SHORT COURSES

CIRCULAR ECONOMY AND SUSTAINABLE MATERIALS FOR LI-BATTERY

University of Lorraine - ENSG
European Lithium Institute

18-19/11/2020
8.45 AM - 5.30 PM
MICROSOFT TEAMS MEETING

WHAT ARE THESE SHORT COURSES?

These short courses on the topic "**Circular economy and Sustainable materials for Li-battery**" are organized by and at the **University of Lorraine**, on **Wednesday November 18 and Thursday November 19, 2020,** after a successful first edition in 2019 about "Exploration and procesing of battery metals (Li, Co, Ni) primary and secondary resources". The event is coordinated by Prof Lev Filippov, vice-director for Education committee of eLi, organized by Alexandra Ferreira and supported by Alexandre Piçarra

This event is incorporated within the framework of the **European Lithium Institute** work, whose aim is to link up competences and infrastructure along the whole **lithium value chain** to generate focused international cooperation and to enable comprehensive policy and industry advice. Thus, the aim is to share knowledges covering the whole chain of Lithium, from Li and other Li-battery metals production to Li-ion battery recycling in the light of closing the loop.

Three main points raised on this event are:

- Global vision of a circular economy and significance for Li-production including the geology and ressources availability of battery metals as well as battery metals market dynamics
- Processing and Recycling of the Li-ion batteries using combined technology to recover Co, Ni, Li, graphite
- Characterization and reuse of materials issued from recycling

The **targeted public** is Master and PhD students. This event is opened to students and staff from the following institutions: University of Lorraine (Otelo, GeoRessources, partner laboratories involved in the Labex "Resources 21", …), EIT Raw Materials and the schools from IMT Grand Est as well as to the other European Universities and Institutions.

Two formats of presentation are proposed:

- 40 min conferences + a 20 min questions & answers session
- 20 min technical presentations + a 10 min questions & answers session

The **presenters** are from the McGill University (Canada), the Bordeaux University (France), the Canadian Institute of Mining (CIM-ESRS), the French Alternative Energies and Atomic Energy Commission (CEA), the Fraunhofer R&D Center Electromobility (Germany), the Fraunhofer Institute for Silicate Research ISC (Germany) , Helmholtz-Institute Freiberg for Resource Technology (Germany), the Geological Survey of Finland/Geologian tutkimuskeskus, the Bureau des Recherches Géologiques et Minières (BRGM) (France), the Institut de Chimie de la Matière Condensée de Bordeaux (ICMCB) (France) and the SMS-Group (Germany).

AGENDA

	Wednesday 18/11/2020	Thursday 19/11/2020
8:45 – 9:00		**Filippov Lev** Introduction
9:00 – 10:00		**Sonnemann Guido (Bordeaux University)** An introduction to using Life Cycle Assessment as a metrics in advancing research towards a sustainable lithium value chain
10:00 – 10:45		**Giffin, Guinevere (Fraunhofer)** Enabling Aqueous Processing of Nickel-rich Layered-Oxide Cathode Materials
10:45 – 11:45		**Lefebvre Gaetan (BRGM)** A brief overview of the battery metals market dynamics in a post-covid context
11:45 – 13:00	LUNCH TIME	LUNCH TIME
13:00 – 13:30		**Bouyer, Etienne (CEA)** Processing and recycling of the Li-ion batteries
13:30 – 13:45	**Bittner Andreas & Filippov Lev** Introduction	**Aymonier, Cyril (ICMCB)** Supercritical fluid technology applied to Li-battery: from material design to recycling
13:45 – 14:00		
14:00 – 14:15	**Zaghib Karim (McGill University)** From Mine to Recycling: Materials and Processes for Li-ion Batteries	**Lorrmann, Henning (Fraunhofer)** High energy anodes for Lithium-ion batteries – silicon and silicon-graphite composite electrodes
14:15 – 14:30		
14:30 – 15:00		**Bittner, Andreas (Fraunhofer)** New fragmentation and sorting technologies for the recycling of Li-ion batteries
15:00 – 15:15	BREAK	BREAK
15:15 – 15:30	**Gloaguen Eric (BRGM)** Raw materials for batteries - The keys to a sustainable European supply: example of Lithium	
15:30 – 16:00		**Dehaine Quentin (GTK)** A global geometallurgical assessment of Co mining & processing
16:00 – 16:15		**Anna Vanderbruggen (HIF)** Recovery of spheroidized graphite from spent LiBs
16:15 – 16:30		
16:30 – 17:15		**Recalde, Andres (CIM-ESRS)** Social and Environmental Concepts of Lithium Exploration and Extraction in South America
17:15 – 17:30		

