ALTA
2020 25 YEARS
ONLINE NOVEMBER

25th annual conference proceedings

Lithium & Battery Technology Conference

Including

Trends in Battery Technology Forum

Sponsored by

Australian Government

ANSTO

4th annual lithium event

ALTA Metallurgical Services, Melbourne, Australia
www.altamet.com.au

Conference Proceedings

ALTA 2020 Lithium & Battery Technology Conference

Including

Trends in Battery Technology Forum

26 November 2020, Online

ISBN: 978-0-6487739-4-8

ALTA Metallurgical Services Publications

To purchase a copy of this or other publications visit www.altamet.com.au

celebrating 35 years of service to the global mining and metallurgical industry

ALTA Metallurgical Services (**ALTA**) was established in 1985 by Metallurgical Consultant and Managing Director, **Alan Taylor**, to serve the worldwide mining, minerals and metallurgical industries. ALTA offers a wide range of services and resources to the metallurgical industry.

High-level metallurgical and project development consulting.

Practically oriented live and online short courses presented by Alan Taylor. Topics include treatment of nickel laterites, copper ore leaching, uranium ore processing, copper SX-EW, heap leaching and solvent extraction.

ALTA conferences are a world-class annual metallurgical conference and a leading platform for innovation. It comprises five international conferences, panel discussions, short courses, and trade exhibition. It features highly focused programs, topical forums and presentations from key international speakers.

Technical proceedings and manuals from ALTA conferences and short courses for online purchase

MetBytes, free technical articles offering metallurgical commentary and insights.

Free resources, including proceedings from ALTA 1995-2019 Nickel-Cobalt-Copper, Uranium-REE, In-Situ Recovery, Gold-PM and Lithium & Battery Technology conferences for free download (1650+ papers). The ALTA free library is expanded regularly, providing a valuable ongoing resource to the industry.

ALTA Metallurgical Services PO Box 1211, Blackburn North, Vic, 3130, Australia
T: +61 (0)411 692 442 | www.altamet.com.au

ALTA Metallurgical Services

Celebrating 35 years of service

about us

ALTA Metallurgical Services (ALTA) was established in 1985 by Metallurgical Consultant and Managing Director, **Alan Taylor**, to serve the worldwide mining, minerals and metallurgical industries. ALTA offers a wide range of services and resources to the metallurgical industry, including…

consulting

High-level metallurgical and project development consulting.

short courses

Practically oriented live and online short courses presented by Alan Taylor. Topics include treatment of nickel laterites, copper ore leaching, uranium ore processing, copper SX-EW, heap leaching and solvent extraction.

Conferences

The ALTA conference is a world-class annual metallurgical conference and a leading platform for innovation. The 25th anniversary event ALTA 2021 will be held 13-20 November. It comprises five international conferences, six short courses, five panel discussions, three technical webinars, and a trade exhibition. It features highly focused programs, topical forums and presentations from key international speakers.

Publications

Online purchase of technical proceedings and manuals from ALTA conferences and short courses.

MetBytes

Free technical articles offering metallurgical commentary and insights.

free library

Includes proceedings from ALTA 1995-2019 Nickel-Cobalt-Copper, Uranium-REE-Lithium and Gold-PM conferences for free download (1650+ papers). The ALTA free library is expanded regularly, providing a major ongoing free resource to the industry.

Alan Taylor has over 40 years' experience in the metallurgical, mineral and chemical processing industries in Australasia, New Zealand, North and South America, Africa, Asia and Europe. He has worked in metallurgical consulting, project development, engineering/construction, plant operations, plant start-up and technology development. Projects and studies have involved copper, gold/silver, nickel/cobalt, uranium and base metals.

Since 1985, as an independent metallurgical consultant, Alan has undertaken feasibility studies, project assessment, project development, supervision of testwork, flowsheet development, basic engineering, supervision of detailed engineering, plant commissioning and peer reviews and audits. Clients have included a variety of major and junior mining, exploration and engineering companies throughout Australia and overseas.

