UNIVERSITÉ DE LORRAINE

RESSOURCES 21

International Congress
METALS FOR ELECTRIC MOBILITY

Dates 19 and 20 September 2023

Location Aquarium Museum of Nancy

Address 34 Rue Sainte-Catherine,
54000 Nancy

INVESTIR L'AVENIR

cnrs

INRAE

International Congress Metals for Electric Mobility

The European Union climate neutrality by 2050 objective is a necessary but also — a very resource-intensive initiative. In the fight against the climate change in the circular economy framework, a great awareness, coordination and innovations across all aspects of material production are required. One of the major predicted consumers of the green technology metals is electric mobility. Cobalt, lithium, rare earth elements, manganese, nickel – all these metals and more are required for production of an electric vehicle.

The International Congress dedicated to the metals for electric mobility organized by LabEx RESSOURCES21 is aimed to promote networking and fruitful exchange between the scientists and the industrial representatives and to spread awareness among the younger audience in regard to the challenges and the state-of-art across the major electric mobility-related fields. Through organized separate sessions, the congress addressed the following aspects of metallic resources directly related to component production for electric vehicles:

- Socio-economic impact associated with metals for electric mobility;
- Geology of concerned metals;
- Extractive metallurgy;
- Metal recycling;
- Legislation;
- Environmental concerns, constraints and available remediation techniques.

International Congress METALS FOR ELECTRIC MOBILITY

19 and 20 September 2023
Aquarium Museum of Nancy, 34 Rue Sainte-Catherine, Nancy, France

PROGRAMME

Day 1, Tuesday, 19 September 2023

Session	Time	Speaker	Title
	9h00	Alexandre Chagnes	Welcoming speech and practical information
Socio-economic impact	9h20	Michel Cathelineau	The challenges of the energy transition: the transverse vision of the RESSOURCES21 LabEx
	9h40	Rajapandian Rajagopal	The EU's battery recycling needs and opportunities
	10h00	Justo Garcia	Battery recycling, an energy transition challenge for Europe
10h20-10h40			*Coffee break*
Geosciences	10h40	Patrick Fullenwarth and Daniela Liebetegger	Exploration in Beauvoir, France: Imerys to become a major player in the European lithium market
	11h00	Cécile Fabre	Advanced characterization methods for light elements
	11h20	António Mateus	Lithium and rare metal granites in Portugal
	11h40	Marie-Christine Boiron	Lithium enrichment from brines in sedimentary basins: A focus on the Rhine graben
12h00-14h00			*Lunch*
Geosciences	14h00	Romain Millot and Clio Bosia	Geothermal lithium in Alsace at the heart of the energy transition
	14h20	Lydéric France	New constraints on carbonatites formation, the main REE deposits: A journey in the Oldoinyo Lengai volcano plumbing system
	14h40	Fabrice Golfier	Contribution of Reactive Transport Modelling to the Understanding of Nickel ore deposits in New Caledonia
	15h00	Christophe Ballouard	A cannibalistic origin for rare-metal granites? Insights from the Velay anatectic dome (Variscan French Massif Central)
15h20-15h40			*Coffee break*
Transversal	15h40	Mathias Dantin	Decarbonation & sovereignty - Key drivers and changes observed from a legal standpoint
Extractive metallurgy	16h00	Kerstin Forsberg	Hydrometallurgical processing of rare earth elements
	16h20	Zubin Arora	Influence of bio-diluents on the extraction of metals using hydrometallurgy in battery recycling
	16h40	Kerstin Forsberg	In-line gallium processing from bauxite residues for e-mobility applications: the EIT VALORE Project
	17h00	Lisa Robillard	European funding opportunities in 'Climat, Energy and Mobility' (Cluster 5, Horizon Europe)
17h20			Flash presentations
18h30			*Cocktail*

International Congress METALS FOR ELECTRIC MOBILITY

19 and 20 September 2023
Aquarium Museum of Nancy, 34 Rue Sainte-Catherine, Nancy, France

PROGRAMME

Day 1, Tuesday, 19 September 2023

Flash presentations			
Session	Time	Speaker	Title
Geosciences	17h20	Steven Kahou	Quantitative mineralogy of the Beauvoir granite and characterization of the metal-bearing minerals
Extractive metallurgy	17h25	Allen Yushark Fosu	Advanced chloride route for lithium extraction from spodumene
	17h30	Sara El Hakim	Development of a new technique for the extraction of lithium from lithiniferous minerals through the use of supercritical fluids
Recycling	17h35	Laurence Muhr	Lithium-ion battery recycling: selective lithium recovery from cathode materials combining ion-exchange and electrodialysis processes
	17h40	Stiven Lopez Guzman	Pathways for direct recycling of high-voltage cathode materials
	17h45	Joshua Vauloup	Cobalt extraction from spent LIBs cathode materials: Mechanochemical reduction and magnetic separation of Cobalt from $LiCoO_2$
	17h50	Pierric Hubert	Leaching of mixed-cathode materials from lithium ion batteries
	17h55	Nicolas Stankovic	Pyrometallurgical treatment of permanent magnets to recover rare earth elements by using liquid magnesium
Transversal	18h00	Alaa Shqairat	The EU regulations of Lithium-ion batteries from electric vehicles
Environment	18h05	Eric van Hullebusch	Potential use of siderophores as bacterially produced biomolecules for the selective extraction of critical elements from solid waste streams
	18h10	Ly Serigne	Physiological response in relation to nickel hyperaccumulation in Bornmuellera emarginata cultivated in hydroponics over a nickel gradient
	18h15	Nicolas Fierling	Impact of lithium on the eukaryotic model Saccharomyces cerevisiae
	18h20	Clement Layet	Exploration and bioleaching of rare earth elements in Lorraine

