

REMHub–EU project clustering session

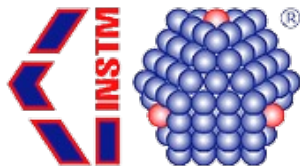
CARMEL Project

**“New CARbothermic approaches to
Recovery criticAI MEtals from spent
Lithium-ions batteries”**

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Li-ion battery recycling value chain

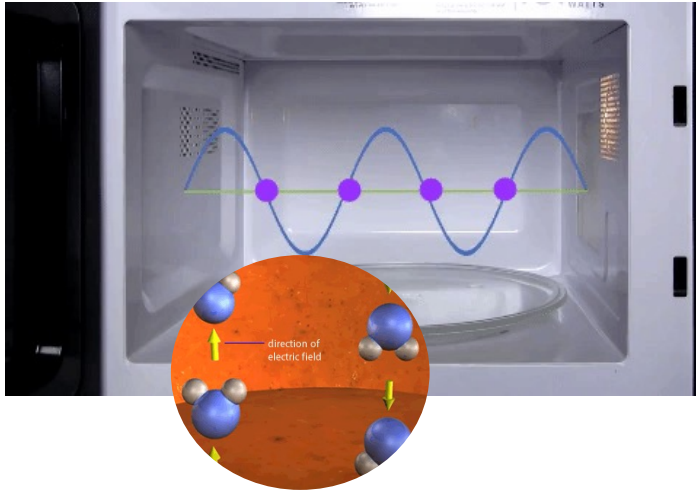


Hydrometallurgy

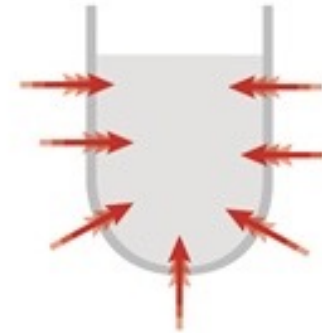


Pyrometallurgy

Microwave (MW)-based heating technology



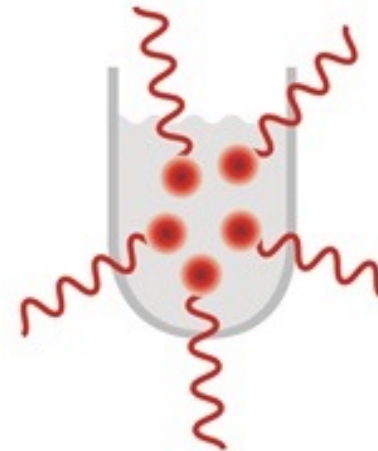
Conventional heating:



Benefits

- Energy saving
- Time saving
- Lab-scale easy-to-use
- Better energy transfer
- Selective of the treatment
- Increased sustainability of the process

