Sodium Ion Battery Recycling: a Dual Strategy

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Introduction and rationale

The emergence of Sodium-Ion Batteries (SIBs) as alternatives to Lithium-Ion Batteries (LIBs) necessitates dedicated circular recycling frameworks. Hydro- and solvometallurgical methods represent highly suitable recycling pathways due to their adaptability, reduced environmental footprint, and alignment with stringent European Union regulatory frameworks. [1]

Growth in global energy demand
- Electrification of transport
- Energy storage systems

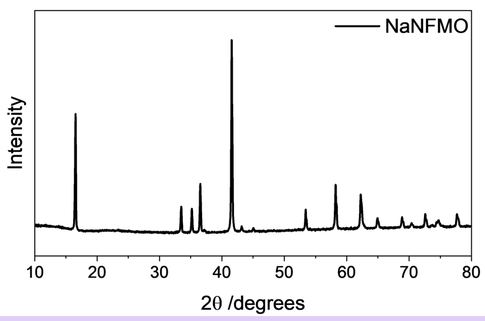
Interest in SIBs
- Na abundant and cheap
- Lower environmental impact
- Same working principle as LIBs

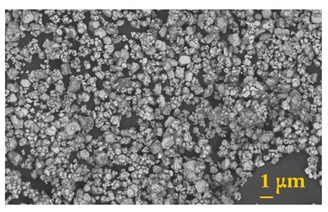
EU regulations
- CRM Act: supply through secondary sources
- Regulation (EU) 2023/1542: minimum recycling targets

Knowledge gap
Need to develop standardized recycling protocols for SIBs

AIM OF THE PROJECT

Evaluating SIBs recycling approaches by adapting optimized LIBs strategies and assessing their transferability to $NaNi_{0.33}Fe_{0.33}Mn_{0.33}O_2$ (NaNFMO)





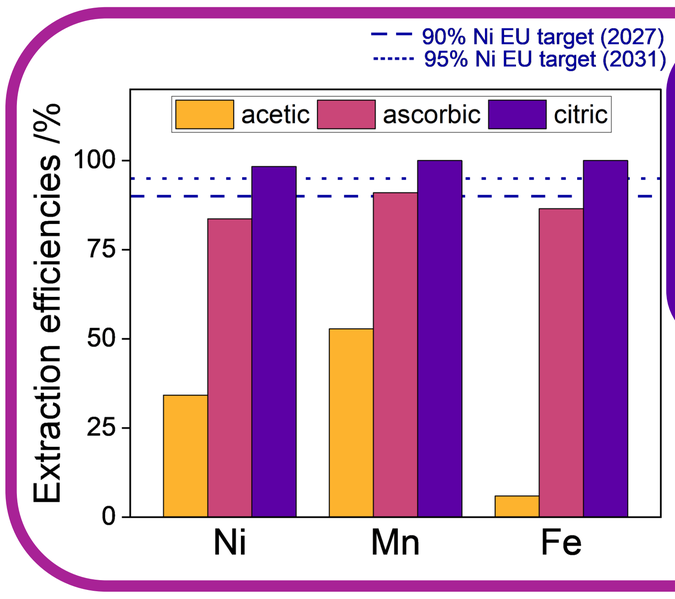
NaNFMO pristine layered oxide

Organic acid leaching: CRMs' recovery

Screening of pre-existing LIB leaching recipes

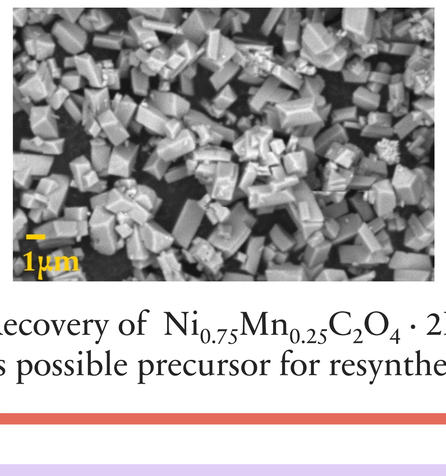
Leaching with organic acid (transfer of LIB optimized recipes) ICP

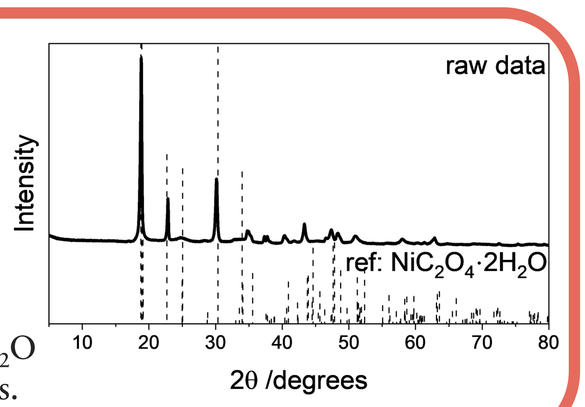
Precipitation with oxalic acid: Ni and Mn recovery XRD, ICP, SEM



- 3.5 M, 4vol% H_2O_2, 1h @ 60°C, 40g/L [2]
- 1.25 M, 0.3h @ 70°C, 25g/L [3]
- 1.25 M, 1vol% H_2O_2, 0.5h @ 90°C, 20g/L [4]

A preliminary screening of recipes optimized for Li-based layered oxides lead to choose **citric acid** as the most performant extractant.