International Congress METALS FOR ELECTRIC MOBILITY

19 and 20 September 2023
Aquarium Museum of Nancy, 34 Rue Sainte-Catherine, Nancy, France

PROGRAMME

Day 2, Wednesday, 20 September 2023

Session	Time	Speaker	Title
Extractive metallurgy	9h00	Laurent Joncourt	Eramet Sonic Bay: a major project to produce battery grade salts
	9h20	Fabien Burdet	Centenario-Ratones lithium project of Eramet
	9h40	Guillaume de Souza	Direct Lithium Extraction, a way for sustainability in lithium brine mining?
	10h00	Alexandre Chagnes	Chloride chemistry to recycle Lithium-ion batteries
10h20-10h40			*Coffee break*
Extractive metallurgy	10h40	Jason Love	Sustainable rare-earth separations by supramolecular precipitation
	11h00	Virginie Nachbaur	Solvothermal Recycling Processes of REE magnets and Li-ion batteries
Transversal	11h20	Patrick d'Hugues	From criticality analysis and policy support to responsible supply of mineral resources: challenges and actions
	11h40	Wu Chen	Material demand for sustainable transportation transitions and potential supply risks
12h00-14h00			*Lunch*
Recycling	14h00	Nathalia Vieceli	Lithium-ion battery recycling: today and future technologies
	14h20	Bart Verrecht	Towards sustainable battery recycling
	14h40	Shabnam Gholamifard	Veolia-Sarpi hydrometallurgical process : a new vision of electric vehicle battery recycling, an innovative approach
	15h00	David Bastin	Electro-hydraulic delamination of end-of-life electrodes of Li-ion batteries
	15h20	Julien Leclaire	Metal & Carbon Waste Recycling (MeCaWaRe): a game-changing eco2-efficient recycling technology for Li-ion batteries
15h40-16h00			*Coffee break*
Environment	16h00	Clémence Siret	How do we measure and minimise the environmental footprint of Li-ion batteries?
	16h20	Damien Blaudez and Laure Giamberini	Multi-scale analysis for deciphering the impacts of Rare Earth Elements on microorganisms and plants
	16h40	Marie-Odile Simonnot	Biosourced nickel as raw material for electric vehicles
	17h00	Jean-Louis Morel	Ecological restoration of rare earth mine sites

ABSTRACTS

The challenges of the energy transition: the transverse vision of the RESSOURCES21 LabEx

Michel Cathelineau [1,*]

[1] Université de Lorraine, CNRS, GeoRessources, Nancy, France

[*]corresponding author: michel.cathelineau@univ-lorraine.fr

The transition to electric mobility is crucial in addressing environmental, economic, and energy security challenges. Primary resource availability and responsible management are paramount to a successful transition. Primary resources, such as lithium, cobalt, nickel, and rare earth elements, play a pivotal role in the electric mobility ecosystem, influencing the growth and sustainability of this industry.

Lithium is a primary component of lithium-ion batteries, which power most electric vehicles (EVs) today. As the backbone of energy storage, lithium is essential for ensuring the efficient and widespread adoption of electric mobility. The growing demand for lithium is directly proportional to the rise in EV production. Although lithium is relatively widely distributed on the planet under different forms, responsible mining and sustainable extraction practices will be imperative to prevent supply chain vulnerabilities and social conflicts around future extraction sites. Cobalt and nickel as refined salts are other vital elements in lithium-ion batteries. Cobalt, in particular, is associated with concerns related to unethical mining practices and environmental degradation in some regions, which favours the search for alternative ores close to or within Europe. Sustainable sourcing and recycling of cobalt and nickel are essential to mitigate these issues and create a more ethical and resilient supply chain.

Primary resources in the electric mobility transition are essential as recycling is insufficient to provide the required mass of metals. Sustainable resource extraction and responsible supply chain management will be essential to minimise the environmental impact of mining and processing primary resources, and the social conflicts. Although reducing the dependence on rare and expensive resources is expected, cobalt is still among the substances listed, which may be the subject of a race to sustainable sources, accompanied by subsequent price volatility. Besides, copper for which reserves have been tripled during the two last decades could also become scarcer and its price multiplied by a factor of 2 or 3.

The future supply of metals for electric mobility probably will not be affected by the geological constraints but by supply chain disruptions due to the delays in getting the necessary means for developing an efficient hydrometallurgy. For instance, there is a complex relationship between bank interest rates and delays in building hydrometallurgical plants. Higher interest rates can increase the cost of financing and potentially hinder project funding. However, other factors like economic conditions, project viability, and government policies also play critical roles in determining whether or not delays occur. Companies and investors must carefully consider these factors when planning and financing large-scale industrial projects. In all cases, the delay between successful prospection and the production of refined metal salts could reach between 5 and 10 years, creating a potential risk of shortage. Finally, developing recycling technologies and encouraging a circular economy for primary resources can reduce the need for new mining and help manage resource scarcity.

