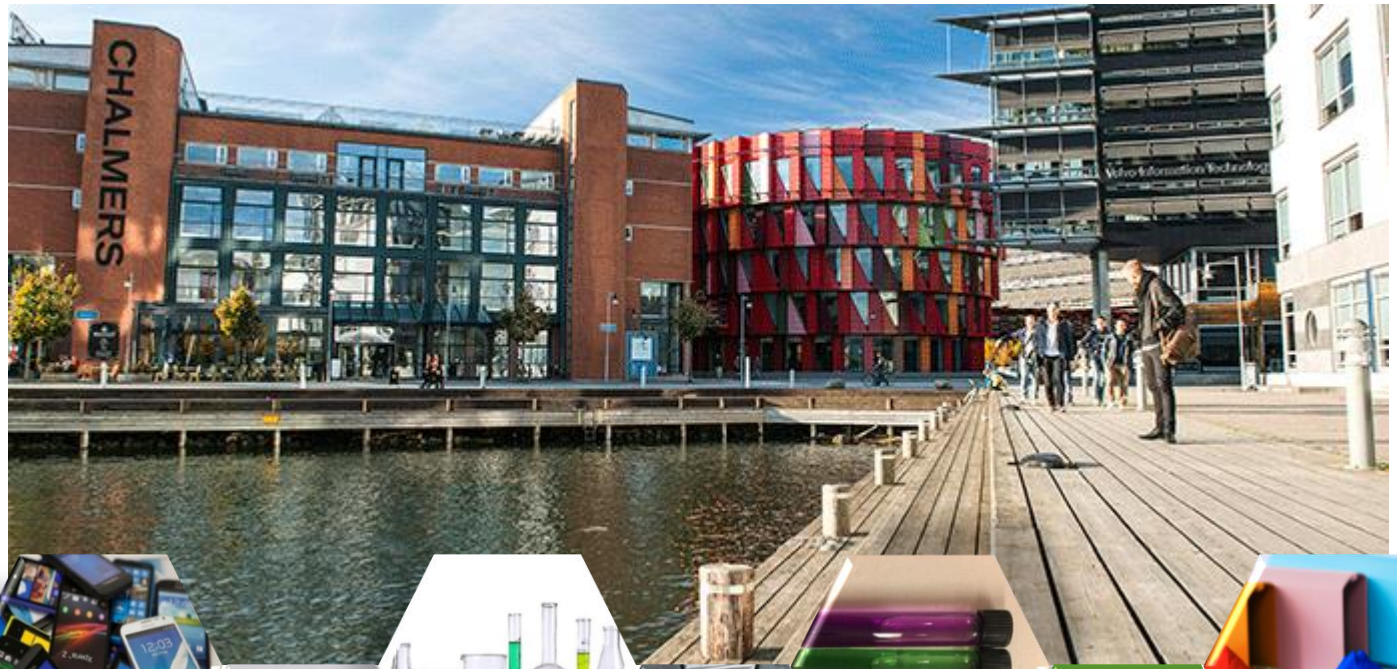
Chalmers University of Technology,
Department of Chemistry and Chemical Engineering
Industrial Materials Recycling



