Technische Universität Braunschweig

IBPC 2019

INTERNATIONAL BATTERY PRODUCTION CONFERENCE

4 to 6 November 2019

CONFERENCE BROCHURE

WELCOME

Dear participants of the IBPC,

batteries are at the heart of electric vehicles as well as of storage of green energy and a main driver of the global mobility revolution. The rapidly growing demand for batteries leads to increasing production capacities worldwide. Innovations in production technologies and systems are a key enabler for higher productivities and have already led to considerable progresses regarding quality, costs per battery cell and pack as well as battery performance. However, the potential to further enhance the battery cell and pack production remains high.
New developments in materials, cell design and processes from lab scale have to be transferred to a mass production scale. Moreover, data- and model driven approaches creating new knowledge on how the various process and material parameters affect cell performance and production cost must be pushed forward.

For this reason, the IBPC International Battery Production Conference brings together experts from industry and academia along the process chain of battery production in a unique event. With excellent keynotes, talks and poster presentations, the IBPC 2018 was a large success and motivated us to continue the journey of annually bringing experts from battery production together. We are very excited to follow up with the IBPC 2019 at the Steigenberger Hotel in Braunschweig. This year's plenary talks, presentations and poster sessions are dedicated to the electrode, cell, module and pack production, cell and pack design, safety, simulation, sustainability and the digitalization of the battery production. Additionally, issues related to the production of all-solid-state and solid polymer batteries are addressed.

We are pleased to welcome international speakers along the battery value chain and are excited for their impulses towards the battery production community.
We are particularly thankful for the support of our partners VDMA Battery Production, the German competence cluster on battery Production ProZell and welcome all their members. A special thank goes to our sponsors Custom Cells, Bio-Logic, EA Elektro-Automatik, Inficon, Netzsch and C3 Prozess- und Analysen-technik. Their support enables us to increase the quality of the conference.

We wish you all a very warm welcome, interesting talks and exciting discussions in the heart of the city of science, Braunschweig.

Prof. Christoph Herrmann & Prof. Arno Kwade

Ch. Herrmann A. Kwade

BATTERY LABFACTORY

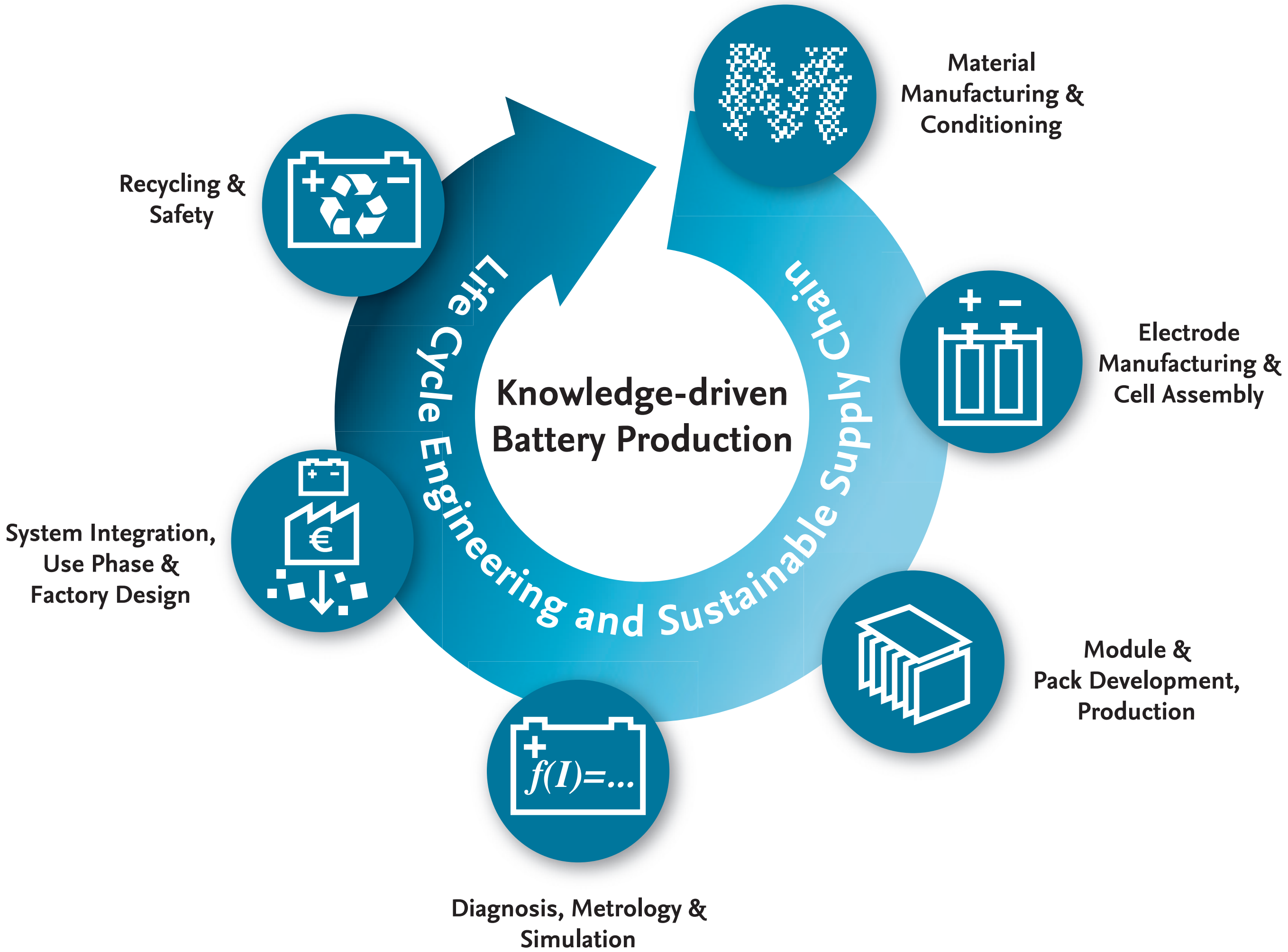
The Battery LabFactory (BLB) stands for an open research infrastructure to investigate and develop electrochemical storage devices from laboratory to pilot plant scale. The research spectrum covers the entire value cycle, from material, electrode and cell manufacturing, up to recycling as well as the subsequent active material resynthesis from recycled raw materials.