In conclusion, primary resources are the lifeblood of the electric mobility transition. A holistic approach is necessary to ensure this transition's long-term sustainability and success, encompassing responsible mining practices, supply chain diversification, recycling efforts, and ongoing research into alternative materials and technologies. By addressing these challenges, we can accelerate the adoption of electric mobility and reap the environmental and economic benefits it promises.

ABSTRACTS

Lithium and rare metal granites in Portugal

António Mateus [1,*]

[1] Universidade de Lisboa, Faculdade de Ciências, Instituto Dom Luiz – Portugal

[*]corresponding author: amateus@ciencias.ulisboa.pt

Portugal is one of the main Li-producers worldwide, largely oriented to ceramic manufacturing. The official inventory (2018) indicates 306kt (in ≈71Mt of aplite-pegmatite) and 53kt as Li-resources and reserves, respectively. Increasing these figures might be possible as implied by known exposures, a few related to highly differentiated granites. Investment in exploration endeavours and mineral research must continue to suitably characterise resources and delimit reserves supporting an added-value chain for Li-products, including those for battery production. Accordingly, inspection of the factors ruling the morphological diversity, tonnage and spatial distribution of Li-rich bodies is paramount. Also significant is the assessment of conditions controlling the relative abundance of spodumene/petalite, amblygonite/montebrasite or lepidolite, along with other minerals that could provide important by-products (Nb, Ta, Sn, Be, Cs). Several overviews on these issues already exist, but comprehensive studies are lacking for many aplite-pegmatite fields, thus hindering a correct management of these increasingly important mineral resources.

ABSTRACTS

Lithium enrichment from brines in sedimentary basins: A focus on the Rhine graben

Marie-Christine Boiron [1,*], Elza Dugamin [1], Michel Cathelineau [1],
Antonin Richard [1], Chantal Peiffert [1], David Banks [2], Frank Despinois [3]

[1] Université de Lorraine, CNRS, CREGU, GeoRessources, F-54000 Nancy, France
[2] School and Earth and Environment, University of Leeds, Leeds, LS29JT, UK
[3] TotalEnergies, Centre Scientifique et Technique Jean Féger, Pau, France

[*]corresponding author: marie-christine.boiron@univ-lorraine.fr

The presence of geothermal brines with high metal concentrations in the present-day Rhine Graben reservoirs, both at the base of the Mesozoic series and in the underlying granitic basement, is well-known from regional academic and industrial works. In this context, the concentration of Li in thermal waters is currently of interest to several companies exploring the potential of saline waters. The idea was to document the hydrothermal paleo-system to understand the primary mechanism for regulating Li enrichments, which is not easily understood by considering data alone on current waters.

Metal sources and paleofluid chemistry were examined by considering the overall geochemical characteristics of the host rocks of the sedimentary cover, basement and vein minerals. The chemical composition of the paleofluids was determined by microthermometry, Raman spectroscopy, LA-ICP-MS and crush leach analysis. Based on the chemistry of the fluids and source minerals, the long-term evolution of metal enrichments in the system could be documented.

Two main reservoirs of fluids were recognized: i) brines with salinities up to 30 wt.% NaCl with Cl/Br ratios significantly lower than the current seawater ratios (290). Such values indicate that the most likely origin of the brines is a primary brine, having reached halite saturation during the evaporation of seawater. ii) dilute fluids of meteoric origin, resulting from the flow of recharge waters along faults. The current waters are the result of mixing between these two end-members.

Significant lithium concentrations up to 800 ppm have been measured in the fluid inclusions of newly formed minerals. The main Li-bearing minerals in the unaltered basement are biotite and chlorite, which probably served as a source, as they are found altered and replaced by illite and quartz, particularly in the damaged zones of the faults.

This study indicates that favourable and unfavourable processes control lithium concentration in fluids. Initial pre-enrichment in primary brines is insufficient to explain the high Li concentrations. A good factor is the metal leaching from favourable source rocks by primary brines, a process enhanced under high temperatures. Mixing between brines and dilute recharge fluids, favoured by fluid convection, is, at variance, an unfavourable factor as it decreases lithium concentrations.

ABSTRACTS

Geothermal lithium in Alsace at the heart of the energy transition

Romain Millot [1,*], Clio Bosia [1] and Guillaume Borrel [1]

[1] Lithium de France

[*]corresponding author: romain.millot@lithiumdefrance.com

The raw materials of the energy and digital transition are found underground, under our feet. These metals, such as nickel, copper, cobalt and lithium, are used in the batteries of our computers, tablets and smartphones, but especially in those used in electric vehicles. Economists agree that the number of batteries will increase significantly in the coming years.

Lithium is an alkaline metal with interesting electrochemical properties that make it an essential mineral resource in the battery industry. On Earth, lithium is concentrated in the Earth's crust (lithium comes from the Greek word Lithos: crust) in solid form (rocks and minerals) or liquid form (salt lakes and geothermal waters).

The supply risks are particularly important for lithium and concern both economic and geopolitical criticality and also societal, ethical and climatic impacts. In such a context, setting up a local industrial sector for lithium production from geothermal resources can have a strong impact on our territories.

Coupling heat production and lithium extraction from geothermal water should allow Alsace not only to develop a competitive industrial sector but also to contribute to the reduction of environmental impacts by producing at a local scale a renewable energy and lithium with a low carbon footprint.

