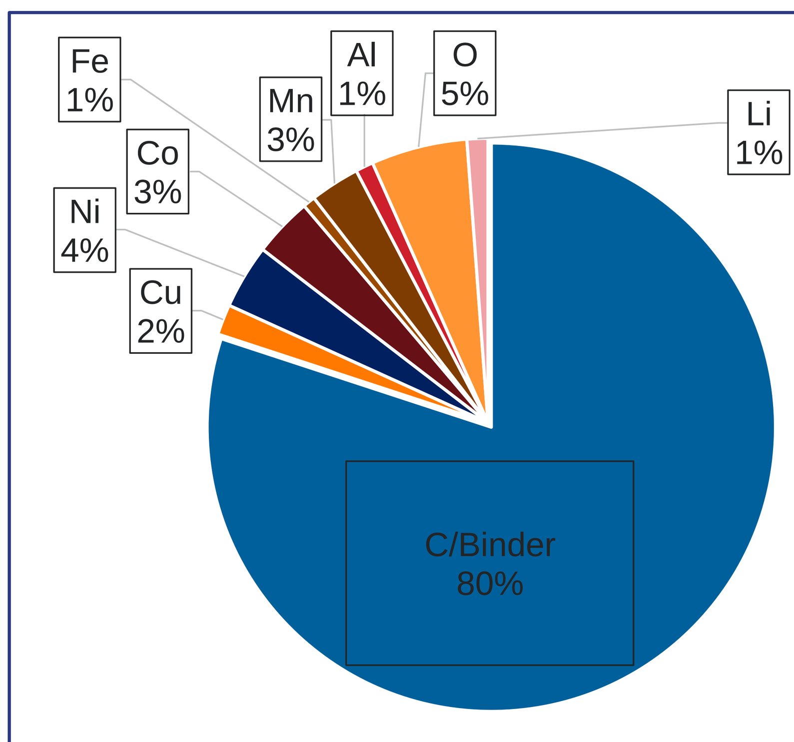


Figure 3. Chemical composition of the non-magnetic product after WHIMS of <40µm sieved black mass.

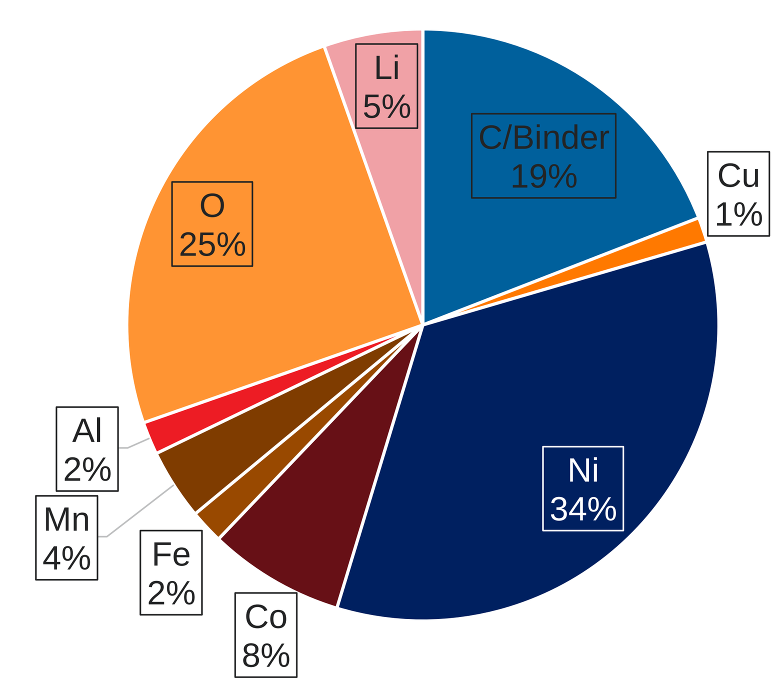


Figure 4. Chemical composition of the magnetic product at 0.2 A after WHIMS of <40µm sieved black mass.

Key findings:

- 30% reduction in contaminants (Cu, Al) from coarse to fine size.
- Elevated Valuable/ critical materials (Ni, Co, Graphite) in finer sizes.

Why minimise contamination?

- Reducing Al and Cu levels improves the cost-effectiveness of hydrometallurgical recycling.
- By separating Al & Cu they can be recycled effectively, rather than discarded as waste during hydrometallurgical recycling. [2]

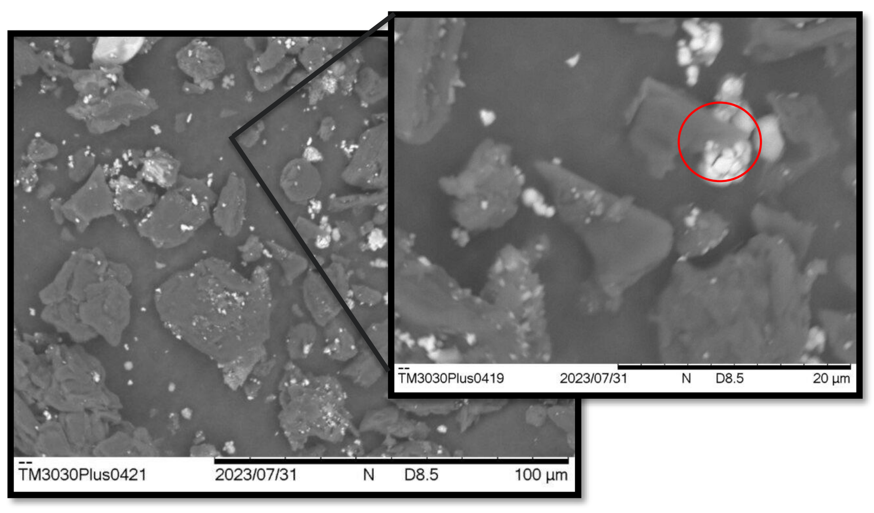


Figure 5: SEM of Non-magnetic fraction from WHIMS used sieved <40µm black mass.