Alan is Founder and Chair of the annual ALTA metallurgical conference.

extensive experience includes

- Gold/Silver
- Copper
- Nickel/Cobalt
- Uranium
- Base Metals

- Leaching: atmospheric, heap, in-place, bio. and pressure
- Cyanidation and CIP/CIL
- Solid/liquid separation
- Flotation
- Electrowinning and electrorefining
- Solvent extraction/ion exchange

Enquiries: allisontaylor@altamet.com.au www.altamet.com.au

ALTA 2020 25 YEARS
ONLINE NOVEMBER

thank you to our sponsors, exhibitors, co-sponsors and partners

sponsors

- EKATO
- LANXESS Energizing Chemistry
- NobelClad
- Air Liquide creative oxygen
- Purolite
- ENVIRO COPPER THE INVISIBLE MINE
- jord proxa future focused
- MOGAS SEVERE SERVICE BALL VALVES
- BASF We create chemistry
- BRISBANE MET. LABORATORY
- SOLVAY asking more from chemistry
- KOCH KNIGHT
- mhwirth
- Metso:Outotec
- Australian Government ANSTO
- AMERICAN ELEMENTS THE ADVANCED MATERIALS MANUFACTURER

exhibitors

- JENIKE & JOHANSON Science Engineering Design
- matec pacific
- CG IS The World's Best Valves
- CORE
- CSIRO
- SysCAD
- PQ Corporation
- Diemme Filtration A brand of Aqseptence Group
- CLEAN TEQ Powering innovation
- MEi
- OLI systems, inc.
- SUNRESIN
- DUPONT Water Solutions
- ALTA

partners and co-sponsors

- SAIMM THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY
- IAEA International Atomic Energy Agency
- CSIRO
- FUTURE BATTERY INDUSTRIES CRC
- amira
- Curtin University
- COM 2020 CONFERENCE OF METALLURGISTS MetSoc
- URANIUM 2020
- AusYGN
- MEi
- INTERNATIONAL MINING
- COPPER WORLDWIDE

ALTA 2020
ONLINE NOVEMBER

Lithium & Battery Technology Proceedings Contents

ALTA 2020 25 YEARS ONLINE NOVEMBER

Lithium & Battery Technology Proceedings

Keynote Address

ESTABLISHING AUSTRALIA’S BATTERY INDUSTRY SUPPLY CHAIN

By

Prof Peter Talbot
The Centre for Clean Energy Technologies and Practices
Queensland University of Technology, Australia

ABSTRACT

Australia is rich in battery mineral resources. However, it has not developed a sovereign lithium-ion battery manufacturing capability. A major limiting factor for establishing this industry is the lack of a local material and component supply chain to support cell manufacturing.

The Future Batteries Industries Cooperative Research Centre (FBI CRC) has been recently established to assist in the development of Australia’s battery industries. One of the FBI CRC’s initial objectives has been to provide an audit of existing capability and future requirements necessary to complete the battery supply chain. This work includes initial reports of the current “State of Play” in Australia’s Battery industry and the viability of producing downstream products by value adding to mineral resources to produce cathode, anode and electrolyte materials for our developing industry.

Federal and state governments, research institutions including universities, CSIRO and DSTG and over 60 local and international companies have come together through the FBI CRC to establish flagship projects to establish the local manufacture of the complete battery supply chain.

These advanced materials-based projects are supported by the National Battery Testing Centre and the Cell Fabrication and Electrochemical Testing projects. They will provide essential electrochemical testing of the advanced materials at both the cell level and at the complete battery systems level for safety, performance and compliance with Australian and International standards.

The commercially accepted method of validation of battery materials is to combine all components of a lithium-ion battery cell into a standard cell format and perform electrochemical testing of capacity, cycle life and safety. This extensive testing is necessary because during initial cell charging and discharging cycles, an essential solid-electrolyte-interface (SEI) is formed between the electrodes and the electrolyte. The SEI is optimised to achieve the best performance of cells. With this in mind, the FBI CRC has designed major projects to be interactive with outcomes of each of the material-based projects, such as an advanced cathode, anode or electrolyte formulation project to combine their products into standard cell formats. The final cooperatively produced cell then undergoes the requisite testing and in doing so, individual participants are able to both cooperatively demonstrate the performance of their cell component in a commercial form suitable for marketing to international suppliers and establish a supply chain for Australia’s developing battery industry.