ABSTRACTS

New constraints on carbonatites formation, the main REE deposits: A journey in the Oldoinyo Lengai volcano plumbing system

Lydéric France [1, 2, *]

[1] Université de Lorraine, CNRS, CRPG, F-54000 Nancy, France
[2] Institut Universitaire de France (IUF), France

[*]corresponding author: lyderic.france@univ-lorraine.fr

Carbonatites are rare magmas that together with their related silicate alkaline magmas represent the main REE deposits on Earth. Their genesis and evolution remain nevertheless poorly constrained. Here we provide new constraints from the trans-lithospheric magmatic plumbing system of Oldoinyo Lengai (OL; N-Tanzania), the only active carbonatite volcanic system, to improve our understanding of the formation and evolution of carbonatite magmas. First we highlight that the alkaline-rich carbonatites emitted at OL (natrocarbonatite), are highly fractionated products of more classical alkali-calciocarbonatites that are equilibrated with phonolite conjugate immiscible magmas. We show that the mantle source is mainly lithospheric, highly metasomatized with H_2O-CO_2 silicate melts (Ti-rich, Cr-poor), and that very low partial melting degrees are not required. C-rich silicate parental magmas are melilitites to Mg-nephelinites that differentiate in a transcrustal igneous plumbing system with a strong role of reactive porous flow in mushy reservoirs. Immiscibility between more evolved silicate magmas and alkali-calciocarbonatites occur upon protracted differentiation whose extreme differentiation lead to the natrocarbonatite. The determination of melt-melt and mineral-melt REE partition coefficients at the successive steps of differentiation helps quantifying the magmatic component of REE enrichments in the ultimate differentiation products.

ABSTRACTS

Contribution of Reactive Transport Modelling to the Understanding of Nickel ore deposits in New Caledonia

Sylvain Favier [1], Fabrice Golfier [1,*], Yoram Teitler [1], Michel Cathelineau [1]

[1] Université de Lorraine, CNRS, GeoRessources, 54000 Nancy, France

[*]corresponding author: fabrice.golfier@univ-lorraine.fr

Weathering processes are involved with many of the current challenges of the geoscience community such as climate regulation, the critical zone formation and the supergene deposits formation of highly demanded metals (e.g., Co, Ni, Sc, U). Yet, understanding the different processes controlling the weathering remains a major challenge. Recent studies have highlighted fractures' critical impact in controlling the dissolution and redistribution processes by creating preferential fluid flow pathways. However, the impact of physical and chemical heterogeneities on the weathering front progression is still not totally understood.

Due to the complexity of the mechanisms involved in the weathering, reactive transport models (RTMs) are a powerful tool to understand, quantify and predict the coupling effect of chemical and physical processes at different scales and across large temporal scales on weathering. The study of the Ni heterogeneous distribution in New Caledonia is an excellent case study to shed light on the impact of fractures on the formation of weathering heterogeneities. In New Caledonia, indeed, Ni-laterite supergene deposits result from the weathering of the peridotite by the downward progression of rainwater. The dissolution/precipitation process leads to the progressive enrichment in Ni at the interface between the saprolite and the oxide horizon. Therefore Ni distribution can be used as a proxy of the weathering front progression.

In this study, we investigate the impact of fracture networks as chemical and hydrological heterogeneities on the weathering front migration in fractured rock mass through different models of increasing complexity. First, a global approach with a 1D dual-porosity model is developed to highlight their impact on weathering pattern by comparing the results with an unfractured porous domain (single porosity model). Then, a discrete approach is presented, where fractures are explicitly defined as 1D interfaces embedded in a 2D porous rock matrix. The effect of the connectivity of the fracture network on the redistribution of metals of interest is thus studied, and potential hotspots of interest are identified. Finally, competition between multiple fracture networks resulting in different dissolution patterns and variable-size boulder formation is investigated. Numerical modeling of weathering accounting for two and three-fracture network has shed light on the influence of these dissolution patterns of both fluid flow and reaction rate conditions. The results are discussed considering field observations from Ni-laterite deposits in New Caledonia.

ABSTRACTS

A cannibalistic origin for rare-metal granites? Insights from the Velay anatectic dome (Variscan French Massif Central)

Christophe Ballouard [1,*], Simon Couzinié [2], Pierre Bouilhol [2], Matthieu Harlaux [3], Julien Mercadier [1], Jean-Marc Montel [2]

[1] GeoRessources, Université de Lorraine, CNRS, 54000 Nancy, France;
[2] CRPG, Université de Lorraine, CNRS, 54000 Nancy, France;
[3] BRGM, 45060 Orléans, France