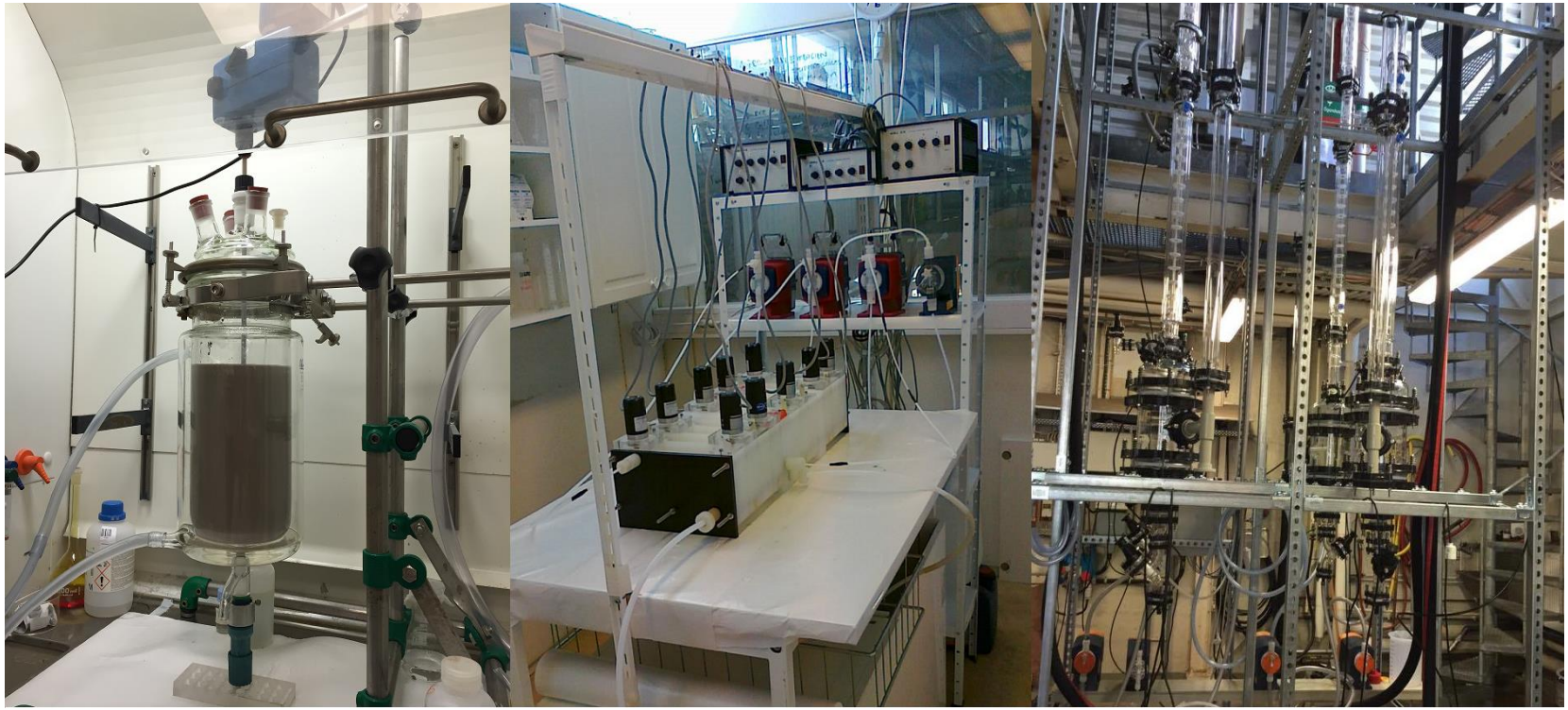
Flexible and efficient (hydrometallurgical) recycling of Li-ion batteries of different chemistry.