ALTA
2020 25 YEARS
ONLINE NOVEMBER

Lithium & Battery Technology Proceedings

Technical Sessions

CHALLENGES TO HIGH PURITY LITHIUM CHEMICAL CONCENTRATE PRODUCTION

By

Chris Griffith, Maree Emett, Michael Page and Adam Roper

ANSTO, Minerals Business Unit, Australia

Presenter and Corresponding Author

Chris Griffith

ABSTRACT

ANSTO's involvement in the lithium processing space began over 10 years ago with process development on the Salar del Rincon brine. Since then we have conducted numerous bench and pilot scale test work programs for myriad of brine and hardrock projects producing high purity lithium carbonate, hydroxide, sulfate and phosphate chemical concentrates.

In reviewing these activities, there has been a consistent increase in the urgency of our clients to produce higher purity chemical concentrates, and by extension, increasing the degree of impurity rejection during processing. Thus, the various challenges posed by such requirements, is something that we have been dealing with for quite some time. This journey and lessons learned really provided the inspiration for this presentation.

ANSTO's historical focus on the management and control of radioactivity in rare earth, copper and gold hydrometallurgical circuits, has in many instances necessitated such a change in mindset to achieve rejection of effectively *'mass less'* amounts of radioactivity to achieve sometimes rigorous specifications. It is evident to us that there are many parallels to this situation posed by the increasing level of impurity rejection required to produce high purity lithium chemical concentrates.

What this presentation is not, is a lesson in Analytical Chemistry (!!), but we will highlight that although the specifications for various high purity concentrates / products can vary widely w.r.t. to key impurities, all projects which look to produce such materials will be challenged, and we suggest that a change in mindset of project development teams, service providers and vendors is required in order to do that.

Keywords: Lithium, High Purity Concentrate, Battery Specification

ANALYSIS OF THE BALD HILL LITHIUM PROJECT FAILURE

By

Damian Connelly

METS Engineering Group Pty Ltd, Australia

Presenter and Corresponding Author

Damian Connelly

ABSTRACT

The Bald Hill lithium project failed in late 1999 and we were asked by a Client to look at the project and see why this occurred. The project development and operation is not a good story. It is a classic fast track project failure with a number of poor decisions made. A number of projections of costs were made but never achieved. There was no information provided on the low grade, lower recovery and very high operating costs in the Australian Stock Exchange (ASX) announcements. The focus on reporting was on the increasing production and the quality of the concentrate. The fast track approach meant the best outcomes were not achieved.

The feed grade (0.8 -0.90% Li_2O) is low compared to Talison Greenbushes, Mt Marian, Pilbara Minerals, Altura lithium projects. The project does not benchmark well against other lithium producers in Western Australia because of low recovery, high operating costs and low feed grade. The by-product tantalum product is a positive.

The Feasibility Study CAPEX and OPEX were never achieved. The Feasibility Study was bare bones and fast track and in a number of respects would not qualify as a Feasibility Study. Ramp up was slow at 12 months due to grade problems and water issues and plant reliability. The Feasibility Study indicated a 12-month payback on capital in reality the project has only ever incurred losses.

The project made a number of mistakes and bad decisions with fast tracking and efforts to reduce capital which has increased operating costs. The softening in lithium prices and funding issues finally resulted in the company going into Administration.

LITHIUM ION SIEVE TECHNOLOGY FOR RECOVERY OF LITHIUM FROM BRINE

By

Mike Dry

Arithmetek Inc., Canada

Presenter and Corresponding Author

Mike Dry

ABSTRACT

Conventional technology for the production of lithium carbonate from salar brine is based on solar evaporation and is economically limited to brines in which the ratio of divalent cations such as calcium and magnesium to lithium is such that the cost of the reagents (lime, sodium hydroxide, sodium carbonate) required to precipitate the divalent cations ahead of the precipitation of lithium carbonate is not prohibitive. The Smackover formation in the southern United States constitutes a large reserve of lithium, but the high ratio of calcium to lithium in this brine renders conventional technology based on solar evaporation uneconomic.

This paper presents a novel circuit based on lithium ion sieve chemistry, that can extract lithium from brine in the presence of large amounts of calcium and does not require prior concentration of the brine. The circuit has been developed through laboratory-batch and continuous mini-pilot testing, to a demonstration plant in Arkansas that was commissioned early in 2020.

This paper outlines the basic chemistry and preliminary economics of the circuit for an oilfield brine. It also presents a comparison of the novel circuit against conventional solar evaporation technology for extracting lithium carbonate from a conventional salar brine.

Keyword: Lithium, high-Ca brine, lithium ion sieve.