[*]corresponding author: christophe.ballouard@univ-lorraine.fr

Major lithium deposits are related to peraluminous magmatism in collisional orogens but crustal melting conditions and protolith compositions for the genesis of rare-metal (Li-Sn-Ta-Cs-Be-F) granites remain controversial. Analyses of silicate minerals from metasedimentary rocks and orthogneisses as well as related granites from the Variscan Velay anatectic dome were coupled to geochemical modeling to assess the Li and F partitioning upon partial melting. The Li concentrations of biotite and cordierite from anatectic metapelites decrease from ~700 to 825°C, reflecting its incompatible behavior and the Li depletion of the melt during biotite breakdown. In contrast, F concentrations in biotite correlate positively with temperature, indicating that Li and F are decoupled during metapelite melting; Li-richest melts (~200-400 ppm) are produced below 750°C whereas F-richest ones (~0.2-0.4 wt%) are produced above 825°C near the biotite-out isograd. Therefore, metapelite melting is not amenable to generate F-Li-rich rare-metal granites but produce melts akin to those in equilibrium with biotite from cordierite-bearing granites. In contrast, silicate melts in equilibrium with biotite from anatectic peraluminous orthogneisses show higher Li concentrations similar to the melts equilibrated with biotite from muscovite-bearing granites. Muscovite and biotite breakdown in orthogneiss occurs within a narrow temperature range (690-730°C) allowing the production of melts concomitantly enriched in F (0.3-1 wt%) and Li (~600-1350 ppm), which, following 80–90 wt% fractional crystallization, generate rare-metal granitic melts (~10000 ppm Li; ~2 wt% F). This study suggests that peraluminous granite re-melting ("cannibalism"), followed by magmatic differentiation, is a viable mechanism to form rare-metal granites.

ABSTRACTS

Hydrometallurgical processing of rare earth elements

Kerstin Forsberg [1,*]

[1] KTH - Royal Institute of Technology

*corresponding author: kerstino@kth.se

Many of today's green and smart technologies require rare earth elements (REEs). In 2021, permanent magnets (29%) followed by catalysts (20%) and glass polishing powder and additives (14%) accounted for the largest shares of global REE consumption. The REE are also used to a large extent in nickel metal hydride batteries, alloys, fluorescent lamps, and ceramics. Of particular economic and strategic importance is the use of REE in permanent magnets, for which the future demand is predicted to increase drastically. The REE (especially Nd and Dy) are essential ingredients in the strongest types of permanent magnets used in for example motors, wind turbine generators and computer hard disc drives.

The rare earths are relatively abundant in the Earth's crust; however, the concentration is usually low making minable sources rare. The world mine production of REE in 2021 is reported by the US Geological Survey to be 280 000 tons of rare earth oxide equivalent, with the top 5 producers being China (60%), US (15%), Burma (9%), Australia (8%) and Thailand (3%).[1] Rare earth elements can also be recovered from secondary sources such as magnet, lamp and battery waste, fly ash, and red mud and as a by-product in phosphate production. Today limited REE quantities are recovered mainly from permanent magnets, batteries, and fluorescent lamps.[1] The European Commission has identified the REEs as critical raw materials for the European union. The EU is world leading in production of electric motors which contain REE magnets. Today China provides more than 90% of EUs total supply of REE.[2] The percentage of overall REE demand that is satisfied through secondary raw materials in EU is reported to be 8% or less in 2020.[2] Actions to diversify the REE supply from primary and secondary sources are promoted by the EU to improve resource security and raw material access.

In this talk different flowsheets for recovery of REE from secondary sources are presented. Fundamental aspects common to all methods of hydrometallurgical REE processing are highlighted to identify challenges and possibilities for separation and to aid in process selection and design. In particular, the effect of crystallization process conditions such as supersaturation and agitation mechanism are discussed with emphasis on the final REE product quality.

[1] U.S. Geological Survey, Mineral Commodity Summaries, January 2022.
[2] Communication from the European Commission to the European Parliament, Brussels, 3.9.2020, COM (2020) 474 final, Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, published by the European Commission in 2020.

ABSTRACTS

Bio-diluents for Battery Recycling

Zubin Arora [1,*]

[1] TotalEnergies Fluids, France

*corresponding author: zubin.arora@totalenergies.com

TotalEnergies Fluids is a leader in the design, production, and sale of high-purity, biodegradable hydrocarbon solvents. Designed as aliphatic diluents dedicated to the solvent extraction (SX) process in hydrometallurgy, the Elixore range offers a choice of perfectly inert, colorless, and odorless solutions for metal extraction in battery recycling.

From the same plant based in the north of France that pioneered the production of Sustainable Aviation Fuel (SAF) at TotalEnergies for the Aviation Industry, TotalEnergies Fluids now produce a range of bio-hydrocarbon solvents, under the name of Biolife range, coming from bio-feedstocks such as Used Cooking Oil (UCO) which offer low carbon footprint solutions to the industry.

These bio-products have been studied in detail over the last year at the Hydrometallurgical lab of CNRS, University of Lorraine, Nancy, France with the aim to design a single Universal Diluent that can be used in the multiple solvent extraction steps of a hydrometallurgical process of Recycling of EV Batteries for extraction of Cu, Al, Mn, Co, Ni, & Li.

One such low-carbon bio product commercialized in July 2023 after excellent results is “Elixore Biolife EV 205.” This presentation shows the characteristics of this new product, its low carbon footprint, a flowsheet of how this product works in the hydrometallurgical process of Battery Recycling, and the carbon reduction benefit it brings in reducing the Scope 3 emissions of a Battery Recycling plant.