Topic 1 : Global vision of a circular economy and significance for Li-production including the geology and ressources availability of battery metals as well as battery metals market dynamics, and battery material description

Topic 2 : Characterisation, Processing and Recycling of the Li-ion batteries using combined technology to recover Co, Ni, Li, graphite

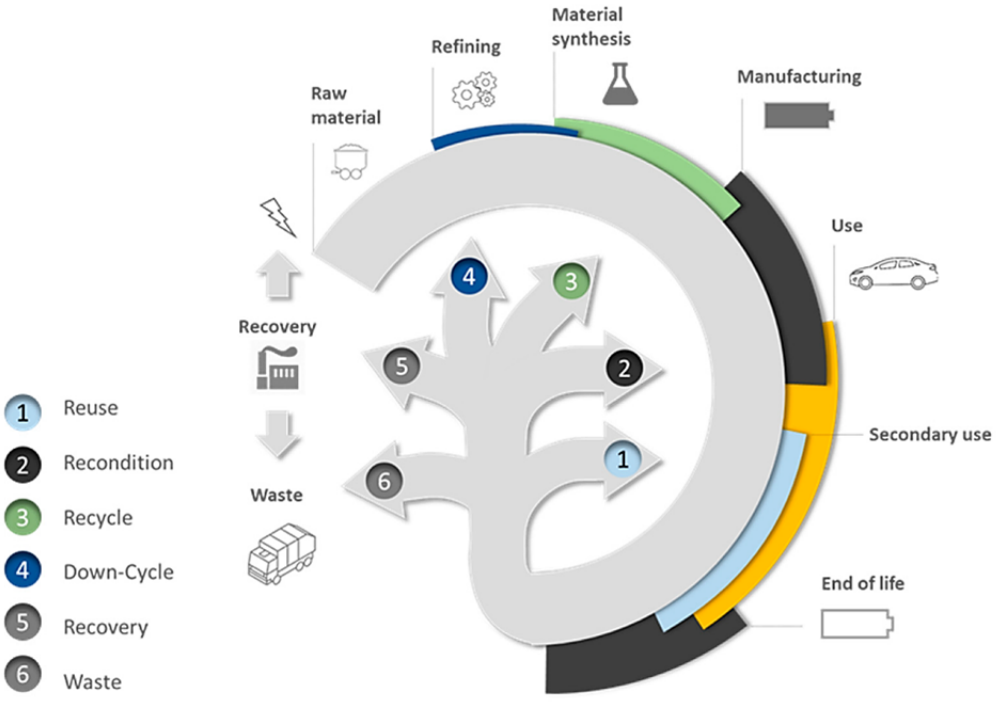
DETAILED PROGRAM

ZAGHIB Karim - McGill University - Canada

Professor in the Mining and Material Engineering Department at McGill University and Strategic Advisor for Investissement Québec

FROM MINE TO RECYCLING: MATERIALS AND PROCESSES FOR LI-ION BATTERIES

The development and deployment of economical and energy efficient solutions for the manufacture of Li-ion batteries for electric vehicles is increasingly becoming a global issue. Based on existing documentation as well as market data, this presentation deals with the following elements: (i) precursors, (ii) anodes, cathodes and their manufacturing process (iii) the manufacture of li-ion cells (Fe vs. Ni vs. Co). The main economic and environmental factors for recycling EV batteries; (iV) the technical and financial challenges of scaling up recycling initiatives, and (V) key recycling process options.



Cyclic flowchart of manufacturing, usage, and EOL LIBs (Zaghib et al., Materials 2020, 13(3), 801)

GLOAGUEN Eric - Bureau de Recherches Géologiques et Minières (BRGM)- France

Economic Geologist

RAW MATERIALS FOR BATTERIES - THE KEYS TO A SUSTAINABLE EUROPEAN SUPPLY: EXAMPLE OF LITHIUM

The needs for energy storage capacity is growing up rapidly throughout the world and personified by the rapid development of Lithium-ion batteries manufacturing capacities.
Beyond lithium, which account for a few percent of battery content, several elements are also needed for the battery industry, mainly copper, aluminium, nickel, cobalt, graphite, manganese and phosphate among others.
Most of these raw materials are sourced outside Europe and their transport throughout the world contributes to the increase of CO2 emission, despite some European deposits and a true potential.
A close examination of European lithium deposits shows that there is significant potential, but they are mainly unconventional lithium deposits. Thus, our ability to produce European lithium depends on the ability to economically extract lithium from new ores and on our ability to understand geological processes to find enough ore deposits.

