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

Recycling of spent batteries

Martina Petranikova, Burcak Ebin, Filip Holmberg, Gabriele Lombardo,
Britt-Marie Steenari, Christian Ekberg

Projects:

1. Hydrochemical and pyrochemical recycling of metals from NiMH batteries (37714-1)
2. Recycling Processes for Alkaline and Zn-C Batteries (39063-1)
3. Process development for reuse and/or recycling of NiMH batteries (37720-1)
4. Flexible and efficient (hydrometallurgical) recycling of Li-ion batteries of different chemistry (40506-1)

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Only collected batteries can be recycled!

Efficient battery collection with consumer focus (37684-1)

The project aims at strengthening the social and technical infrastructure for the collection of spent small portable batteries as well as batteries in different types of household equipment and thereby making the collection more efficient.

Per EO Berg, Yuliya Kalmykova
Department of Civil and Environmental Engineering, Chalmers University of Technology
Helena Åberg, Maria Jose Zapata Santos and Ulrika Holmberg
The Faculty of Education, University of Gothenburg

First findings from the national survey
(in cooperation with SOM)

- Frequency of battery recycling is similar to light bulbs/strip lights
- Frequency of battery recycling is similar for most consumer categories (gender, age, income, education and urban/rural doesn't really matter)
- Households with children (esp. 7-15 years) spend more money on home electronics and purchase and recycle batteries more often than others
- Storing time for used batteries are longer in households with children, and among consumers with higher income and high education
- Highly educated perceive battery recycling to be more troublesome