The BLB holds the production infrastructure and characterizing equipment to develop large-sized batteries as well as battery modules and packs. This allows the research on fundamental and application-oriented aspects. The scope of BLB is to establish a knowledge-driven electrode and cell production to accomplish a fast transfer of R&D-based developments into technical or pilot scale production processes. For this purpose, the transdisciplinary team of BLB engineers and scientists combine their expertise. In detail, 8 institutes of the TU Braunschweig, the Physikalisch-Technische Bundesanstalt Braunschweig (PTB), and institutes of the TU Clausthal and LU Hannover come together in this joined LabFactory.

The Battery LabFactory represents an open platform for R&D on processes, cell design, diagnostic and simulation of todays and future battery technologies.

BLB BATTERY LABFACTORY BRAUNSCHWEIG

CIRCULAR BATTERY PRODUCTION



CONTENT

PARTNER

CUSTOMCELLS® is a world leading company in the development of special lithium-ion battery cells. CUSTOMCELLS® produces application-specific battery cells from prototypes up to medium series. On the basis of flexible manufacturing concepts and state-of-the-art research, CUSTOMCELLS® guarantees high-tech solutions for special applications. We are specialized in fulfilling our customer's requirements by developing and producing customized electrodes, electrolytes, battery cells and battery modules. Your special areas of application are standard for us.

www.customcells.de

INFICON is one of the world's leading developers, producers and suppliers of instruments and devices for leak detection in air conditioning, refrigeration and automotive manufacturing. The company has manufacturing facilities in Europe, China and the United States, as well as sales and service offices throughout the world. More information about INFICON automotive technology is available at:

www.inficonautomotive.com.

EA Elektro-Automatik is Germany's leading manufacturer of laboratory power supplies. EA offers an especially large product spectrum of programmable high-tech power supplies and electronic loads for research and development, industry and vocational training.
EA applications are equipped with optimal energy utilization and an above average efficiency. Development, innovation and reliability are key drivers at EA. With more than 250 staff in Viersen (Lower Rhine) and at our branch in China we produce and dispatch customized products to the whole world.

www.elektroautomatik.com

The NETZSCH Business Unit Grinding & Dispersing offers an extensive machine program for process engineering, providing solutions for wet and dry grinding, mixing, dispersing and deaeration. Long-term experience, consistent development work, daily contact with our customers and developments with more than 100 patents ensure our technical competence and further attest to our quality-consciousness. The bundling of process-engineering expertise and the extensive machine program, ranging from laboratory to production machines to complete production lines, is unique worldwide.

www.netzsch-grinding.com

C3 offers a broad range of analytical tools and laboratory devices for battery applications. The systems from Gamry Instruments (electrochemistry) are dedicated to characterize battery or fuel cell systems in the field of R&D and QC. Software packages like EIS (Electrochemical Impedance Spectroscopy) are used here. The adiabatic Battery Calorimeter "ARC" from thermal hazard technology are used to characterize safety relevant thermal properties of complete batteries or battery components under normal and abuse conditions. The high efficient mixers from Thinky are used in laboratories and production for production of extreme homogeneous bubble-free electrode slurries.

www.c3-analysentechnik.de

Bio-Logic S.A.S. is a global leader for high precision potentiostats/galvanostats and multipotentiostats, battery cyclers and Electrochemical Scanning system for more than 20 years. We provide integrated EIS systems, either in multi-channels format for battery cyclers or single portable potentiostats. Our leadership in the energy testing is balanced by our ability to explore low current as well for analytics and sensors investigations. Powerful EC-Lab & BT-Lab software platform proposes all kind of electrochemical tests procedure with built in the calculations tools. All our products are developed and designed in Seyssinet-Pariset, France (potentiostat, multi-potentiostat, battery cyclers, stopped flow and Optical CD) or Macclesfield, UK (Scanning) . Bio-Logic skill is dedicated to strong support and relies on optimized partners distribution network. We invite you to learn more about our new BCS range.

www.bio-logic.net

PARTNER

VDMA

Batterieproduktion

The VDMA Battery Production department is the partner for all questions relating to machine and plant construction in the field of battery production. The member companies of the department supply machines, plants, machine components, tools and services for the entire process chain of battery production: From raw material preparation, electrode production and cell assembly to module and packaging production. The current focus of VDMA battery production is on Li-ion technology. We research technology and market information, organize customer events and road shows, hold our own events, such as the annual conference, which has established itself as an important industry meeting place, and are in dialogue with research and science on current topics and on joint industrial research.

http://battprod.vdma.org

ProZell
Kompetenzcluster zur Batteriezellproduktion

The aim of the competence cluster for battery cell production (ProZell) is to research and improve the production process of battery cells and its influence on cell properties and product development costs. After successful 3 project years, the second phase of the clusters commenced in October 2019. Within the projects of the ProZell Cluster, scientists from various German research institutions are working together, building a network of science and industry in close cooperation with the BMBF and the KLiB. Together they establish the basis for a powerful and cost-effective battery cell "Made in Germany".

www.prozell-cluster.de

Scientific Partner
Fraunhofer
IST

Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig
The Fraunhofer IST in Braunschweig is an innovative partner for research and development in surface technology, with expertise in the associated product and production systems. Around 120 employees work together with customers from industry and research to develop customized and sustainable solutions: from prototypes, through economic production scenarios, to upscaling to industrial magnitudes- and all this whilst maintaining closed material and substance cycles.

www.ist.fraunhofer.de

VDMA
Battery Production

VDMA Battery Production

The VDMA department is the direct contact for all questions relating machine- and plant construction. The member companies of the department supply machines, plants, machine components, tools and services for the entire process chain of battery production: From raw material preparation, electrode production and cell assembly to module and packaging production. The current focus of VDMA Battery Production is on Li-ion technology. Our activities:

- We research technology and market information: (Roadmap Battery Production Equipment 2030, Process Flyer Battery Production, business climate survey, short expert reports on employment effects)
- We organize customer events and roadshows (most recently in China with CATL, BAK and BYD or in Korea with LG Chem and Samsung SDI)
- We supervise fairs (Battery Japan, CIBF) and hold our own events, such as the VDMA Battery Production Annual Conference: Established itself as an important industry meeting
- We are in dialogue with research and science on current topics and on joint industrial research.
- We represent our industry in politics and the public.

If you have any questions, please do not hesitate to contact us!