THE EFFECT OF IMPURITIES ON THE CALCINATION OF SPODUMENE

By

Mark G. Aylmore, Martin Wells and Matthew R. Rowles

John de Laeter Centre, Faculty of Science & Engineering, Curtin University, Australia

Presenter and Corresponding Author

Mark Aylmore

ABSTRACT

Spodumene, $LiAl(SiO_3)_2$ in LCT pegmatite ores is the main source of lithium which is a key component in the manufacture of Li batteries. The processing of spodumene concentrate usually involves a combination of elevated temperature and chemical treatment processing to extract lithium from silicate minerals. Heat treatment to convert α -spodumene to β -spodumene (~1100°C) is considered essential to expand the volume of spodumene to release lithium from its crystalline structure.

The mechanism and intermediate phases formed during the conversion of α-spodumene to β-spodumene is known and related to heating rate and particle size. However, the effect of elemental (e.g., Mn, Fe, Ca, Mg) and mineral impurity inclusions on the thermal properties of spodumene and particle rheology are not well understood. As part of a research project evaluating the geometallurgical properties of different LCT pegmatite ores in Western Australian the thermal properties of a suite of spodumene samples have been investigated.

A combination of X-ray diffraction, including in-situ HT-XRD analysis, electron microscopy and thermal gravimetric techniques, have been used to track the composition changes of both spodumene and the partial melting of gangue materials at levelled temperatures. The findings and inferences on clinker formation and on lithium extraction process are reported from this work.

Keywords: spodumene calcination impurities, lithium

VALUE ADDED PRODUCT RECOVERY FROM SPODUMENE LEACH RESIDUE

By

[1]Goutam Kumar Das, [1]Dianne Bedell, [2]Yatendra Sharma and [2]Chris Reed

[1]CSIRO Mineral Resources, Australia
[2]Neometals Pty Ltd, Australia

Presenter and Corresponding Author

Goutam Das

ABSTRACT

Spodumene leach residue is a waste material from the processing of spodumene concentrate to recover lithium. Conversion of this leach residue to a value-added product is expected to make processing more attractive. As the leach residue is an alumino-silicate bearing waste, an approach to convert this into an alumino-silicate based product such as zeolite appeared to be most practical. This research was mainly focussed for the synthesis of a value zeolite product, zeolite 4A (Linde Type A), from spodumene leach residue through a calcination and water leaching/aging route. Zeolite 4A is a sodium-based zeolite with the chemical composition of $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}]$ or $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}].nH_2O$ having a Na:Al:Si molar ratio of 1. To achieve the desired molar ratio of Al to Si in this study, spodumene leach residue was mixed with a required amount of gibbsite $[Al(OH)_3]$ reagent. A mixed pulp of spodumene leach residue, gibbsite and NaOH was calcined at higher temperature followed by cooling and grinding. The ground solid was water leached and aged before crystallisation to form zeolite 4A. The parameters found to be suitable for zeolite 4A synthesis were 2-4 times stoichiometric NaOH, calcination at 600 °C, 24 h aging of the water leach slurry at ambient temperature and further aging/crystallisation at 50-70 °C. A high purity zeolite 4A product was prepared under these conditions having Na:Al:Si molar ratio of ~1 with a pore volume for absorption of ~1.6-1.9 L/kg. Based on the adopted synthesis route, a process flowsheet was developed for the treatment of spodumene leach residue to recover zeolite 4A.

Keywords: Spodumene leach residue, zeolites 4A synthesis, sodium hydroxide, calcination, leaching/aging

ACCURATE MINERALOGICAL ANALYSIS FOR EFFICIENT LITHIUM ORE PROCESSING

By

[1]Nicholas Norberg, [1]Uwe König, [2]Olga Narygina and [2]Hari Bhaskar

[1]Malvern Panalytical B.V., the Netherlands
[2]Malvern Panalytical, a division of Spectris Australia Pty Ltd, Australia

Presenter and Corresponding Author

Olga Narygina

ABSTRACT

Increasing demand for effective energy storage used in personal devices, electrical cars, renewable energy storage facilities, etc. boosted the global demand for lithium. Two main lithium production sources are hard-rock lithium deposits and lithium brines. The former is regarded as a more reliable source of lithium due to the even geographical distribution, and not-climate dependent extraction process.