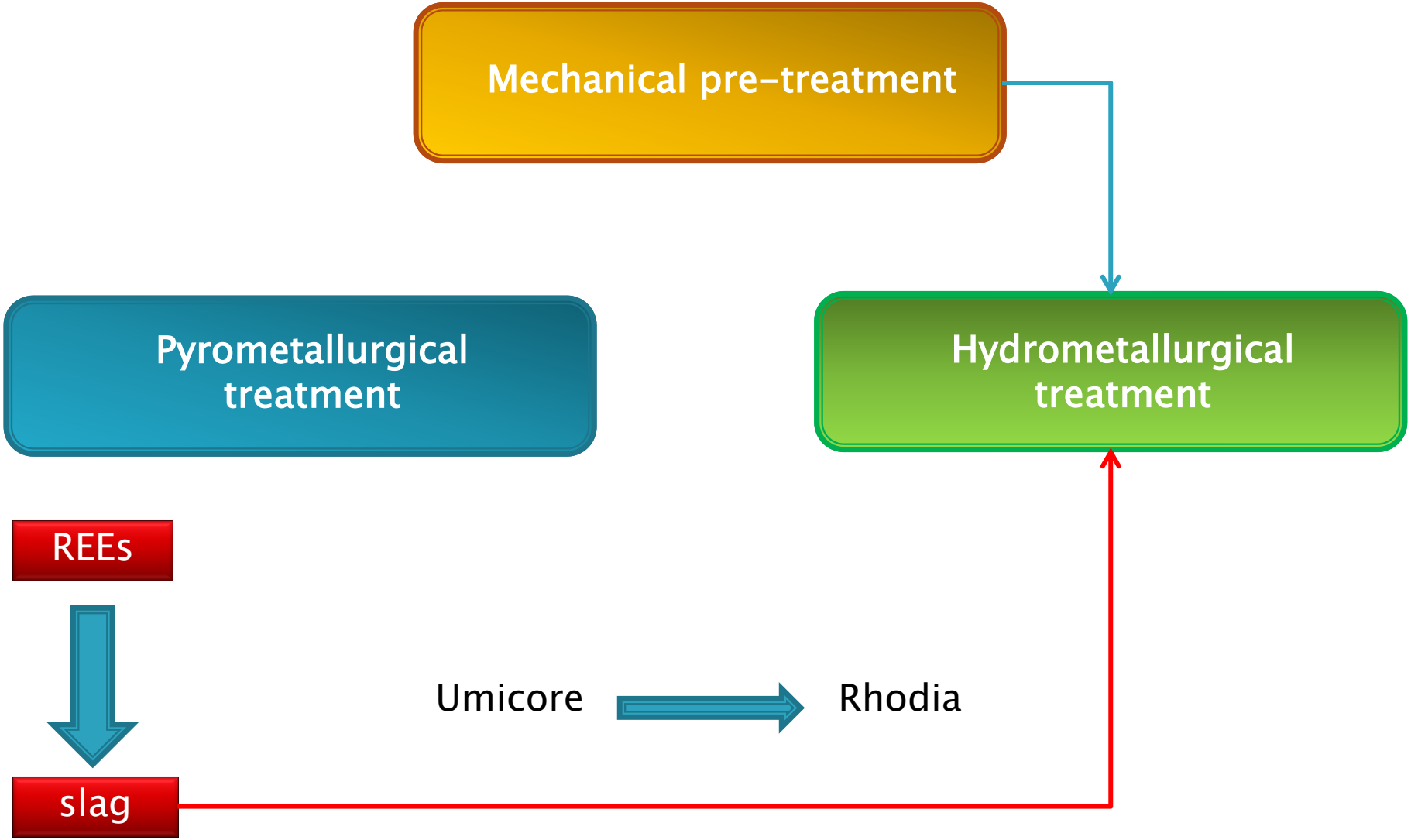
Conclusions and future work

- Synchronize social and technical infrastructures.
- Strengthen the view that batteries are hazardous waste and must be separately collected and recycled.
- Support recycling rituals (i.e. after X-mas cleaning) and support co-collection.
- A new method for collection efficiency estimation is developed for primary batteries.
- Disposal patterns point at necessity of further behavioral studies in order to find influence points for timely and correct disposal.
- Future work includes method development for the collection efficiency of the built-in batteries and other secondary batteries as well as a decision support model, combining the mechanisms of behavior, infrastructure and battery flows.

Hydrochemical and pyrochemical recycling of metals from NiMH batteries

Martina Petranikova, Irena Herdzik Koniecko, Burcak Ebin, Britt-Marie Steenari, Christian Ekberg

Current state of NiMH recycling



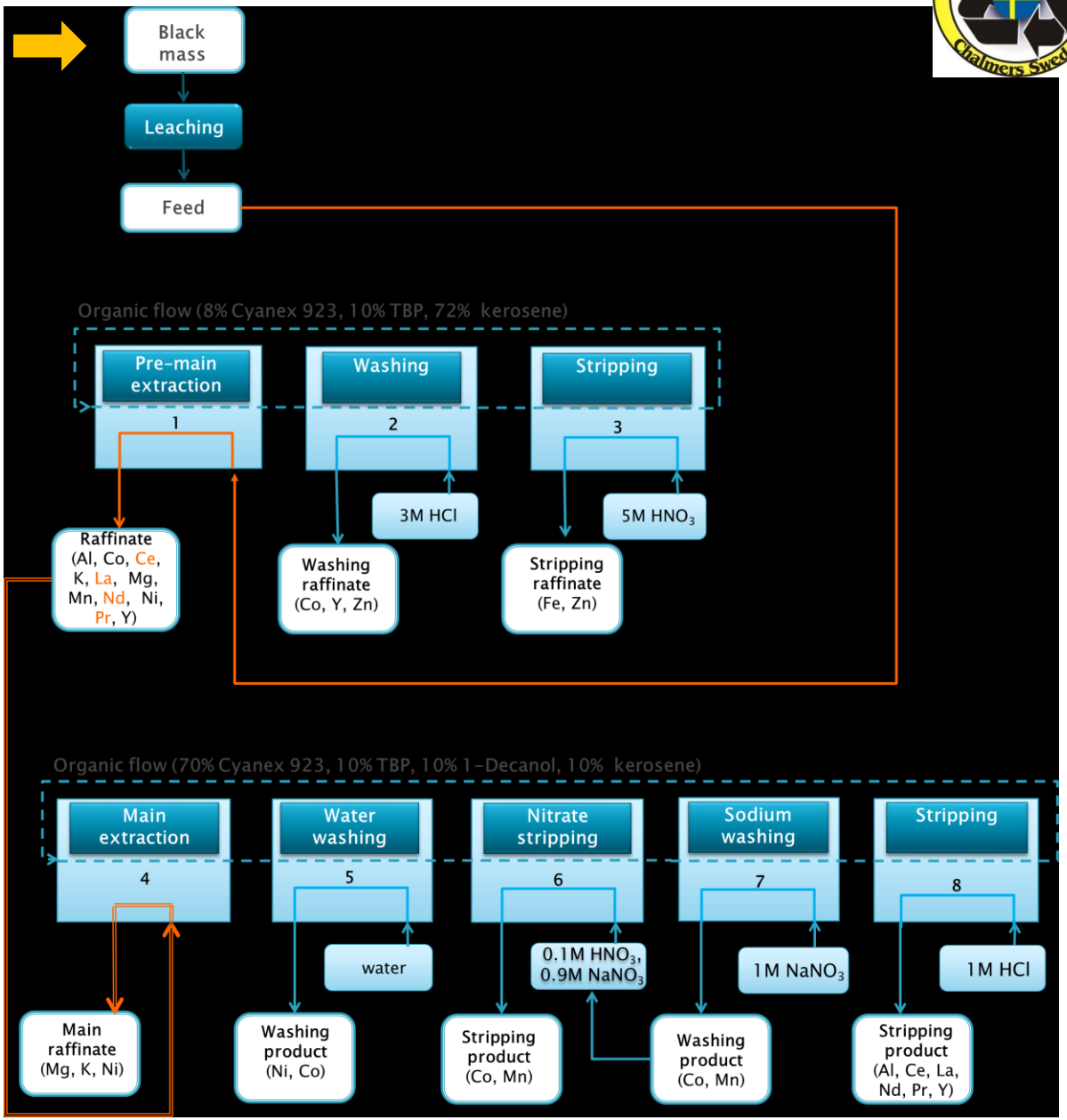
Hydrometallurgical process developed at Chalmers