Contact:
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PROGRAM

CONFERENCE DAY 1 | Nov. 4th

8:30 I Arrival of Attendees

9:00 I Welcome by the Conference Chairs

9:20 I Keynote by Matthias Machnig, InnoEnergy
Battery Activities in the EU

9:50 I Keynote by Maximilian Wegener, Manz
Challenges for Machine Builders for the Production of Lithium-Ion Batteries

10:20 I Keynote by Rüdiger Daub, BMW
BMW Battery Cell Competence Center – Opportunities for Improvements in the Production of Lithium-Ion-Cells

10:50 I Coffee Break

11:20 I **Parallel Sessions**

Electrode Production (I)
Room Maschinenhalle I Chair: Dr.-Ing. W. Haselrieder

Continuous mixing process for LIB electrode slurries contributes to cost-effective cell manufacturing
P. Stoessel, Bühler

Continuous suspension Production: Influencing electrode properties via extrusion process design
M. Haarmann, TU Braunschweig/iPAT

Batch and continuous production of Electrode Masses in the Laboratory and GWh Production Scale
S. Gerl, Maschinenfabrik Gustav Eirich

Cell Assembly (I)
Room Nimes I Chair: Prof. K. Dröder

High throughput joining process within productivity increased assembly of electrode-separator-composites for lithium-ion-batteries
S. Sezer, TU-Berlin

Agile battery production – a novel concept for the manufacturing of battery cells flexible in format and material
T. Storz, KIT - wbk Institute of Production Science

Scaling up new materials to mass cell production – challenges, experience and process solutions
S. Rößler, ZSW

12:30 I Lunch Break

13:15 I Poster Session

14:00 I **Parallel Sessions**

Battery Production 4.0 (I)
Room Maschinenhalle I Chair: Dr.-Ing. S. Thiede

Smart Manufacturing of battery cells: The concept of Traceability
S. Singh, Fraunhofer IPA

IoT adapted to future Battery Factories
K. Eberhardt, Exyte Management

Challenges And Answers In Battery Production
J. Köhler, Siemens

Cell Assembly (II)
Room Nimes I Chair: Prof. K. Dröder

Customizing of Lithium-Ion Cells – From First Prototypes to Flexible Series Production
J. Diekmann, CustomCells

Influences of increasing coating thicknesses and calendering degrees on single sheet stack formation
H. Weinmann, Karlsruhe Insitute of Technology

High Power Battery Cells
A. Würsig, Fraunhofer ISIT

15:00 I Coffee Break

15:20 I **Parallel Sessions**

Battery Production 4.0 (II)
Room Maschinenhalle I Dr.-Ing. S. Thiede

Cost Optimization in Battery Cell Manufacturing through Simulation
M. Stalder, Bern University of Applied Sciences

Data- and Expert-Driven Analysis of Cause-Effect Relationships in the Production of Lithium-Ion Batteries
T. Kornas, BMW Group

Simulating Process-Product Interdependencies in Battery Production Systems
M. Thomitzek, TU Braunschweig/IWF

Formation & Aging
Room Nimes I Chair: Prof. M. Kurrat

A modeling perspective on the multiscale nature of SEI formation
F. Röder, TU Braunschweig/InES

Efficient and Easy to Scale Cell finishing from Laboratory Cell to Mass Production
J. Lang, PEC

Shortening Cell Manufacturing time: A comparative study of 2 methods
A. Gröbmeyer, Keysight Technologies

16:20 I Coffee Break

16:40 I **Parallel Sessions**

Electrode Production (II)
Room Maschinenhalle I Chair: Prof. A. Kwade

Coating, Drying and Solvent Recovery – Material Throughput and Effects on Pilot and Mass Production of Battery Electrodes
A. Keil, Dürr Megtec

Advantages and Limitations of Intermittent Coating
R. Diehm, KIT, Institute of Thermal Process Engineering (TVT) - Thin Film Technology (TFT)

Cellulose-based composite electrodes production on a paper machine
L. Sandberg, BillerudKorsnäs AB

Challenges in the prelithiation of electrodes within lithium ion cell production
B. Stumper, Technical University of Munich, Institute for Machine Tools and Industrial Management (iwb)

Cell & Pack Housing, Design & Safety
Room Nimes I Chair: Prof. T. Vietor

Thermal Runaway propagation at the battery pack scale: Evaluation of the impact of design parameters by multiphysics modelling
D. Buzon, CEA

Li-Ionen battery protection and automotive requirements
V. Buchmann, Hugo Benzing

Separator finite-element modelling for improving the prediction quality of short circuits within Li-ion cells caused by mechanical loads
P. Kolm, VIRTUAL VEHICLE Research Center

Safety Assessment and Design Optimization of Battery System using Simulation Techniques
M. Siddiqui, TU Braunschweig/IK

18:00 I End of Day One

19:30 I Reception at the Conference Lobby, Steigenberger Hotel

20:00 I Dinner at the Maschinenhalle, Steigenberger Hotel

PROGRAM

CONFERENCE DAY 2 | Nov. 5th

8:30 I Keynote by Cécile Tessier, SAFT
Improvement of Li-ion Batteries Performances by Improving Electrodes Formulation and Process

9:00 I Keynote by Idoia Urdampilleta, CIDETEC
Water-based Electrode Manufacturing with Advanced Li-ion Battery Materials

9:30 I Coffee Break

9:50 I **Parallel Sessions**

Electrode, Cell and Module Diagnostics during Production
Room Maschinenhalle I Chair: Dr. T. Heins/Dr.-Ing. F. Röder

Analysis and monitoring of the percolating network of battery electrode films during the drying process using eddy current technology
M. Wild, Fraunhofer IKTS

DEM-based simulation of the mechanical and electrical behavior of lithium-ion battery electrodes
C. Sangrós, TU Braunschweig/iPAT

In-line measurement of wrinkle formation and strains for NMC 622 cathodes while calendering to derive a suitable counteraction
B. Bold, Karlsruhe Institute of Technology KIT

Stochastic 3D modeling of the three-phase microstructure of electrodes in Li-ion batteries by means of synchrotron tomography
B. Prifling, Institute of Stochastics, Ulm University

Production of Solid Polymer Batteries and All Solid State Batteries
Room Nimes I Chair: Prof. A. Kwade

From Li-ion Batteries to All-Solid-State Batteries: A Life Cycle Comparison
S. Blume, Fraunhofer IST

Production Technologies for Sulfide-based All Solid State Battery Electrodes
B. Schumm, Fraunhofer IWS