Economically valuable lithium containing minerals that occur in hard-rock granite pegmatites deposits are spodumene, apatite, lepidolite, tourmaline and amblygonite of which spodumene is the most common lithium-bearing mineral. Beneficiation of lithium hard-rock ore includes crushing, concentration by froth floatation and calcination to convert *α*-spodumene into its *β*-modification. The latter step allows easier lithium extraction during the further processing. Flotation and calcination efficiency is directly determined by the ore mineralogy. Therefore, frequent, fast and accurate mineralogy monitoring is essential for the optimised recovery rate and stable product quality.

X-ray diffraction (XRD) is an established technique for comprehensive, fast and accurate mineralogical analysis. XRD probe can be easily implemented in the process flow at mine operation and processing plant. In the case study we discuss the added value of XRD for the process monitoring of hard-rock lithium ore beneficiation using samples from an operating lithium mine. The XRD analysis of raw ore samples prior to the flotation step showed that even though the mineralogy of the ore samples is consistent, the relative mineral quantities differ from sample to sample. Therefore, ore blending might be beneficial for the consistent outcome of the following processing steps: froth flotation and calcination. Analysis of the corresponding concentrates and tailings after flotation and calcination does show reasonably good recovery rate. However, the *β*-spodumene yield can be improved by further optimization of calcination step.

Keywords: lithium, hard-rock deposits, x-ray diffraction, mineralogy

OUTOTEC LITHIUM HYDROXIDE PROCESS – A PROGRESS UPDATE

By

Marika Tiihonen, Liisa Haavanlammi, Sami Kinnunen and Eero Kolehmainen

Metso Outotec, Finland

Presenter and Corresponding Author

Marika Tiihonen

ABSTRACT

This paper outlines an update of the recent development and progress steps of the Outotec Lithium Hydroxide Process, a proprietary technology for spodumene concentrates refining. The process offers a fast throughput, direct leach process for spodumene concentrates to produce battery grade lithium hydroxide monohydrate product of excellent quality.

During the past year Outotec merged with Metso to create a new company called Metso Outotec. At the same time, we have taken some very important steps forward in commercialization of our proprietary technology, for example piloting and operation of a continuous demonstration plant campaign.

A demonstration plant campaign was operated for Keliber Oy (Finland) at the Metso Outotec Research Center in Pori, Finland in January 2020. Our demonstration plant equipment includes the main equipment needed in the process: a continuously operating horizontal OKTOP autoclave and atmospheric reactors, Outotec Larox PF & polishing filters, IX columns, vacuum evaporator and a pusher centrifuge. The scale of the operation was approx. 100 kg/day feed of calcined spodumene. Outotec completed the campaign successfully. All the process stages and circuits from calcined spodumene feed to production of crude LiOH*H2O crystals were operational continuously at the same time. The quality of the crude crystals from a single stage evaporation-crystallization was excellent, exceeding battery grade, se table below for an average impurity analysis.

Mg ppm	Al ppm	Cd ppm	Cr ppm	Mn ppm	Fe ppm	Ni ppm	Cu ppm	Rb ppm	Sr ppm	Mo ppm	Pb ppm
<2	<10	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
B ppm	**Na ppm**	**Si ppm**	**P ppm**	**S ppm**	**K ppm**	**Ca ppm**	**Zn ppm**	**Cl^- %**	**F^- %**	**C %**	
<10	<50	<60	<20	<50	<20	<10	<5	<0.005	<0.005	<0.05	

Outotec has also completed a basic engineering of the process, involving all the engineering disciplines. This engineering task also confirmed that significant improvements to the operation cost of a lithium hydroxide production projects are achievable via Outotec process. The basic engineering is an important step forward to commercialize the process.

Keywords: Lithium Hydroxide, Metso Outotec, Spodumene, Lithium hydroxide

APPLICATION OF CHELATION RESINS AND MEMBRANES TO SOLVE PURITY AND RECOVERY NEEDS IN THE LITHIUM AND BATTERY SPACE

By

[1]Daryl Gisch and [2]Jaco Bester

[1]DuPont Water Solutions, USA
[2]DuPont Water Solutions, the Netherlands

Presenters and Corresponding Authors

Daryl Gisch and **Jaco Bester**

ABSTRACT

As industrial demand for lithium ion batteries continue to grow, the need for higher purity lithium feedstocks and options for recovery and purification of valued metals from recycled batteries evolve, these challenges can be addressed using various chelation resins and polymeric membranes. Depending upon the geological finger print of lithium feed stocks from brine or hard rock sources, the common theme is a need to reduce impurities such as divalent ions calcium (Ca) and magnesium (Mg), or low levels of boron (B), that if present impact battery quality. Chelation resins can be applied in high concentration brine and lithium concentrates to reduce and remove targeted ions to low parts per million levels. Application of chelation resin unit operations offer better purity control for the manufacturing high purity lithium salts.