SONNEMANN Guido - Bordeaux University - France

Professor in Sustainable Chemistry, Head of the CyVi Group in the Institut des Sciences Moléculaires (ISM), supervisor of the KIC EIT Raw Materials program

AN INTRODUCTION TO USING LIFE CYCLE ASSESSMENT AS A METRICS IN ADVANCING RESEARCH TOWARDS A SUSTAINABLE LITHIUM VALUE CHAIN

Life cycle assessment is the only internationally standardised methodology for evaluating the environmental impacts associated with all the stages of a material and the related processes in a product system. It has become a crucial tool for orientating research towards sustainable innovation. In this context, life cycle assessment will be introduced and first examples of its use for advancing research towards a sustainable lithium value chain will be presented.

GIFFIN Guinevere - Fraunhofer R&D Center Electromobility - Germany

Head of Li-ion Technology at FZEB

ENABLING AQUEOUS PROCESSING OF NICKEL-RICH LAYERED-OXIDE CATHODE MATERIALS

Water-based electrode manufacturing process for the positive electrode can lower the overall battery price and improve environmental impact of the electrode production process. However, the implementation of this process for Ni-rich layered-oxide cathode materials remains challenging due to the negative effects of water contact.
These effects include degradation involving nickel-driven processes that lead to lithium leaching combined with the increase of the pH value into the alkaline region. LiNi0.8Co0.15Al0.05O2(NCA) is particularly sensitive to water exposure not only during aqueous processing but also in ambient air. Water exposure results in the formation of water-induced surface species and water-induced leached species related not only to lithium and nickel but also to aluminum. These water-induced species lead to a severe deterioration of the cells due to the resistive nature of such surface moieties and their involvement in side reactions during cycling. One successful strategy to combat these issue is the protection of NCA surface with a suitable coating, which can remarkably improve the performance of cells containing aqueous-processed NCA electrodes.

LEFEBVRE Gaétan - Bureau de Recherches Géologiques et Minières (BRGM) - France

Geologist and Metal market analyst

A BRIEF OVERVIEW OF THE BATTERY METALS MARKET DYNAMICS IN A POST-COVID CONTEXT

Battery materials are the ones at stake in the current (and future) composition of Lithium-ion batteries (LIB) namely lithium, cobalt, nickel and graphite. In coming years, their supply will remain crucial for many operators as energy storage and clean mobility appear as key strategic sectors in many economies, Europe in particular. Despite a similar effect of the COVID pandemic on these markets, which has been a periodic slowdown of demand, each one has its own specificities and challenges for the decade to come, which will be detailed in this short course.

BOUYER Etienne - Alternative Energies and Atomic Energy Commission (CEA)- France
Adjunct director of the New Technology for Energy Program

PROCESSING AND RECYCLING OF THE LI-ION BATTERIES

Deployment of electrical mobility is a strong driver for massive development of Li-battery industry. This growing industry will need to become as sustainable as possible. Thus, circular economy has to penetrate the battery sector all along the value chain.
This short presentation aims to give a flavor on what are the main steps of processing (from material synthesis to system integration through key component manufacturing and testing) and recycling of the Li-ion batteries. This will be illustrated thanks to existing project examples.

AYMONIER Cyril - Institut de Chimie de la Matière Condensée de Bordeaux - France
Head of Research