Scalable manufacturing processes for all-solid-state batteries
P. Michalowski, TU Braunschweig/iPAT

Laser cutting of novel battery materials for all-solid-state batteries
J. Kriegler, TUM - Institute for Machine Tools and Industrial Management

11:20 I Lunch Break

12:05 I Poster Session

12:50 I Keynote by Jens Tübke, Fraunhofer Allianz Batterie
Production Research for Battery Manufacturing – Establishment of the Necessary Infrastructure

13:30 I **Parallel Sessions**

Recycling & Sustainability
Room Maschinenhalle I Chair: Prof. C. Herrmann

Recycling 4.0- A System of Systems approach to enable circular economy
M. Mennenga, TU Braunschweig/IWF

Ecofriendly Recycling of Lithium Ion Batteries
C. Hanisch, Duesenfeld

Innovative Production Concepts
Room Nimes I Chair: Prof. A. Kwade

Electrospinning as a Key Technology for fast Battery Production Processes
K.-H. Pettinger, University of Applied Sciences Landshut

Concepts for innovative battery housings and their production
C. Singer, Technical University Munich - Institute for Machine Tools and Industrial Management (iwb)

14:20 I **Parallel Sessions**

International Value Chains
Room Maschinenhalle I Chair: Prof. C. Herrmann

Giga battery factories in Norway, the path ahead
O. Stokke Burheim/A. Stromman, NTNU

The Future Battery Industries CRC: A catalyst to grow Australia's battery industries within the circular economy of global battery value chains
J. Eksteen, Future Battery Industry CRC

Module & Pack Production (I)
Room Nimes I Chair: Prof. K. Dilger

The Key to a reliable leak testing process in battery production
F. Werner, ZELTWANGER

Integrity testing of battery packs
S. Seitz, INFICON

15:00 I Coffee Break

15:20 I **Parallel Sessions**

Module & Pack Production (II)
Room Maschinenhalle I Chair: Prof. K. Dilger

Automated inline inspection of weld seams in battery production
P. Daniel, VITRONIC

Advanced Laser Technologies for E-Mobility: New Manufacturing Solutions for High-Performance Energy Storage
P. Kallage, Coherent

free configurable, tailored vacuum gripper kit to handle electrodes, separators and cells in nearly any possible design
H. Kuolt, J. Schmalz

Manufacturing Solutions for Battery Module and Pack Assembly Considering the Current Market Development
L. Ebert, ThyssenKrupp Systems Engineering

Electrode Production (III)
Room Nimes I Chair: Dr.-Ing. W. Haselrieder

Strategies to improve energy and power density of Li-ion batteries by virtual electrode design
S. Hein, DLR at HIU

High Energy Li-Ion Electrodes prepared via a Solventless Melt Process
B. Dufour, HUTCHINSON

Production Process for overcoming the limited rate capability of ultra-thick electrodes for LIB
A. Hoffmann, ZSW-

Composite electroforming: a novel production method for binder-free and conducting carbon-free battery electrodes with unique properties
T. Sörgel, Aalen University, Research Institute for Innovative Surfaces (FINO)

16:40 I End of Conference I Start of Guided Tour BLB (meet in front of Steigenberger Hotel)

POSTER SESSION

Electrode Production

P1-01 Microstructural investigation of deformations of Al foils in cathode current collectors during compression of electrode coatings
Andreas Kopp

P1-02 Highly Productive Industry Compatible Roll-to-Roll Vacuum Process for Deposition of Porous Silicon Thin Film Anodes
Claus Luber

P1-03 Interaction between mixing process and characteristics of electrode slurries
Desiree Grießl

P1-04 Precursor mixing: Improving battery quality right from the start
Dirk Jakobs

P1-05 Investigation of post-drying processes to enhance quality and efficiency of Lithium-ion batteries
Fabienne Huttner

P1-06 Impact of the cathode compression on the electrode quality for large-scale format PHEV1 cells
Hai Yen Tran

P1-07 The perfect slitting of battery foil (anode, cathode material)
Hermann Jeremies

P1-08 Fluidized bed granulation of silicon-carbon composites
Jannes Müller

P1-09 Post Lithium Storage- Potential and Challenges
Julian Klemens

P1-10 Influence of the carbon black amount on suspension and electrode properties of lithium-ion batteries
Julian Mayer

P1-11 Investigations of format-flexible coating processes with quality impact on electrodes
Sandro Spiegel

Cell Assembly

P2-01 How to Fill Large Lithium-Ion Cells
Florian Günter

P2-02 Liebherr-Verzahntechnik GmbH
Jan Pollmann

P2-03 Simulations and measurements of the expansion of Li-ion cells with Si-based anodes with a meso-mechanical – electrical finite-element model
Philip Kargl

P2-04 Production technologies for next generation batteries
Thomas Abendroth

Battery Production 4.0

P3-01 Data acquisition and data management for data mining in lithium-ion battery cell production
Artem Turetskyya

P3-02 Optimization of cell production by means of machine learning: Learning from 17.000 m of electrodes
Stefan Mähr

P3-03 Manufacturing lithium-ion batteries - Welding copper and aluminum using ultrasonics
Yuko Stiffel

Formation & Aging

P4-01 Key figure-based evaluation and process quality relationships of the formation result of lithium-ion batteries
Louisa Hoffmann

P4-02 Fast Charging Formation
Robin Drees

Cell & Pack Housing, Design & Safety

P5-01 Development of a scalable bipolar battery design for multiple battery chemistries
Lukas Wilhelm

P5-02 High power load test for battery saftey elements
Philip Dost

P5-03 Modelling and Simulation of a Battery Cell Abuse Tests with Finite Element Method
Shraddha Suhas Kulkarni

P5-04 The Influence of Different Cell Capacities on the Results of Nail Penetration Tests of Lithium Ion Batteries
Stefan Doose/Alexander Hahn

Electrode, Cell and Module Diagnostics during Production

P6-01 A novel method to measure the swelling of water-soluble PVDF binder system and its electrochemical performance for Lithium-Ion Batteries
Christina Toiga

P6-02 On the Correlation between Contact Resistance and Electrode Cutting Technique: an Electrochemical Impedance Spectroscopy Study
Gilberto Carbonari

P6-03 Methods for evaluating the quality of lithium-ion batteries
Jan Niedermeier

P6-04 X-Ray based Visualization of Electrolyte in Lithium-Ion Batteries
Philip Gümbel