ABSTRACTS

In-line gallium processing from bauxite residues for e-mobility applications: the EIT VALORE Project

Carsten Dittrich [1,*], Davris Panagiotis [2], Efthymios Balomenos [2], Elena Mihaela Seftel [3], Bart Michielsen [3], Kerstin Forsberg [4], Michael Svard [4], Tjalling Rekker [5], Lei Zhang [5], Sabeeth Srikantharajah [5], Beate Orberger [6]

[1] MEAB Chemietechnik GmbH, Dennewartstr. 25, 52068 Aachen, Germany
[2] MYTILINEOS Al Greece, Maroússi, Greece
[3] VITO, Boeretang 200, 2400 Mol, Belgium
[4] KTH, Brinellvägen 8, 114 28 Stockholm,Sweden
[5] BASF, Carl-Bosch Strasse 38, 67063 Ludwigshafen am Rhein, Germany
[6] CATURA, Géosciences Conseils, 2 rue Marie Davy, 75014 Paris, France

*corresponding author: carsten@meab-mx.com

Gallium nitride (GaN) is used for efficient and compact motor designs for e-mobility. GaN has high electron mobility and a low temperature coefficient. Therefore, it is beneficial for motor drives to reduce noise, magnetic loss, and costs, while increasing precision. Gallium oxide (Ga2O3), a new material for ultra-wide bandgap semiconductors can be used for high-power devices (> 6.5V), e.g., for electric transportation (GOPOWER project; https://www.insa-lyon.fr/en/fp-enjeu/energie-pour-un-developpement-durable).

The EIT VALORE Project (N°2118) develops vanadium (V) extraction followed by gallium (Ga) extraction to be fully integrated in the Al-production chain.

Ion exchange is the main method applied in industry for gallium recovery from Bayer liquor. However, the co-extraction of V and the degradation of the resins (Duolite ES-346 and DHG586) is still hindering its industrial application.

In the 3-year EIT VALORE project, we will upscale new ion-exchange material showing high stability in alkaline conditions and being selective for vanadium. The VALORE solution can overcome the 2 main challenges associated with the state-of-the-art technology to recover Ga from Bayer liquor.

The installation of a V extraction unit upstream of a Ga extraction unit will increase the Ga extraction efficiency. Up to 15% savings in extractants, service and maintenance time are estimated. In addition to the revenues generated from the valorization of the by-products, the extraction of V from spent Bayer liquor is also advantageous for the productivity of the refinery itself. Reduced V concentrations have a positive effect on the precipitation of alumina. Moreover, V extraction reduces its risk for negative environmental impact. The concept of in-line V and Ga extraction added to Al production can be transferred to European alumina refineries to reduce import risks of these strategic elements.

ABSTRACTS

Centenario-Ratones lithium project of Eramet

Fabien Burdet [1,*]

[1] Eramet

[*]corresponding author: fabien.burdet@eramet.com

Eramet owns a large deposit in Argentina of about 10 Mt lithium carbonate equivalent (LCE), together with perpetual mining rights. A strong Corporate Social Responsibility policy has been implemented from the very beginning of the project (10 years ago) ensuring the support of the project's stakeholders.

Eramet has developed a Direct Lithium Extraction (DLE) process using an aluminum-based sorbent which is today the only industrial proven DLE technology, operated for more than 20 years at industrial scale and now implemented in 5 plants around the word. In partnership with IFPEN, Eramet has developed a proprietary sorbent with improved performances making the lithium extraction process more sustainable and more competitive not only compared to the conventional process (based on natural evaporation) but also compared to other DLE projects.

The DLE process enables a high lithium recovery yield leading to a minimization of the pumped brine volume and, therefore, a better management of the hydric balance of the aquifer compared to the conventional process.

Eramet's process also differentiates compared to other DLE processes:

1. Eramet's proprietary lithium sorbent is able to extract the lithium at the native temperature of the brine (close to 20°C) avoiding the brine heating and therefore saving energy;
2. Regeneration of the lithium sorbent is made by water only (DLE based on Titanium or Manganese sorbents use acid for the regeneration) and 60% of the water is recycled;
3. Regeneration is performed at 20°C saving again energy compared to sorbent requiring an elution at 30-35°C.

In addition, Eramet's project is characterized with a high technology readiness level: Eramet has been working for 10 years to develop an efficient DLE technology which has been tested for nearly 4 years on site in real conditions, integrating all the steps of the process, from brine pumping to battery grade lithium carbonate production.

The construction of the plant has started in May 2022 with Tsingshan as a partner and funder. The feedback from the on-site operation combined with the expertise of both the project team and the selected suppliers are excellent conditions to achieve a swift start-up and to reach full capacity and the targeted battery grade quality.

The resource and process combination ensures a competitive operation. The first tons of lithium carbonate will be produced in Q2 2024, amid a market in strong tension. These two factors point to the very attractive profitability prospects and competitiveness of Eramet project.

ABSTRACTS

Direct Lithium Extraction, a way for sustainability in lithium brine mining?

Guillaume de Souza [1,*]

[1] Founder of Adionics

*corresponding author: guillaume.desouza@adionics.com

Direct Lithium Extraction is foreseen as a breakthrough approach for Lithium Brine Mining because of its potential ability to double lithium recovery yield, reduce drastically footprint, brine water evaporation, salt harvesting, time from well to product, as well as time to market, Capex & Opex.

All these positive factors open a way for sustainability in lithium brine mining.

Adionics, as a disruptive DLE supplier, has gained a conviction on the fact that sustainability in lithium mining is a major goal to succeed the energy transition by the introduction of Lithium-ion batteries in the transport and Energy sectors.