With growth in the lithium ion batteries, the drive to recover, separate and purify key battery metals are seen as a value driver of sustainability for the electric vehicle market to move forward both in economic and environmental terms. Recovery for re-application of battery metals, like cobalt (Co), nickel (Ni), lithium (Li), manganese (Mn) provide a focus of value while being able to remove and separate away undesired metal impurities like aluminum (Al), iron (Fe) and copper (Cu) for example. The streams as processed within this space are acid digest solutions, typically prepared by dissolving the ground metal recycled products in sulfuric acid (H2SO4). Chelation resins as known and applied to the hydrometallurgy mining segments for base metal recoveries can been retooled to address needs for battery metals recycle.

In addition, the application of nanofiltration (NF) and reverse osmosis (RO) offer solutions for the dewatering and concentration of divalents like Ca and Mg in primary brine applications and concentration of Co and Ni for lithium ion battery metals recycling. Both standard and acid stable membrane elements provide options for both selective fractionation and metal concentration depending upon the needs of the feedstock.

This work looks to survey how various chelation resins and membranes can be applied to solve purity and recovery needs in the lithium battery space.

Keywords : lithium, battery metals, chelation resin, nanofiltration, reverse osmosis.

ALTA
2020 25 YEARS
ONLINE NOVEMBER

Lithium & Battery Technology Proceedings

Trends in Battery Technology Forum

DEVELOPMENT OF ADVANCED ELECTROLYTES FOR LITHIUM (ION) BATTERIES

By

[1]Adam S Best, [1]Marzi Barghamadi, [1]Gavin E. Collis, [1]John Chiefari, [1]Anthony F Hollenkamp,
[1]Mustafa Musameh and [2]Thomas Rüther

[1]CSIRO Manufacturing, Australia
[2]CSIRO Energy, Australia

Presenter and Corresponding Author

Adam S. Best

ABSTRACT

Lithium-ion batteries are ubiquitous in our lives and underpin our highly connected lifestyles through portable computing and mobile phones through to electric vehicles, energy storage on the grid and most excitingly disruptive mobility aka flying cars. However, the demand to store ever increasing amounts of electrical energy as chemical energy delivers profound challenges in the design of materials that are (electro)chemically and thermally stable and preferably non-hazardous especially when they are under “abuse” conditions.

At present, lithium-ion batteries are seeing incremental increases in energy density through improvements in the specific capacity of the electrode materials or the use of composite architectures, such as graphite and silicon composites at the anode. However, the traditional electrolytes used in these devices are based on volatile and flammable organic solvents that enable impressive device performance but also have significant safety challenges.

To deal with these challenges, there is a significant push towards the use of non-volatile and non-flammable electrolytes such as ionic liquids or “salt in solvent” solutions to remove or reduce the flammable constituents. However, the true breakthroughs that will enable the next generation of battery solutions lie in the use of solid-state electrolytes, particularly those based on glassy-ceramics, polymers or combinations thereof. Whilst this enhances the safety of these devices, the performance of devices using these electrolytes can be significantly impacted by the lower rate of lithium ion diffusion and lower ionic conductivity as compared to traditional electrolytes used in today’s lithium-ion batteries.

The “holy grail” of batteries is the use of the lithium metal anode, which has the highest specific capacity (3865 $mAh.g^{-1}$) and is the most electronegative (-3.05 V vs. SHE) of all potential battery anodes. To realise the promise of batteries such as Lithium–Sulfur (Li-S) and Lithium-Air, electrolytes need to be developed that enable plating and stripping of lithium at reasonable current densities (> 1 $mAh.cm^3$) with a coulombic efficiency that can support at least 1000 cycles without the formation of microstructured or dendritic lithium which can lead to catastrophic failure.

In this presentation we will describe the current state-of-the-art for lithium (ion) battery electrolytes, describe some of the research that is being undertaken towards improving safety and performance of these materials, the development of solid state electrolytes and finally a discussion of electrolytes for lithium metal anodes and the resultant impact on next generation battery development.