P6-05 The effect of expander formulation on the electrical performances of the Lead-acid cell
Samir Briche

POSTER SESSION

Production of Solid Polymer Batteries and All Solid State Batteries

P7-01 Automated Assembly Station for All-Solid-State Batteries
Arian Fröhlich

P7-02 Influence of rotational speed of a drum collector electrospinning setup on polymer electrolytes
Bernhard Springer

P7-03 Influences of process parameters on the conductivity of polymer electrolyte based all-solid-state cathodes
Laura Helmers

P7-04 Development of a scalable manufacturing process for sulfide-based solid-state batteries
Mattis Batzer

P7-05 Syntheses of nickel-rich active materials and sulfide solid electrolytes for ASSB cathodes
Michael Grube

P7-06 Coatable, fully amorphous PEG based polymer electrolyte for lithium ion battery with adapted adhesion properties for graphite electrodes
Silvia Dr. Janietz

P7-07 Towards a solid state nickel / iron battery
Wolfdietrich Meyer & Dario Gomez Vazquez

Recycling & Sustainability

P8-01 A conceptual framework for a sustainability assessment of Li-S batteries in aviation
Alexander Barke

P8-02 Sustainable supply chains for lithium-ion batteries: Integrated assessment of environmental and socio-economic hotspots
Christian Thies

P8-03 Characterisation of lithium-ion battery stacks in terms of second use applications
Julia Brockschmidt

P8-04 Recycling 4.0 – Mapping digitalisation onto the Circular Economy for Li-Ion Batteries
Steffen Blömeke

POSTER ABSTRACTS

Electrode Production

Microstructural investigation of deformations of Al foils in cathode current collectors during compression of electrode coatings

Andreas Kopp
Materials Research Institute, Aalen University

Highly compressed electrode foils are used to increase the capacity and volumetric energy density in Li-ion batteries. During the calendering the microstructure of the electrodes undergo tremendous changes. For instance, the fraction of pore spaces reduces while the fraction of binder and active material per unit volume increases during compaction. The compression process influences the Al foil of the cathode current collector. Depending on the size and morphology of the active material the particles are pushed into the Al foil. Due to the deformation and the embedded particles the adhesion of the electrode coating and mechanical stability of the electrode is increased. Depending on the design concept and production techniques used, not all areas of the Al foil are coated and covered with the slurry paste. The edges of the current collector foil are not always coated. These uncovered regions partly remain after electrode cutting and are used to connect the current collectors to the battery pins. The Al foil consists of highly deformed and coated regions in the middle and undeformed and uncoated regions at the edges. This leads to the formation of wrinkles in the uncoated areas which decrease the processability and can lead to unusable electrodes due to structural damages. To understand the formation of the wrinkles and to help to assist with the development of solutions in order to avoid these wrinkles, the microstructure of the current collector is investigated. Different methods such as light microscopy, electron microscopy, FIB-preparation, electron backscatter diffraction (EBSD) and x-ray diffraction are applied. We aim to visualize microstructural changes such as deformation, residual stress, grain size and grain orientation in the transition area between coated and uncoated areas. The results help to understand the process of wrinkle formation and supports the development of solutions for a compression process with reduced formation of wrinkles.

Highly Productive Industry Compatible Roll-to-Roll Vacuum Process for Deposition of Porous Silicon Thin Film Anodes

Claus Luber
Fraunhofer FEP

As electromobility is becoming more and more mature, the demand on high capacity batteries is rapidly growing. Exisiting battery technologies are still in the vast need of improvement with regard to technical parameters and of course with regard to cost. They need to be rethought and alternatives have to be considered.
Silicon as alternative to graphite or lithium metal is recognized to be a promising candidate for novel anode materials.
As prelithiated Si-films show the same performance in a full cell arrangement as Li anodes, they can be significantly thinner than state of the art anodes and thus reduce the overall weight of a cell but keep capacity the same.
From the production view, vacuum thin film technologies can offer process alternatives for various parts of the battery.
They can provide thin film deposition of a large variety of materials, with good quality and purity and a wide range of film thicknesses can be achieved.
Combining these two aspects of novel materials and novel production technology, Fraunhofer FEP demonstrates the use of Physical Vapor Deposition methods to deposit thick silicon layers (up to 12 µm thick) on very thin copper foils (down to 10 µm thin) by using of cost efficient Roll-to-Roll technologies with an advantageous layer morphology. Dynamic deposition rates for silicon of up to 250 nm*m/min for a width of 300 mm were achieved. Further upscaling to larger band widths is planned.
A capacity comparable with the theoretical silicon capacity was measured in half cells tests. FEP is able to provide such double side coated samples for battery test cells on special customer demand.
In the poster, we present recent results and possibilities for further upscaling of the process.

Interaction between mixing process and characteristics of electrode slurries

Desiree Grießl
BMW AG

The mixing process is an essential step in the electrode production. Apart from material selection and constitution, remarkable influence of the mixing procedure on the electrode properties have been detected. Through the energy application of a mixing device, materials are supposed to be homogenized and potentially desagglomerated. Different approaches exist in order to produce an electrode slurry.
Continuous and discontinuous processes for slurry production are being investigated and product characteristics are being analyzed and compared.

Precursor mixing: Improving battery quality right from the start

Dirk Jakobs
Gebrüder Lödige Maschinenbau GmbH

The mixing of the NMC oxide material with Lithium Carbonate or Lithium Hydroxide is one of the first steps in the production chain of lithium-ion batteries. But already in this precursor mixing step some precautions have to be taken to ensure the quality of the battery cell.One critical parameter for this precursor is the iron content of the material. An increase of the iron concentration must be avoided in any case.
Within the last ten years the effort to reach this target has been significantly increased. The first mixers provided for this application had a ceramic lining of the machine drum and alumina based coating on the mixing tools to reduce metal contamination. Based on the experienced made with these machines the design has been modified to reach the following targets:
a) Further reduction of free metal surfaces getting in contact with the product
The mixing drum and the mixing tools already represent 85% of the product contact parts. By additional coating of the mixer shaft, inlet nozzles and some smaller surfaces the amount of covered parts could be increased to 99%.

b) Better mechanical properties to reduce maintenance effort
The Alumina coating of the shovels showed good wear protection against the powdery NCM material but due to its brittleness contact with hard foreign matter could damage the thin protection layer on the shovels.
New, tungsten carbide based coating materials have better mechanical properties.

c) Avoiding other contaminants
Besides od iron also other metals have been identified as critical components. The use of copper and zinc has been prohibited completely. Even outside parts of the machine not being in contact with product must be free of zinc and copper. The use of standard components like zinc plated washers or solenoid valves wasn’t possible anymore.

d) Cost reduction
With the increasing demand for production capacities for Lithium batteries several local machine suppliers entered the Asian market. To be competitive costs had to be decreased without reducing the quality. A significant reduction could be reached by standardisation and design simplification.