1. Crushing of batteries

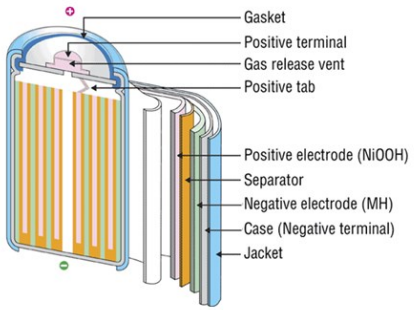
2. Separation of batteries

3. Leaching of electrode material with HCl

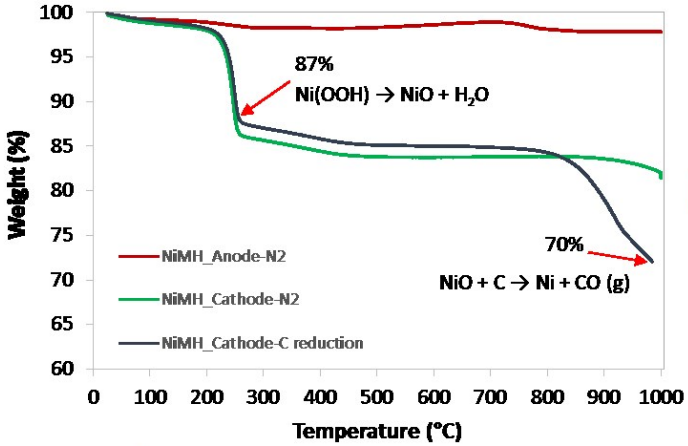
4. Solvent extraction using Cyanex 923


Black mass
Leaching
Feed
Organic flow (8% Cyanex 923, 10% TBP, 72% kerosene)
Pre-main extraction
1
Washing
2
Stripping
3
3M HCl
5M HNO3
Raffinate (Al, Co, Ce, K, La, Mg, Mn, Nd, Ni, Pr, Y)
Washing raffinate (Co, Y, Zn)
Stripping raffinate (Fe, Zn)
Organic flow (70% Cyanex 923, 10% TBP, 10% 1-Decanol, 10% kerosene)
Main extraction
4
Water washing
5
Nitrate stripping
6
Sodium washing
7
Stripping
8
water
0.1M HNO3, 0.9M NaNO3
1M NaNO3
1M HCl
Main raffinate (Mg, K, Ni)
Washing product (Ni, Co)
Stripping product (Co, Mn)
Washing product (Co, Mn)
Stripping product (Al, Ce, La, Nd, Pr, Y)