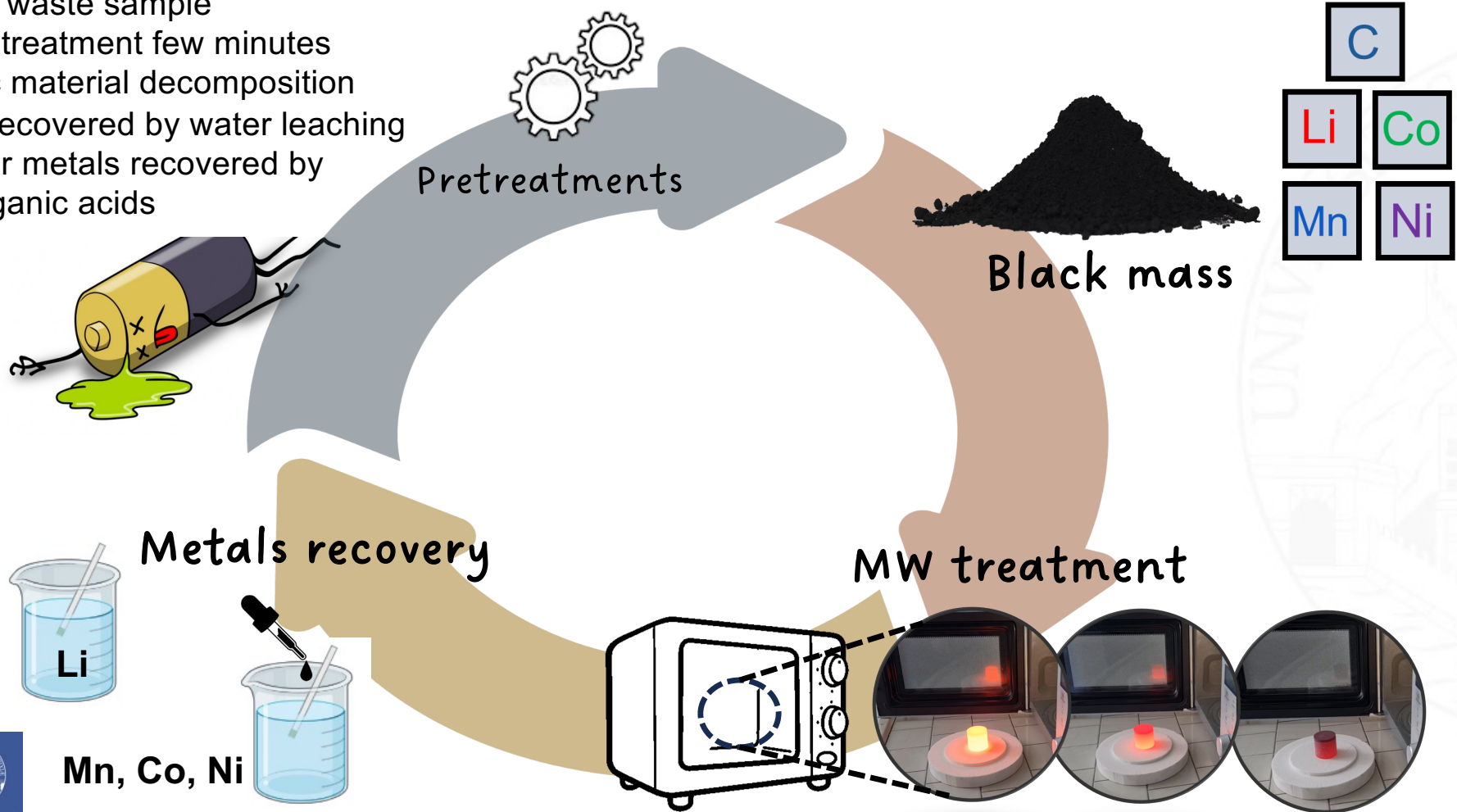
Microwave heating:



Co-funded by the Horizon 2020 programme
of the European Union

Microwave (MW)-based heating technology

- Real BM waste sample
- Thermal treatment few minutes
- Cathodic material decomposition
- Lithium recovered by water leaching
- The other metals recovered by using organic acids



Technology advantages

- This treatment induces a unique transformation of BM, which cannot be achieved either with conventional treatment or simple MW heating (**a new pyrometallurgical process**).
- The method is very flexible, requires **minimum** treatments and reduced quantities (**near to zero**) of **commercial chemicals**.
- The treatment, based on carbothermic reactions, can be applied to **all cathodic Li-based materials, also on mixed batteries waste**.
- It simplify the recovery step because **graphite can be recovered after metals leaching**.
- Preliminary energy evaluation allows us to conclude that the method is **more sustainable** in comparison to standard pyrometallurgical treatments.
- The method is flexible, then it may be suitable to treat also **future batteries** made on mixed metals oxides, and then it is suitable to be extended.

Future improvements

- The **carbon dioxide generated** by carbothermic reduction could be recovered to promote lithium-ion carbonation and the recovery of the Li_2CO_3 phase.
- All the aspects connected with **gas production** must be investigated in detail in the next future.
- The technology may be applied to recover other strategic materials (as P, and Rare-earth elements)



CAMEL FISA project – next steps

- Design and realisation of the prototype (new patent)
- Advanced recovery strategy (new patent)
- Sustainability evaluation of the proposed technologies

<https://caramel.unibs.it/>

Major prizes and recognitions:

- “SusCritMOOC business idea competition on Critical Raw Materials” from European Institute of Innovation & Technology (EIT) Raw Materials;
- Intellectual Property Award 2024 prize of Ministero delle Imprese e del Made in Italy for the CLIMATECH category;
- Expo 2025 Osaka presentation, with other 10 selected patented technologies.
- Inserted in the AIRI publication: **Innovazioni del Prossimo Futuro** (presented May 28th 2025, in Rome)

<https://www.airi.it/event/giornata-airi-per-linnovazione-industriale-2025/>





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