Investigation of post-drying processes to enhance quality and efficiency of Lithium-ion batteries

Fabienne Huttner
TU Braunschweig | Institute for Particle Technolgy (iPAT)

In the context of the current global energy turnaround, electrochemical energy storage techniques are regarded as a key factor for the development and establishment of electromobility and stationary energy storages. For these applications, Lithium-ion batteries (LIBs) are presently thought to be the most promising energy storage technology, showing clear benefits compared to other battery systems. Beside disposing an outstanding cycling stability for various applications, they can also be designed both for high power and for high energy applications [1-6].
However, the manufacturing of LIBs includes a lot of complex process steps and is subjected to various internal and external influences. Consequently, highly reproducible manufacturing processes as well as strict quality controls are required to meet the growing demands on battery life-time, safety, reliability, cycling capability and specific energy and power [4, 5, 7].
Here, a quite critical contamination is represented by moisture [7-10]. Residual moisture in the battery cells can cause cell degradation and thus pose a high safety risk. In addition, it can hinder the formation of an effective Solid Electrolyte Interface, which protects the active material from direct contact with the electrolyte [1, 5, 7]. Hence, electrodes and separators for Lithium-ion batteries need to be post-dried directly prior the cell assembly to reduce the moisture content in the cells below a critical level. However, there is still little research about post-drying in general and the interdependency between type and intensity of post-drying regarding the residual moisture and the resulting influence on the electrochemical performance.
To better understand this process step and to enhance quality and efficiency, different post-drying processes and their impact on the physical and electrochemical properties were investigated. The residual moisture was measured via coulometric Karl-Fisher-Titration and correlated to the resulting electrochemical performances. The analyses showed that the type of post-drying and its intensity have a high impact on the physical and structural properties of the electrodes and thereby influence their achievable electrochemical performance significantly. An enhanced electrochemical performance is consequently not only guaranteed by a low remaining water content, but in particular by a gentle post-drying. On the basis of these insights, gentle post-drying processes were developed leading to an improved electrochemical performance and efficiency.

[1] S. Nowak, M. Winter, J. Anal. At. Spectrom. 2017, 32, 1833.
[2] P. Bieker, M. Winter, Chemie in unserer Zeit 2016, 50, 172.
[3] L. Froboese, P. Titscher, B. Westphal, W. Haselrieder, A. Kwade, Materials Characterization 2017, 133, 102.
[4] A. Kwade, W. Haselrieder, R. Leithoff, A. Modlinger, F. Dietrich, K. Droeder, Nat Energy 2018, 3, 290.
[5] J. Vetter, P. Novák, M. R. Wagner, C. Veit, K.-C. Möller, J. O. Besenhard, M. Winter, M. Wohlfahrt-Mehrens, C. Vogler, A. Hammouche, Journal of Power Sources 2005, 147, 269.
[6] L. Froboese, P. Titscher, B. Westphal, W. Haselrieder, A. Kwade, Materials Characterization 2017, 133, 102.
[7] M. Stich, N. Pandey, A. Bund, Journal of Power Sources 2017, 364, 84.
[8] A. V. Plakhotnyk, L. Ernst, R. Schmutzler, Journal of Fluorine Chemistry 2005, 126, 27.
[9] L. Terborg, S. Nowak, S. Passerini, M. Winter, U. Karst, P. R. Haddad, P. N. Nesterenko, Analytica chimica acta 2012, 714, 121.
[10] S. F. Lux, I. T. Lucas, E. Pollak, S. Passerini, M. Winter, R. Kostecki, Electrochemistry Communications 2012, 14, 47.

Impact of the cathode compression on the electrode quality for large-scale format PHEV1 cells

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NMC622 cathodes, composed of 1.5 wt% of PVDF and 3 wt% of carbon additives, have been calendered between 3.0 and 3.5 g cm-3. The influence of the calendering on the electrode quality for PHEV1 jelly rolls has been systematically analyzed in terms of surface morphology, porosity and electrochemical performance. It has been shown that a proper calendering of NMC622 can improve the volumetrically energy density of the PHEV1 cells without negatively interfering the cell assembly process. Preliminary results demonstrate that PHEV1 cells with NMC622 cathode having a density of 3.3 g cm-3 maintained their capacity regarding the cycle life better than the others.

The perfect slitting of battery foil (anode, cathode material)

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DIENES Werke für Maschinenteile GmbH & Co. KG

Slitting battery foil is a comprehensive process. Highest demands are necessary regarding the precision of the cutting edge quality and the service life of the knives. The avoidance / minimization of metallic knife wear and reduction of slitting dust are further material-typical challenges that DIENES, as a slitting specialist with over 100 years of experience, has to face and DIENES has already gained experience in the development and manufacturing of slitting tools.
DIENES explains which cutting parameters have to be observed in order to achieve the perfect cut for the battery foil:

- Knife guidance
- Knife edge geometry
- Knife overlap
- Shear angle
- Axial- und radial deviation (manufacturing tolerances)
- Knife contact force
- Bottom knife lead

Fluidized bed granulation of silicon-carbon composites

Jannes Müller
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Lithium-ion batteries are currently the most promising technology for sustainable mobility and energy storage but with state-of-the-art active materials a further enhancement of capacity and energy density is limited [2]. The replacement of graphite by new silicon-composite materials on the anode side opens further perspectives [1]. Silicon, however, exhibits a large volume change during lithiation [3, 4], a thereof resulting worse electrode stability [1, 2] and a higher electrical resistance [5].
The aim of this study is to overcome these issues by establishing a scalable granulation process to form an optimized particle structure. Therefore, nano-sized silicon particles were prepared by grinding in stirred media mills and then granulated in fluidized bed with larger graphite host-particles. The nano-sized silicon forms a layer on the graphite particles alongside binders and conductive additives to improve the mechanical and electrical properties. The mechanical stability of the composite particles is an important factor in subsequent water-based dispersing but also in the electrode during electrochemical testing. For that reason, different granule binders were investigated in terms of electrode and particle stability. In addition to that the electrochemical performance is strongly influenced by the electrical properties and thus, the usage of different conductive additives in the granulation step was further evaluated. First electrochemical results indicate a good stability of the prepared composite electrodes and correlate well to the physical characteristics.