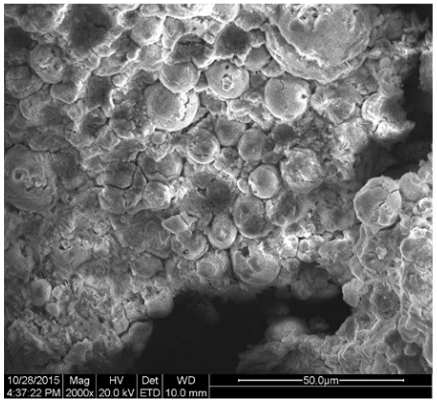
NiMH Battery Waste



Pyrolysis



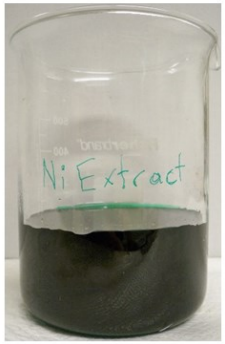
Recovered Ni particles

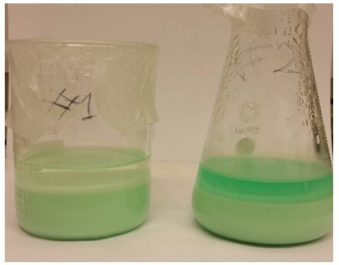


Combination of Hydro- and Pyro-processing

Sol-Gel Process

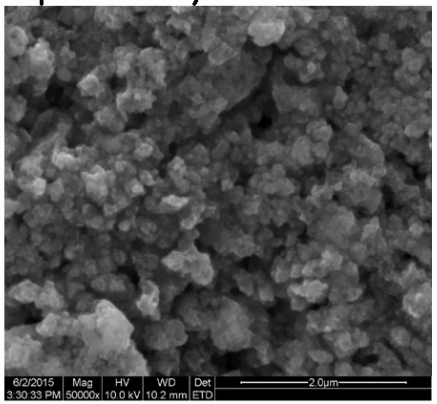
Ni recovery rate 99%





Filtration&Drying

Production of NiO and Ni nanoparticles by calcination



Recycling Processes for Alkaline and Zn-C Batteries

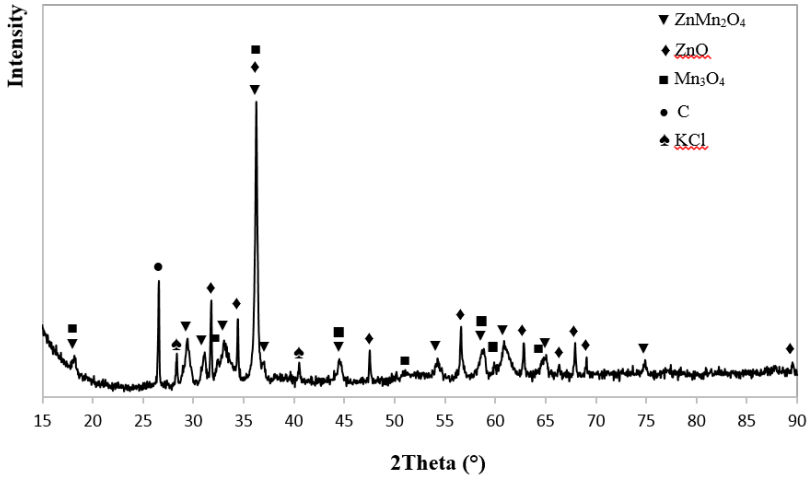
Martina Petranikova, Burcak Ebin, Britt-Marie Steenari, Christian Ekberg

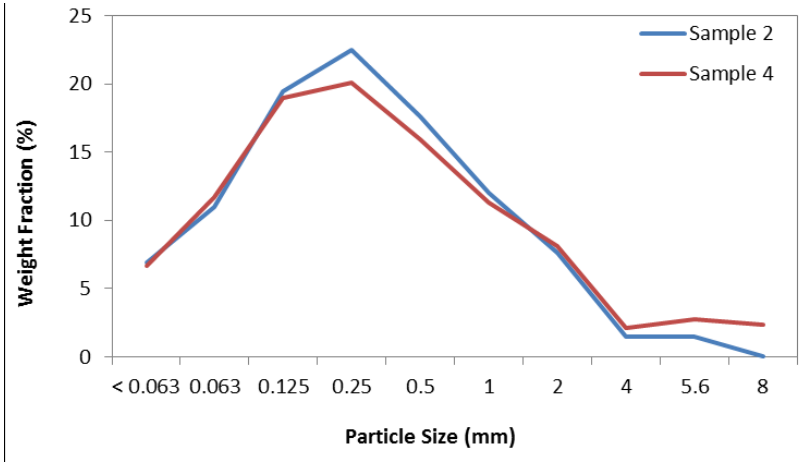
Analysis of Alkaline Battery Waste

ICP-OES

Elements	Battery Waste % (w/w)
Mn	28 ± 1
Zn	25 ± 1
K	4 ± 0.6
Fe	0.83 ± 0.04
Ni	0.1 ± 0.06
Co	0.01 ± 0.004
Cu	0.03 ± 0.01
Cr	0.02 ± 0.005
Pb	0.02 ± 0.002
Cd	0.01 ± 0.003
Hg	0.00
C	7