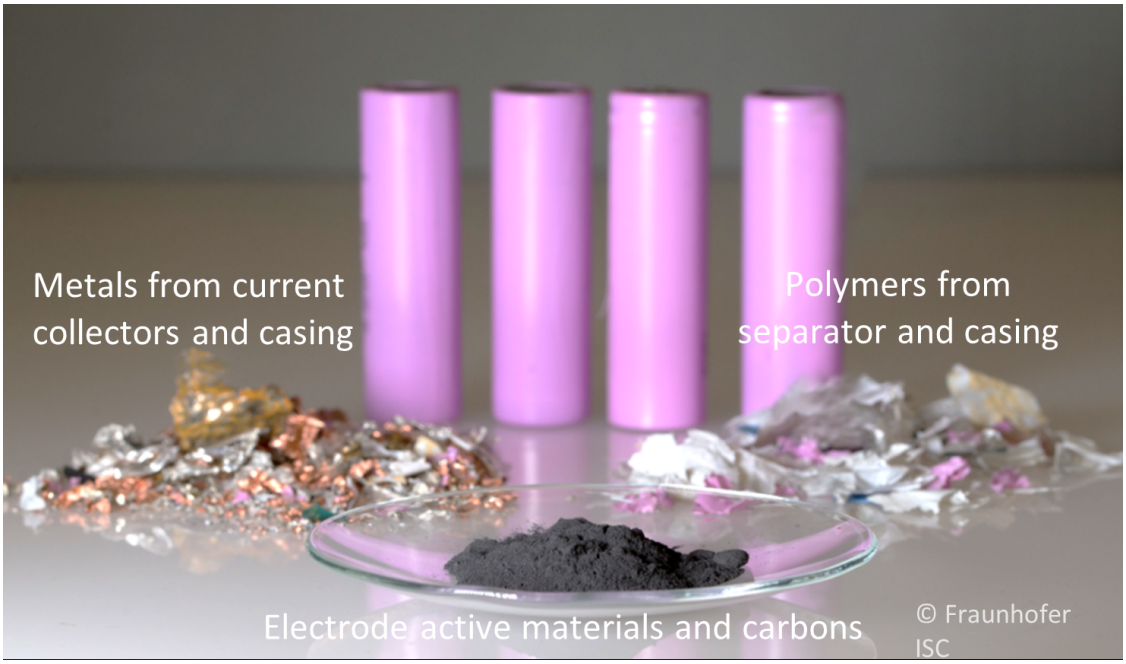
SUPERCRITICAL FLUID TECHNOLOGY APPLIED TO LI-BATTERY: FROM MATERIAL DESIGN TO RECYCLING

Supercritical fluids-based technologies are developed for more than 40 years. Years after years, the supercritical fluids route finds new applications in the field of materials processing but also materials recycling. In the last 25 years, the use of supercritical water and supercritical carbon dioxide as solvents has been extended to other fluids to increase the versatility of this materials processing and recycling method considered as a sustainable one. After an introduction to the specific properties of supercritical fluids, this presentation will be focused on the interest and potentialities of these advanced supercritical fluids-based technologies. This will be illustrated with examples going from material design to recycling, especially what has already been performed in the field of Li-battery. The benefits of the supercritical fluid route include not only better performances for advanced applications but also environmental issues associated with the synthesis and recycling processes. This will be emphasized with the studies performed using LCA approaches coupled with risk assessment ones. At the end, the state of development of these supercritical fluids-based technologies will be discussed.

BITTNER Andreas - Fraunhofer Institute for Silicate Research ISC - Germany
Director European Lithium Institute | Head of New Business Development Fraunhofer ISC

NEW FRAGMENTATION AND SORTING TECHNOLOGIES FOR THE RECYCLING OF LI-ION BATTERIES

In order to establish a sustainable circular economy for Li-ion batteries, Fraunhofer ISC and its partners work on new efficient battery recycling processes. The heart of the innovative recycling approach is a materials selective fragmentation of lithium-ion battery cells, which enables the selective recovery of battery materials via simple physical separation methods such as sieving, filtering and centrifugation (fig.). The recovered materials fractions can be fed into standard hydrometallurgical processes with reduced amounts of process chemicals or refined and reused as functional materials. As an example, valuable electrode materials of production residues can be directly applied for the production of new battery cells without new energy-intensive materials synthesis. This saves costs, resources and CO2 emissions. The presentation will give an overview of different battery recycling routes and introduce innovative recycling technologies.



Recovered materials fractions from electrohydraulic fragmentation process

LORRMANN Henning - Fraunhofer R&D Center Electromobility - Germany
Head of Fraunhofer R&D Center Electromobility

HIGH ENERGY ANODES FOR LITHIUM ION BATTERIES – SILICON AND SILICON-GRAPHITE COMPOSITE ELECTRODES

The lecture start with an overview on Lithium ion battery active materials and going more into detail on high energy anodes. We will talk about the relevant active and passive components in a battery regarding their volumetric and gravimetric share in order to discuss the leverage potential of high energy anodes from the component's and the cell's perspective. In the second chapter we'll talk about Silicon litiation and delitiation processes and the most prominent degradation mechanisms. In the third and last chapter potential solutions on these degradation root causes will be discussed. Concepts will comprise materials and cell design as well as charging strategies and prelitiation of the anode.