References

[1] Casimir, A., Zhang, H., Ogoke, O., Amine, J. C., Lu, J., and Wu, G. 2016. Nano Energy 27, 359–376.
[2] Chae, S., Ko, M., Kim, K., Ahn, K., and Cho, J. 2017. Joule 1, 1, 47–60.
[3] Hatchard, T. D. and Dahn, J. R. 2004. J. Electrochem. Soc. 151, 6, A838.
[4] Obrovac, M. N. and Christensen, L. 2004. Electrochem. Solid-State Lett. 7, 5, A93.
[5] Pollak, E., Salitra, G., Baranchugov, V., and Aurbach, D. 2007. J. Phys. Chem. C 111, 30, 11437–11444.

Post Lithium Storage - Potential and Challenges

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Electrochemical storage is a key technology of the 21st century. In the future, electricity storage systems will become more important components of energy systems, especially for the upcoming electro mobility and for everyday use. Lithium-ion batteries (LIB) are currently the most important electrochemical energy storage devices. The lagerly mature technology is characterized by high gravimetric and volumetric energy densities. The increasing demand for LIB in the future gives rise to concerns about the availability of certain raw materials such as lithium and cobalt and causes a price increase. In particular, this represents a risk for cell manufacturers. Furthermore, there are environmental difficulties due to the active components of the battery.

The aim is to develop sustainable and environmentally friendly but also powerful and reliable storage systems. Sodium-ion batteries (SIB) could be one of these alternatives, especially for medium and large energy storage systems. SIBs are already being investigated and further developed on a pilot scale. The challenge consists in the development of active components for anode, cathode and electrolyte on the one hand and in the large-scale processing of the battery on the other. In this work the processing from the formulation of the active components for anode and cathode to coating and drying is investigated. The focus is on identifying the challenges in each process step and developing solutions. For this purpose, knowledge about the processing of lithium-ion electrodes is used and comparative analyses are conducted.

The advantages of non Lithium-ion batteries, the processing challenges and first results concerning the comparison of the processing of LIB and SIB will be presented.

This work contributes to the research performed at CELEST (Center for Electrochemical Energy Storage Ulm-Karlsruhe).

Influence of the carbon black amount on suspension and electrode properties of lithium-ion batteries

Julian Mayer
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Energy storage is a key technology for alternative drive systems, like electric and hybrid electric vehicles. Lithium-ion batteries (LIBs) are widely used for this purpose due to their high energy density and their meanwhile decreased costs. However, electrified transportation requires further development in terms of simultaneously available power density or especially fast charging capability.

The fragmentation of carbon black (CB) aggregates and CB agglomerates, respectively, within the dry and wet dispersion process has a high impact on the resulting mechanical integrity as well as conductivity of electrodes and, furthermore the electrochemical performance of LIBs. The slurry formulation has been performed with a planetary mixer of industrial relevance and contains more than 95% active material and less than 2.5% CB. To achieve optimized and according the application desired power densities as well as to reduce cost and process time to adjust the corresponding particle sizes and its distributions, a systematic investigation of process and formulation parameters of the dispersion is required. Additionally, an in-depth understanding of the carbon black disintegration and breaking process will lead to a generalized knowledge about the necessary energy input to adjust an optimal CB size distribution for improved electrochemical properties. Optimized CB size and structure of electrode will open for minimizing the amount of CB. Consequently and to further increases energy and power density of LIB's. Hence, the presentation addresses the influence of the CB fraction and the resulting CB-binder ratio in the recipe, while an emphasis is placed on the resulting properties of the cathodic suspensions (e.g. viscosity, CB particle size) and electrodes (e.g. adhesion force, conductivity, electrochemical performance). Especially, the impact of the portion of CB agglomerates and aggregates are discussed.

Investigations of format-flexible coating processes with quality impact on electrodes

Sandro Spiegel
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In the future, electricity storage systems will become an increasingly important aspect of the energy industry, especially for the upcoming e-mobility and for everyday use. Due to their properties such as high-energy density, high-power density and in addition high cycle stability, lithium-ion batteries (LIB) are regarded as the basis for electrification. At this point of time, LIBs are manufactured in production lines, which are highly inflexible in terms of cell material, dimensions and quantity. Especially the utilization in mobile devices like power tools or Smart Watches requires a cell design, which suits the application in terms of geometry. This goal can be achieved with the help of a format-flexible electrode coating process. Moreover, the efficiency of the electrode production can be increased with an intelligent manufacturing process by minimizing waste due to cutting away the side edges and optimizing the quality of electrodes.

In this work, a format-flexible coating system involving a special design of a coating station with a slot die was designed and put into operation. At first, the properties and challenges of a format-flexible coating application were examined. Therefore, the relative position of the slot die to the coating direction and its influence on the coating quality and homogeneity were investigated. In a next step, the impact of material properties, e.g. the viscosity of the electrode slurry, on the edge quality was determined. For this purpose, graphite anodes with different solid contents were produced in the coating station set up and examined with suitable measuring procedures. The resulting film profile was registered with laser triangulation.

The measured profiles were then evaluated with regard to film homogeneity, coating defects and quality of the side edges. The increase of the viscosity results in higher side edges with a negligible impact of the relative slot-die position.

Cell Assembly

How to Fill Large Lithium-Ion Cells

Florian Günter
Technical University of Munich, Institute for Machine Tools and Industrial Management (iwb)

The filling of lithium-ion cells consists of dosing and subsequent wetting and is decisive for the final product quality. Especially with large format cells with high energy density, the process gains in complexity and has a strong in-fluence on the costs of the cell due to long wetting times. In order to cut these costs, throughput times must be reduced, as lower throughput times reduce the fixed costs per cell. For this purpose, the process design must be designed in dependency on the customer's requirements and therefore in dependency on a given cell format and a given material system.

The presentation discusses physical connections of the process and in connection optimization of the process parameters. In conclusion, the in-sights lead to a generally valid method for process design.