Facts are presented on the different DLE technology approach and on their utility consumption.

Adionics' DLE performances and economics in lithium brine mining are also presented with examples.

The need for depleted brine reinjection is also exemplified via a quantification of associated evaporated water volumes and salt harvesting tons if lithium done as usual, with no reinjection.

ABSTRACTS

Chloride chemistry to recycle Lithium-ion batteries

Alexandre Chagnes [1,*]

[1] Université de Lorraine, CNRS, GeoRessources, France

*corresponding author: alexandre.chagnes@univ-lorraine.fr

Lithium-ion battery is the technology of choice in the development of electric vehicles. This technology is now mature although there are still many challenges to increase their energy density while ensuring an irreproachable safety of use. For this goal, it is necessary to develop new cathodic materials that can be cycled at higher voltages and electrolytes compatible with these materials. But the challenge does not only concern the production of efficient batteries for the electrochemical storage of energy since lithium-ion battery technology relies on the use of critical and/or strategic value resources. It is therefore crucial to include Lithium-ion batteries development in a circular economy approach very early. In particular, optimized recycling and reuse of battery components must both minimize their impact on the environment and limit geopolitical issues related to tensions on the mineral resources necessary for lithium-ion battery production. Although recycling will never replace mining, it reduces resource dependence by ensuring the presence of exploitable resources in the territory, which is particularly important for countries like France where exploited or exploitable resources are limited.

After introducing the main challenges in the field of lithium-ion battery recycling, this conference addresses the development of a new hydrometallurgical process relying on the chloride chemistry combining leaching of cathodic material from spent lithium-ion battery and solvent extraction. Most of recycling processes reported in the literature rely on the sulphate route and a few studies investigate the potentialities of the chloride route despite many advantages and the possibility to develop new chemistry, which could get easier the metal separation. The leaching mechanisms and the solvent extraction equilibria will be presented in this conference. Based on the comprehension of the physicochemistry of leaching and solvent extraction, the present study will introduce a new hydrometallurgical process for the production of cobalt, nickel, manganese and lithium from spent cathodic materials.

ABSTRACTS

Sustainable rare-earth separations by supramolecular precipitation

Jason Love [1,*], Joseph O'Connell-Danes [1], Carole Morrison [1], Bryne Ngwenya [1]

[1] University of Edinburgh

*corresponding author: jason.love@ed.ac.uk

Rare-earth element dependent technologies are crucial for renewable energy generation and storage, electric vehicles, and electronic displays. However, access to these metals, in large part due to difficulties in their separation, is limited and is dominated by China. Improving how rare earth elements are separated is essential to prevent metal supply limitations from derailing climate efforts. Supramolecular strategies for RE separations are emerging which amplify the limited changes in properties across the series to bias selectivity in extraction or precipitation.

This presentation focuses on the development of a new method for rare-earth element separations using a pre-organised, bowl-shaped, triamidoarene platform which, under acidic, biphasic conditions, uniquely encapsulates and selectively precipitates light REs as their hexanitratometalates. The capsules exhibit both intra and intermolecular hydrogen bonds that promote precipitation and dictate selectivity. This discovery provides a new self-assembly route to metal separations that exploits size and shape complementarity, resulting in separation factors that exceed state-of-the-art existing extractants and achieve unprecedented light/heavy RE separation. Furthermore, we demonstrate how the system can be integrated into existing industrial processes for the separation of critical REs from end-of-life permanent magnets and rare-earth ores.

Reference: J. G. O’Connell-Danes, B. T. Ngwenya, C. A. Morrison and J. B. Love, Nature Communications, 2022, 13, 4497

ABSTRACTS

Solvothermal Recycling Processes of REE magnets and Li-ion batteries

Virginie Nachbaur [1,*], Marwa Kchaw [2], Firas Ayadi [2], Samuel Jouen [2], Jean Marie Le Breton [2], Cyril Aymonier [3], Gilles Philippot [3], Valérie Pralong [4]

[1] University of Rouen, Groupe de Physique des Matériaux CNRS UMR6634
[2] GPM UMR CNRS 6634
[3] ICMCB UMR CNRS 5026
[4] CRISMAT UMR CNRS 6508

*corresponding author: virginie.nachbaur@univ-rouen.fr

There has been growing concern in recent years about the security of supply of strategic raw and advanced materials that are critical for our modern technologies. This is the case of Rare Earth Permanent Magnets (REPMs) and Li-ion Batteries (LiB). For the latter, Europe is almost fully dependent on import of both battery cells and their constituting raw and processed materials, exposing the industry to supply uncertainties and potential high costs. This is the reason why boosting the recycling of LiB and REPM is necessary, in order to allow key elements such as Rare Earth Elements, cobalt, lithium, manganese and nickel to be recovered and reused.

In this study, we present new and environmentally friendly approaches for recycling REPMs and cathodes of LiB. The recycling processes are based on solvothermal treatments, and their advantages, compared to existing processes are as follows :

- They lead to the separation of the elements initially present in the materials (NdFeB magnets or cathodes of LiB)
- They are performed at low temperature (<500°C);
- They do not require the use of acids or bases since the materials remain solids throughout the process;
- They use low environmental impact and low cost solvents.

We have shown that the completed process leads to the separation of all the chemicals elements in solid form, but also in the case of NdFeB magnets, that if the process is stopped at the right time, it makes it possible to obtain a magnetic powder which can be used directly to make new magnets.