Lithium, battery, electrolyte, solid-state, next generation materials

LITHIUM BATTERY ANODE R&D TRENDS

By

[1]Mahdokht Shaibani, [2]Nicolas Eshraghi and [1]Mainak Majumder

[1]Monash University, Australia
[2]University of Liège, Belgium

Presenter and Corresponding Author

Mahdokht Shaibani

ABSTRACT

The world's increasing demand for energy storage has unleashed a growing global push to invest much more in innovations around battery technology. Most innovative R&D battery programs have at their heart, lowering the manufacturing cost, sustainable sourcing of the currently used materials, exploring the use of promising alternative materials, and the relatively new consideration of strategic decoupling from China's supply chain. One key component of the lithium-ion battery, which has been the subject of substantial research and development, is the negative electrode or the anode where the focus is on graphite, silicon, and lithium metal. Battery manufacturers continuously try to find a replacement or at least reducing dependence for the low capacity graphite anode.

The energy density of Li-ion batteries based on the graphite anode is around 220 Wh kg^{-1}, far from the 500 Wh kg^{-1} goal of most applications, particularly EVs. The poor capacity of graphite for holding lithium (370 mAh g^{-1}) will never allow achieving this target; however, the use of graphite brings durability and safety. Lithium metal (3860 mAh g^{-1}) and silicon (3579 mAh g^{-1}), at least on paper, could provide several times more capacity for holding lithium but at the cost of rapid degradation (large capacity brings large stress). Nonetheless, research around lithium and silicon is speeding up with several success stories, including increased cycle life and near-target energy density values. Herein, some of the recent success stories will be discussed.

Keywords: Li-ion battery, Anode, Graphite, Lithium metal, Silicon

LITHIUM FERRO PHOSPHATE – THE ‘SAFE’ LITHIUM-ION BATTERY

By

[1]Adrian Griffin and [2]Mike Vaisey

Lithium Australia, Australia
VSPC Limited, Australia

Presenter and Corresponding Author

Adrian Griffin

ABSTRACT

In 2019, John B. Goodenough, M. Stanley Whittingham and Akira Yoshino, the ‘fathers’ of the lithium-ion battery, shared the 2019 Nobel Prize in Chemistry for developing this revolutionary form of energy storage. Having examined many chemistries and structures, in 1999 Goodenough led the team granted the patent for olivine-structured lithium ferro phosphate (LFP) as a battery cathode material.

LFP is in many ways superior to the more widely used spinel-type cathodes, a group that includes most of the poly-oxide materials, including lithium nickel manganese cobalt oxide (NMC), lithium manganese oxide (LMO) and lithium cobalt oxide (LCO). Generally, lithium/transition metal oxides have a higher energy density than conventional LFP, making them the choice for many mobile devices. Heavy-transport applications, however, are less sensitive to the energy density of the battery pack, and for them LFP is a good choice: the components are cheaper and less toxic and do not incorporate so-called ‘conflict’ metals in their production. Most importantly, the safety of LFP is unsurpassed compared to the alternatives.

Key to the greater safety of LFP batteries is the strength of the bond between the iron, phosphorous and oxygen, and the dimensional stability of the olivine-structured lattice during the transition of lithium ions. Indeed, use of LFP was mandated in battery-driven vehicles for mass transport of humans in the People’s Republic of China. As a result, this type of battery makes up a significant proportion of those produced for such applications in China today. Energy storage is another application in which LFP batteries excel.

With safety and performance as its prime objectives, Lithium Australia NL, through its subsidiary VSPC Ltd, is heading a A$5 million Australian federal government co-funded programme (partnering with CSIRO, the University of Queensland and others) to develop a battery for the electrification of Australian pubic transport systems, with LFP the platform of choice.

Keywords : lithium, LFP, battery, safety

AUSTRALIAN BATTERY RECYCLING CHALLENGES AND OPPORTUNITIES

By

Andrew Mackenzie

Envirostream, Australia

Presenter and Corresponding Author

Andrew Mackenzie

ABSTRACT

Envirostream Australia Pty Ltd will present on the challenges of battery collection, transport, volumes and recycling. Topics covered will go into details regarding regulation, hazards, chemistry types, critical metal recovery and commodities produced via todays extraction technology.