XRD





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Hydrometallurgical method

Leaching

Selective precipitation of Mn

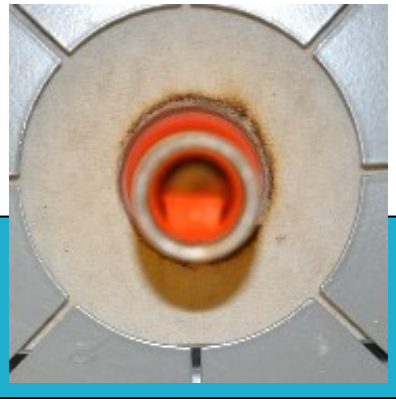
Electrowinning of Zn

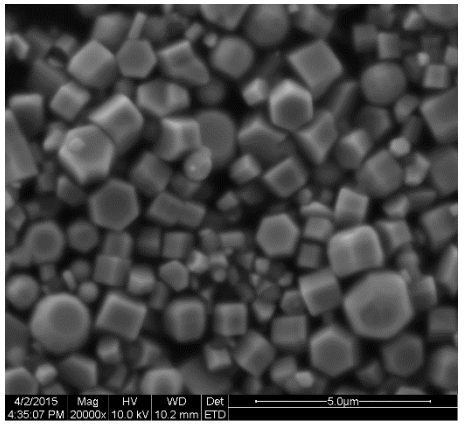
Pyrometallurgical method

Distillation of Zn

Utilization of Mn

Pyrolysis





Research Parameters

- ✓ Temperature
- ✓ Time
- ✓ Gas Flow Rate
- ✓ Reducing Agent
- ✓ Type of Gas
- ✓ Feeding Amount

Process development for reuse and/or recycling of NiMH batteries

Filip Holmberg, Martina Petranikova, Burcak Ebin, Britt-Marie Steenari, Christian Ekberg

Aim:

Reduce scrap within the manufacturing process and reuse of the active materials (Nilar AB).

Tasks:

- Separation of active materials (STENA Recycling, Uppsala University, Stockholm University)
- Regeneration of spent hydrogen storage alloy (Stockholm University)
- Reproduction of spent hydrogen storage alloy from battery waste (Uppsala University)
- Separation of metals and reproduction of active materials (Chalmers)

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

Process developemend at Chalmers:

1. Pyrolysis

2. Separation

3. Leaching

4. Solvent extraction

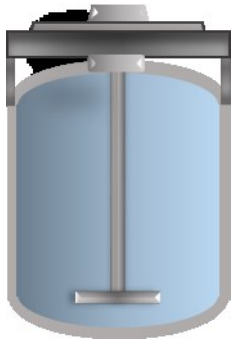
Pyrolysis of the black mass from spent lithium ion batteries and metal recovery by hydrometallurgical methods

thermal treatment

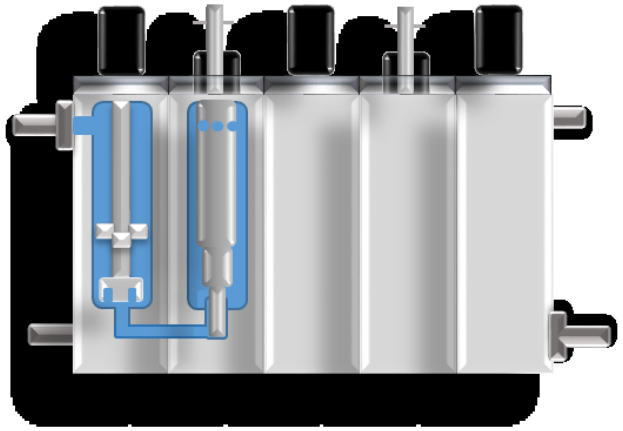
change of the phase and chemical composition

change of the leaching behavior

Leaching - Several parameters such as different leaching agents, temperature, and solid to liquid ration were studied in the leaching process. The aim will be to determine optimal conditions for the leaching process.



Solvent extraction process: In the process of metal ions recovery different extractants were used to determine optimal conditions for system.



The developed processes will be scaled up in pilot scale mixer settlers.

Future work:

1. Hydrochemical and pyrochemical recycling of metals from NiMH batteries (37714-1) – separation of particular metals within the groups – metal production.

2. Recycling Processes for Alkaline and Zn-C Batteries (39063-1) – development of both pyrometallurgical and hydrometallurgical process for recycling.

3. Process development for reuse and/or recycling of NiMH batteries (37720-1) – implementation of the developed technology for battery recycling.

4. Flexible and efficient (hydrometallurgical) recycling of Li-ion batteries of different chemistry (40506-1) – development of combined recycled technology.

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Thank you for your attention!