DEHAINE Quentin - Geological Survey of Finland/Geologian tutkimuskeskus (GTK)
Postdoctoral Researcher in the Circular Economy Solutions Unit

A GLOBAL GEOMETALLURGICAL ASSESSMENT OF COBALT MINING & PROCESSING: STRATEGIES TO RESOURCE FUTURE SUPPLY AND DEMAND

Cobalt (Co) is a transition metal featuring unique physical properties making its uses critical for many high tech applications such as high strength materials, magnets and most importantly, rechargeable batteries. The bulk of world cobalt output usually arises as a by-product of other metal extraction, mostly nickel (Ni) and copper (Cu), from a wide variety of deposit types including copper sediment-hosted, nickel laterites, nickel sulphides or hydrothermal and volcanogenic deposits. Differences in ore geometallurgical propertie (geochemistry, mineralogy, alteration and physical properties) are significant between cobalt-hosting deposits as well as within a single deposit, which can host a range of ore types. This presentation will briefly review the main geometallurgical properties of cobalt ores with a particular focus on ore mineralogy which exerts a significant control over ore processing behaviour and Co extraction, such as the oxidation state, i.e. oxide or sulphides which drives the selection of the processing route (leaching vs flotation), the associated gangue mineralogy, which can affect acid consumption during leaching or flotation performance. Next, the main processing challenges and associated geometallurgical issues faced by each deposit type are then reviewed. An extensive dataset of cobalt recovery rates from various mining operations worldwide is also analyzed. Overall, recovery efficiency of Co is highly variable and generally low, it varies as a function of the deposit type and processing route, leading to significant Co losses in mine tailings or smelter slags. Overall, recovery efficiency of Co is highly variable depending on the deposit type and process used. On average, cobalt recovery is relatively low (less than 60%), in particular for sediment-hosted Cu-Co deposits, leading to significant Co losses in mine tailings or smelter slags. As a result, the amount of recoverable cobalt from the currently identified cobalt resources and reserves is greatly impacted. With a forecasted demand expecting to outrun supply in the upcoming years due to the electric mobility transition, solutions to remediate this issue will be discussed.

VANDERBRUGGEN Anna - Helmholtz Institute Freiberg for Resource Technology - Germany

PhD candidate in the Department of Processing

RECOVERY OF SPHEROIDIZED GRAPHITE FROM SPENT LITHIUM ION BATTERIES

Recycling of lithium ion battery has attracted a lot of attention and is particularly focusing on the valuable metals such as cobalt, nickel and lithium. Despite the growth in graphite consumption and the fact that it is counted as a critical material in Europe, USA and Australia, there is little previous work focusing on graphite recycling. Thus, graphite usually remains in slags from the metallurgical treatments. The aim of this research is to increase the recycling recovery of the LIBs by developing a new innovative process, which minimizes metal losses and is able to recover graphite. By integrating a flotation stage, this recycling process is able to separate battery electrode materials while preserving their functional integrity in order to reintegrate them in the value chain of LIB production. Two valuable products, one of graphite and one with the valuable metals are recovered using a batch mechanically agitated Outotec flotation cell. Batch flotation study shows that pre-treatment, such as attritioning, improves the process. The graphite recovery is +98 % with a grade of 80 wt. %. This research aims to reach closed-loop system for spheroidized graphite from spent LIBs.

Recalde Andres - Canadian Institute of Mining (CIM-ESRS)

Executive officer/Working Group Director Mining4Good

SOCIAL AND ENVIRONMENTAL CONCEPTS OF LITHIUM EXPLORATION AND EXTRACTION IN SOUTH AMERICA

Lithium value chain for exploration and mining companies operating in South America face a double challenge. It must keep a fragile balance with a dynamic interplay between environment and local stakeholder's livelihoods. Operators must demonstrate that their extraction and processing activities ultimately contribute positively to social development not overdrawing on natural resources or over-burdening the environment in an irreversible manner. The ultimate goal would be to achieve social and environmental sustainability represented by the existence of a social license to operate. Local regulations most of the time are not updated to grant licenses and permits for Lithium operations considering its uniqueness when comparting with basic or precious metals.