Envirostream process batteries on-shore in Australia to aid the local employment needs, guarantee brand protection and best practice environmental standards are met with over 95% of all battery cells being recovered for commodity reuse. Envirostream has developed safe and innovative management solutions for what is potentially one of the world's most pressing environmental problems.

Envirostreams Australian facility is designed and built by its in-house team and is based on international best practice and sustainability. The facility captures all cathode and anode powders, foils, management circuit boards, casings and electrolytes.

Envirostream business operations also cover the collection and transport across the Oceania region to secure the supply of feed for the plant. This comes with challenges as batteries are hazardous and classed as electronic waste which requires various permitting and packaging standards.

Envirostream recovers the energy metals cobalt, nickel, lithium and graphite to produce a mixed metal dust ('MMD') as the primary material, as well as scrap steel, zinc, manganese, copper, aluminium and plastic, which are returned to the various industrial sectors.

Keywords : recycling, on-shore, local employment, cobalt, nickel, lithium and graphite

FINLAND-BASED CIRCULAR ECOSYSTEM OF BATTERY METALS (BATCIRCLE)

By

Pyry-Mikko Hannula, Antti Porvali, Pertti Kauranen and Mari Lundström

Aalto University, Finland

Presenter and Corresponding Author

Mari Lundström

ABSTRACT

The use of lithium-ion battery technologies is projected to increase exponentially in the coming years. This trend is accelerated by the needs of a carbon free society; renewable energy and transportation. However, the production of lithium-ion batteries requires a considerable amount of various raw materials including Li, Ni and Co. In order to foster a battery markets capable of supporting the necessary changes our society is facing, the sustainable sourcing of raw materials and recycling of end-of-life batteries is a necessity.

The availability of the raw materials is a critical issue for lithium-ion batteries. Globally, up to 125 million electric vehicles are estimated by The International Energy Agency to be on the roads by 2030. To meet this demand, large increases in the production of raw materials will be required. The Finnish BATCircle project tackles these issues by combined efforts on primary raw materials and recycling of Li-ion battery metals. The BATCircle consortium comprises four universities, two research centers, 22 companies, and two cities.

At Aalto, the research on recycling of batteries has been an effort focusing on practicality. It is essential to progress in the research at two-levels. The grass-roots, or micro-level, research focuses on basic research of relevant physicochemical phenomena, such as interaction of individual impurities in the acid leaching of spent active materials. These micro-level phenomena are mirrored to the macro-level, where entire process flowsheets are investigated and, for example, integration of secondary streams to primary streams are suggested. At both levels, it is vital that the link is maintained and that the investigated phenomena are considered relevant to the goal of practical application.

Keywords: Lithium-ion, battery, LIB, cobalt, nickel, recycling, ecosystem

RECENT INSIGHTS ON LITHIUM-ION BATTERY TECHNOLOGIES

By

Alexandre Chagnes

Université de Lorraine, CNRS, GeoRessources, France

Presenter and Corresponding Author

Alexandre Chagnes

ABSTRACT

The development of new technologies for electrochemical energy storage is one of the main challenges of the next decades with the emergence of electric mobility and the development of energy transition. Many hopes now rely on lithium-ion batteries (LiBs) that have invaded the market of laptops and which appear to be the best choice with the short time for electric vehicles, and perhaps for network applications (electricity storage from wind turbines or solar cells for example).

A lithium-ion battery (LiB) is made of five principal components: electrolyte, positive electrode, negative electrode, separator, and current collector. The first lithium-ion battery commercialized by Sony Corporation in 1991 was composed of a graphite negative electrode and a lithiated cobalt oxide ($LiCoO_2$) positive electrode. However, the search for high-density and safe lithium-ion batteries for new applications has stimulated the development of new negative and positive electrodes exhibiting high-energy and good cycling ability as well as new electrolytes compatible with these electrodes. Besides, the availability of raw materials to manufacture lithium-ion batteries and the environmental impact of their production have to be taken into account very early in the design of new lithium-ion battery technologies.

There are therefore many challenges to face up not only regarding the electrochemistry of lithium-ion batteries and material sciences, but also in the implementation of sustainable extraction of raw materials and the development of the circular economy approach to better control the value chain of lithium-ion battery.

This paper will give a brief overview of recent insights and challenges in lithium-ion battery technology.

Keywords: lithium-ion batteries; cathode; anode; electrolyte; challenges