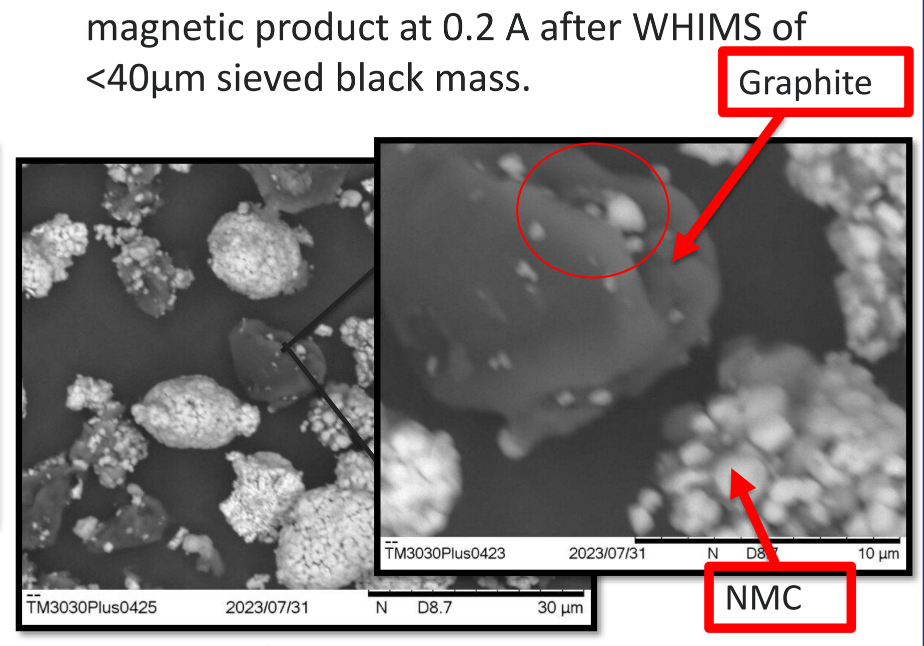


Figure 6. SEM of Magnetic concentrate separated at 0.2 A in WHIMS- sieved <40µm black mass.

STEP 2: Magnetic separation

Key findings:

- The separation was performed on the finest fraction.
- Effective separation of graphite and NMC was achieved by exploiting their differing magnetic susceptibilities.[3]
- Grade of Ni was increased from 20 to 34% respectively. Graphite from 28 to 80% (*See Table 1*).

Component	Recovery (Wt%)	Grade (Wt%)
Ni* in 0.2 A	50.4	34.0
Co* in 0.2A	26.5	8.0
Graphite in Non-Magnetic	30.1	80.0

Table 1. Grade and recovery in wt % for selected fractions, metals in Wt %. * Metals are given as wt %, but are in oxide form, which reduces the grade.

Why is the magnetic separation not 100%?

- The attachment of NMC and graphite results in cross-contamination.
- During the recycling process, NMC particles became embedded in the graphite causing carry over.

CONCLUSIONS

- Increased the value of black mass by two physical separation techniques.
- Used simple sieving to separate Ni/Co and graphite from contaminants Cu/Al.
- Used a mineral processing technique in a novel field and applied it to battery recycling, resulting in cost-effective separation of Ni/Co from graphite.
- This pretreatment can help further recycling processes like hydrometallurgy be more cost and energy-efficient.

Impact / Next steps

- Address the NMC and graphite attachment by focusing on:
- Limiting intimate mixing of anode and cathode during shredding
- Ultrasonication to liberate NMC embedded in Graphite
- Selective leaching of NMC from Graphite

This helps to achieve the ultimate goal of direct recycling of Li-ion batteries.

References

[1] Sommerville, R. et al. (2020) 'A review of physical processes used in the safe recycling of lithium ion batteries', Sustainable Materials and Technologies

[2] Sommerville, R. et al. (2021) 'A qualitative assessment of lithium ion battery recycling processes', Resources, Conservation and Recycling, 165, p. 105219.

[3] Jorge (2019) Wet magnetic separation https://www.911metallurgist.com/wet-magnetic-separation/#:~:text=The%20magnetic%20characteristics%20of%20the%20particle%20affect%20the,a%20direct%20function%20of%20both%20H%20and%20dH%2Fdx.

Kaja Glazer is studying MSci Chemistry at the University of Birmingham. Interested in battery recycling and wishes to undertake a PhD in a related field. Aspiring to become a researcher in the battery recycling industry.

*Kaja at the Ecobat Ltd site visit

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