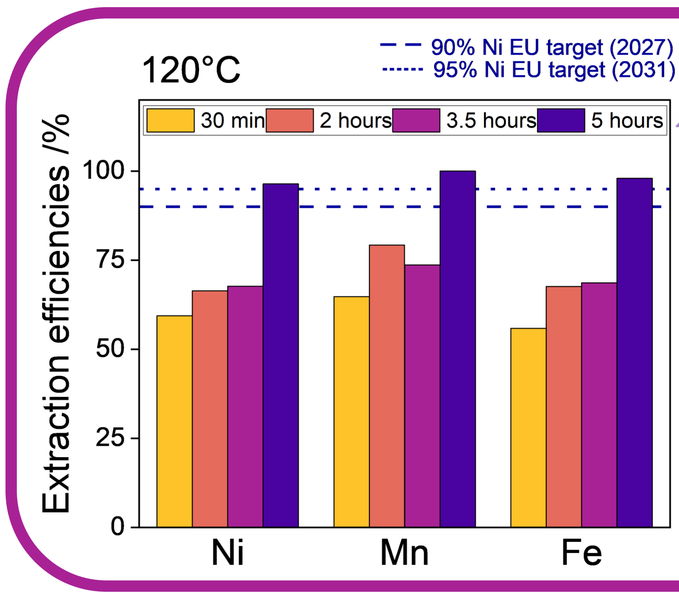
Recovery of $Ni_{0.75}Mn_{0.25}C_2O_4 \cdot 2H_2O$ as possible precursor for resynthesis.

DES leaching: a closed-loop approach

Adapting the pre-existing patented LIB leaching recipe

Leaching with DES Choline Citrate based: recipe optimization ICP

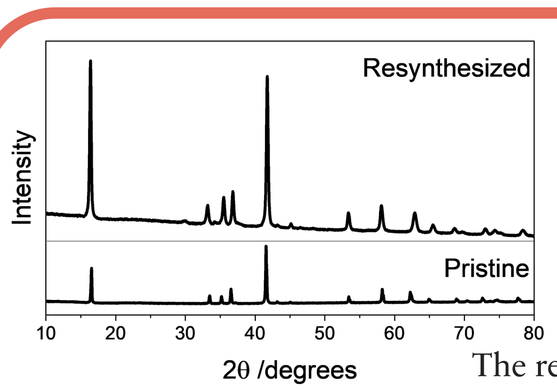
Direct resynthesis: obtaining of the cathode XRD, ICP, SEM

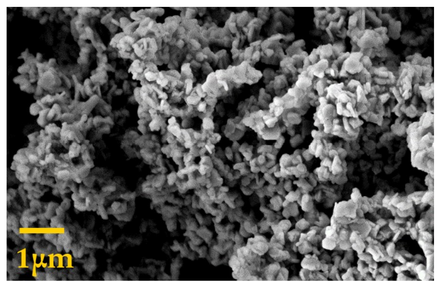


PATENTED

DES composition [5]
Choline Citrate : Ethylene Glycol (1:2)

DES leaching for 5h @ 120°C guarantees to meet the Ni recovery target; DES degraded matrix is the ideal matrix for sol-gel-like resynthesis.





The resynthesis is performed after a 10 h treatment in a muffle furnace at 750°C.

CONCLUSION

The explored approaches guarantee the **recovery of CRM**, coherent with the EU legislative requirements. In particular:
- CRM recovery through oxalate precipitation → possibility of repurposing the oxalate e.g. synthesis of different SIB or LIB cathodes
- DES-driven direct resynthesis → closed-loop approach, from NaNFMO dissolution to cathode resynthesis without precipitation steps

References:
[1] doi.org/10.1002/bte2.70082 [2] doi.org/10.1016/j.jclepro.2018.01.040 [3] doi.org/10.1016/j.jpowsour.2012.06.068 [4] doi.org/10.1016/j.jhazmat.2009.11.026
[5] Patent: Procedimento per il riciclo di batterie al litio (n° 102023000022644)

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