Martina Petranikova

Recovery of Critical Raw Materials

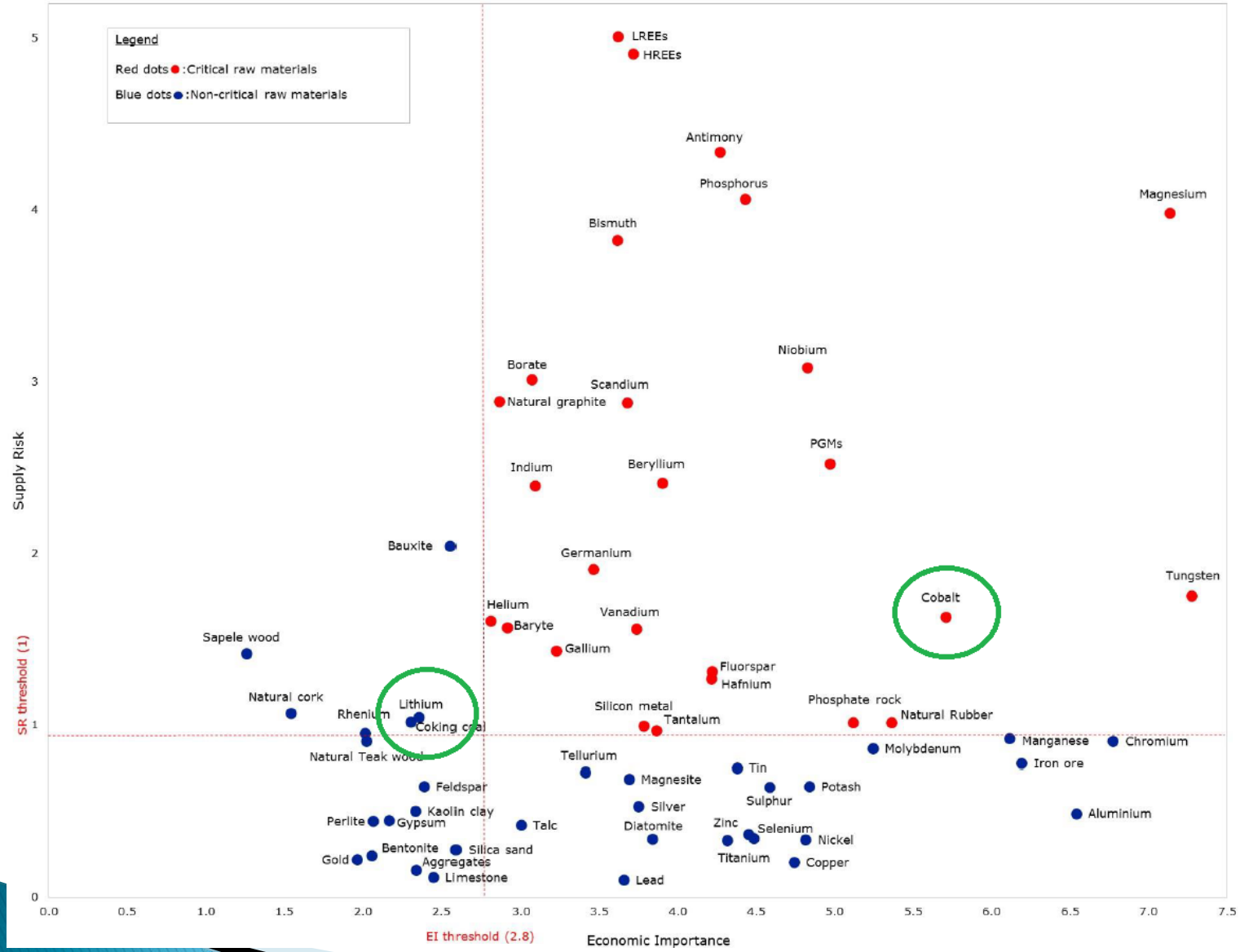
Antimony, beryllium, borates, chromium, cobalt, coking coal, fluorspar, gallium, germanium, indium, magnesite, magnesium, natural graphite, niobium, PGMs, phosphate rock, heavy REEs, light REEs, silicon metal and tungsten.

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 $LiMn_2O_4$
- 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

1. Pyrolysis

Why thermal pre-treatment?

- **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_3O_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

ELECTRODE MATERIALS

The quest for new electrode materials for lithium-ion batteries (LiB) with high energy density and low cost has seen major advances in intercalation compounds like carbonaceous electrodes or alloying materials for negative electrodes and layered metal oxides, spinels, polyanion materials, and composite oxides for positive electrodes.

DESIGN DEVELOPMENT

Lithium-ion batteries can be optimized by playing on the chemistry (electrode materials, electrolyte, separator) or by modifying the battery design whatever the technology (Lithium-ion battery, metal-air batteries, Li-S or all solid-state batteries, etc.).

ELECTROLYTES

Since the first lithium-ion batteries (LiB), many efforts have been made on the development of new electrodes with high capacity, high energy density and good cycling ability at the expense of the search of new electrolytes for lithium-ion batteries.

RECYCLING

The need of the sustainable development has been a substantial motivation to recover valuable materials from spent batteries. The efforts are made to increase the material recovery rate by the development of efficient recycling technologies.

APPLICATIONS

There are many types of battery technologies depending on their applications. These batteries can be used for portable applications, electric mobility, stationary applications or smart grids.

Thank you for your attention!

for more information contact:

Me: martina.petranikova@chalmers.se

Gabriele Lombardo: gablom@chalmers.se