ABSTRACTS

Veolia-Sarpi hydrometallurgical process: a new vision of electric vehicle battery recycling, an innovative approach

Shabnam Gholamifard [1,*]

[1] Veolia Environnement

[*]corresponding author: shabnam.gholamifard@veolia.com

Veolia, through its hazardous waste expert business unit SARP Industrie (SARPI), has been treating and recycling batteries for more than 20 years. Euro-Dieuze Industrie battery recycling site in France has today 2000 tons of discharging, shredding and sorting capacity for EV battery packs and production scraps.

Today SARPI is going further in the recycling value chain of the end of life Lithium batteries from Electric Vehicles (EV) by building a hydrometallurgical unit in Metz, east of France, with 7000 tons of Black Mass processing capacity per year. Cedilor plant, with more than 20 years of experience and know-how in liquid hazardous waste treatment and Nickel valorization is hosting this new hydrometallurgical unit to extract Nickel and Cobalt metals from the Black Mass by 2023. Lithium extraction will be a second phase of this project to comply with regulatory evolutions from 2025.

Using an innovative approach and a new vision of hydrometallurgical process, SARPI is developing a robust process able to overcome the hurdles of Black Mass processing and selective extraction of high value metals from it. The process is able to manage:

- high variability of battery and Black Mass compositions, and
- high rate of impurities in the Black Mass as Aluminium, Manganese and organics.

Waiting for the development of refining processes in Europe able to produce battery grade metals salts, SARPI, as a recycler, should comply with very ambitious European directives for battery and metal recycling rates from 2025.

This innovative process makes it possible to:

- go further in the recycling value chain,
- pay more value back to the clients,
- provide low impurity and organic content metal hydroxides or sulphates for refining and precursor production players, and so reduce the back-end costs.

ABSTRACTS

Electro-hydraulic delamination of end-of-life electrodes of Li-ion batteries

Bastin David [1,*], Klevisa Celibashi, Fanny Lambert

[1] University of Liège – GeMMe

[*]corresponding author: David.Bastin@uliege.be

The concentration of blackmass from EOL Li-ion batteries currently involved mechanical fragmentation stages. Mechanical fragmentation leads to incomplete liberation of the electrode active materials and induces fine metallic Al and Cu particles reporting to the blackmass concentrate and complexifying the downstream extractive metallurgy. This work explores the potential of high voltage pulse fragmentation for the delamination of the electrodes.

ABSTRACTS

Metal & Carbon Waste Recycling (MeCaWaRe) : a game-changing eco2-efficient recycling technology for Li-ion batteries

Julien Leclaire [1,2,*]

[1] Université Claude Bernard Lyon 1, 43 bvd du 11 Novembre 1918 69622 Villeurbanne cedex
[2] MeCaWaRe SAS, 41 bvd Marcel Sembat, 69200 Vénissieux

[*]corresponding author: julien.leclaire@univ-lyon1.fr

To successfully perform its energy transition and develop circular economy, Europe set the ambitious objective of recycling within the European boundaries the entire content in metallic ingredient involved in technological devices used for the renewable energy production and storage, including manufacturing scraps.

In this context, *the Institut de Chimie et Biochimie Moléculaires et Supramoléculaires de Lyon* (ICBMS) together with *MeCaWaRe* Corp. co-develops an eCO2-efficient recycling process to recover the 6 metals (Lithium, Aluminium, Manganese, Cobalt, Nickel, Copper) contained in End-of Life (*BlackCO2MET* project) and manufacturing scraps (*ScrapCO2MET* project) of lithium ion batteries.

Offering a drastic change in the traditionnal hydrometallurgy paradigm, which requires massive amounts of strong inorganic acids, kerosene generates byproducts and hazardous effluents, our disruptive technology valorizes the organic compounds produced during the capture of CO_2 from industrial exhaust fumes by industrial amines. These innovative chemical systems offer a game-changing solution for (i) the selective and sequential acid-free leaching of metals from NMC-originating *blackmass* and (ii) the selective and sequential precipitation of metal ions as hydroxides and carbonates in a single unitary operation with high yields. This carbon negative disruptive technology integrates nearly all the 12 pillars of sustainable hydrometallurgy.

ABSTRACTS

Multi-scale analysis for deciphering the impacts of Rare Earth Elements on microorganisms and plants

Damien Blaudez [1,*], Laure Giamberini [1],

[1] Laboratoire Interdisciplinaire des Environnements Continentaux (LIEC UMR CNRS), University of Lorraine

[*] corresponding author: damien.blaudez@univ-lorraine.fr

The rapid development of green energy sources and new medical technologies contributes to the increased exploitation of rare earth elements (REEs). They can be subdivided into light (LREEs) and heavy (HREEs) REEs. Mining, industrial processing, and end-use practices of REEs have led to elevated environmental concentrations and raise concerns about their toxicity to organisms and their impact on ecosystems. We have developed complementary investigations on the impact of REEs on a wide range of organisms, including laboratory and environmental models from both terrestrial and aquatic ecosystems. Multi-scale analyses have been performed from the genomic level to the population level and reveal discrepancies between LREEs and HREEs in the response of cells and organisms. We will also discuss on the importance of taking into account the speciation of the different REEs for ecotoxicological evaluations.