Flexible and efficient (hydrometallurgical) recycling of Li–ion batteries of different chemistry.
Recovery of Critical Raw Materials

Antimony, beryllium, borates, chromium, cobalt, coking coal, fluorspar, gallium, germanium, indium, magnesite, magnesium, natural graphite, niobium, PGMs, phosphate rock, heavy REEs, light REEs, silicon metal and tungsten.
Centrum of separation technologies (pilot plant)
Flexible and efficient (hydrometallurgical) recycling of Li-ion batteries of different chemistry.
List of critical raw materials for EU – 2017

Study on the review of the list of Critical Raw Materials, EU, 2017
MATERIAL COMPOSITION

- **External case** - steel, aluminium, plastic
- **Separator** - polyethylene or polypropylene
- **Current collectors** – aluminium and copper foils
- **Positive electrode** – LiCoO$_2$, LiNiO$_2$ or LiMn$_2$O$_4$
- **Negative electrode** – graphite
- **Salts** - LiClO$_4$, LiPF$_6$, LiBF$_4$
- **Solvents** – organic compounds
- **Binders** – polymers (e.g. PVDF)
- **Printed circuit boards** – plastics, components, solders, etc
- **Current joining** - gold-plated pad
Current state of Li–ion batteries recycling

Mechanical pre-treatment

Pyrometallurgical treatment

Hydrometallurgical treatment

Li

slag
Steps of the process being developed at Chalmers:

1. Pyrolysis
2. Mechanical Separation
3. Leaching
4. Solvent extraction
Challenge:
The presence of polyvinylidene fluoride (PVDF) – the binder for the active material to be attached with the current collectors (thin copper and aluminium foils).

- It affects:
  1. The mechanical separation process in which it obstructs the separation of the active material and carbon (also called black mass) from the foils.
  2. The leaching process in which it prevents the contact of the leaching media with the material.

Solution: Removal of PVDF by thermal methods (pyrolysis or incineration).

Benefit: Utilization of carbon.

Excludes the discharging of the batteries.
Pyrolysis

- thermal treatment
  - change of the phase and chemical composition
    - change of the leaching behavior
  - studied parameters:
    - temperature, time, gas flow, etc.
    - characterization: XRD, SEM, etc.
    - temperature, time, leaching agent, etc.

Benefits:
- By-products (tar and off gas are analyzed and investigated for further utilization).
- Separation of black mass from foils is improved – enhanced material recovery rate.
- By selection optimal parameters for thermal pre-treatment – leaching process can be simplified and efficiency is increased.

- Partial decomposition of LiCoO$_2$ to Co$_3$O$_4$.
- Partial decomposition of LiCoO$_2$ to CoO.
Mechanical Separation

Separation of black mass from aluminum and copper foils by sieving.

Improved purity of input material for hydrometallurgical treatment.

Simplification of solvent extraction process and decreasing of the energy demands for recovery of copper and aluminium.
Circular Economy of Battery Production and Recycling
Gothenburg, 24–26th of September 2018

www.ceb2018.org
Thank you for your attention!

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