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Simulations and measurements of the expansion of Li-ion cells with Si-based anodes with a meso-mechanical – electrical finite-element model

Philip Kargl
VIRTUAL VEHICLE Research Center

During battery cell production, the different components already face significant mechanical stresses, which impact the performance and lifetime of the cell during regular operation. The production steps are complex, and mechanical quantities are hard to monitor. For instance, the mechanical stresses introduced into the jelly roll during winding/stacking are not known in detail. Simulations might be a useful tool to unveil and analyse these stresses.

The PhD project SimCP funded by the Austrian Funding Agency (FFG) aims to provide suitable models to support cell

production and to investigate the influence of production-related stresses on regular cell operation. Another important mechanical issue which arises during cell operation is electrode swelling due to Li-ion intercalation. This effect is especially pronounced in Si-based materials, which will be used as anodes in the project.
For investigating the phenomena, a meso-mechanical FE-model is set up. In this model, all cell components are resolved separately (but homogeneously) resulting in a representation of the cell layer structure which enables investigation of the mechanical inter-layer interactions during a simulation. Each component requires its own parameter set, which is obtained via mechanical testing (tensile, compression) of the cell components. The mechanical model will be coupled to an electrical model calculating the cell voltage evolution during operation.
As a first step towards the cell production simulations, a model for a pouch cell is set up. With this model a sound understanding of the mechanical-electrical coupling will be achieved. For validation, measurement data is generated on a specifically designed test rig, which allows to monitor the cell expansion and the force evolution of lab-scale pouch cell for various external conditions.
The model will be transferred to different cell types and used as basis for the simulations of the winding/stacking process in a later stage of the project.

Production technologies for next generation batteries

Thomas Abendroth
Fraunhofer IWS

Next generation batteries involve materials with new requirements on material processing or electrode layout. In all-solid-state and Li-S batteries lithium metal is targeted to be applied as anode due to its very high theoretical capacity of 3860 mAh/g. Also the manufacturing of electrodes and solid electrolytes will become more challenging due to moisture sensitive materials or requirements to minimize the amount of non-active materials.
The poster will present different scalable production technologies for manufacturing components for next generation batteries:
- melt deposition of thin lithium films on current collectors (thickness range: 1- 50 µm)
- automated laser cutting of lithium metal electrodes
- solvent-free technology for sulfide solid electrolyte based cathode processing (binder content < 1 %)
By implementing these technologies, the pouch cell manufacturing of next generation batteries could be demonstrated successfully. Resulting cell performance of pouch cells will be presented for all-solid-state as well as for Li-S cell chemistry.

Battery Production 4.0

Data acquisition and data management for data mining in lithium-ion battery cell production

Artem Turetskyy[a,b], Jacob Wessel[a,b], Sebastian Thiede[a,b], Christoph Herrmann[a,b]
[a]TU Braunschweig / Institute of Machine Tools and Production Technology (IWF), [b]Battery LabFactory Braunschweig (BLB)

The production chain of lithium-ion battery cells consists of many different processes covering batch as well as single unit processes including converging and diverging material flows. Besides the influence of these processes, the product quality is affected by further criteria such as the amount and type of used material as well as ambient conditions. This complexity makes it harder to control and regulate economic and ecological target criteria (e.g. product quality, cost, energy demand). Therefore, it is necessary to develop a holistic system understanding as well as to identify and evaluate the interactions between the process steps within the production chain of battery cells and their effects on the relevant cell properties.
A suitable approach can be to acquire production data, preprocess it and analyze towards desired goal criteria using data mining methods. However, due the complexity of lithium-ion battery cell production and possible process-product-interactions as well as the effects of ambient conditions upon the cell quality, data acquisition and management need a sophisticated approach. Therefore, the framework for the implementation of such system includes the identification of all relevant parameters of production processes and technical building services as well as environmental conditions, detailed value and energy streams during manufacturing and intermediate product features. The framework consists furthermore of data acquisition concept along the production line including technical building services, cell diagnostics and whether conditions. It includes automated and manual data acquisition as well as an interface for further investigation of the acquired data. The integration of further sensors and in-line analytical devices allows a visualization of product data and energy consumption live and its analysis and evaluation compared to given KPIs (key performance indicator). The gathered data is preprocessed and allocated to given production orders and can be furthermore analyzed towards desired goal criteria.

Optimization of cell production by means of machine learning: Learning from 17.000 m of electrodes

Stefan Mähr
ZSW – Zentrum für Sonnenenergie- und Wasserstoff-Forschung

The poster describes possible applications of Machine Learning in the field of process-, electrode- and cell diagnostics. These findings result from the end-to-end cell production at the Center for Solar Energy and Hydrogen Research (ZSW). During electrode and cell production, large amounts of data are recorded at the research production line at the ZSW in Ulm. We show that these structured datasets are very well suited to create models from deep learning.
With the learned models we are able to create a target that:
- identifies relevant influencing variables
- determines the sensitivity of the relevant influencing variables
- optimizes the process and thus the cell quality through Active Learning.
The necessary prerequisites and expenses for personnel, software, hardware and process technology are presented.
Finally, the current results will be presented on the basis of cell production at the ZSW. The above mentioned approaches were used and applied to the processes of the research production line.
Finally, two analyses with data from cell production at the ZSW are presented. One looks at data from the electrode production, i.e. mixing and coating process. The other analyses PHEV1 cells. For this purpose, data from the entire value chain was used. The above approaches were used and applied to the processes of the research production line.

Manufacturing lithium-ion batteries - Welding copper and aluminum using ultrasonics

Yuko Stiffel
Herrmann Ultraschalltechnik GmbH & Co. KG

The ultrasonic welding of nonferrous metals such as copper and aluminum is an established process and is currently booming in connection with the growing market for lithium-ion batteries (LIB) – now the main storage source for electromobility. Herrmann Ultraschall has been a specialist in ultrasonic welding for decades and has now developed a new weld system for metals, the HiS VARIO B.
Ultrasonic welding is a clean, safe, and environmentally friendly process, which is not only suitable for the pre-welding and main welding for anodes and cathodes in LIB manufacture but also for electrical connections in the automotive, consumer, and electronics industries. The process can be utilized at a manual work station or incorporated automated into production lines. The advantages are:

- High weld strength
- Short weld times
- Low energy consumption
- No consumables

Longitudinal vibrations break up the oxide layer

Ultrasonic welding is primarily used to join conductive nonferrous and precious metals. The energy required for joining is supplied by mechanical vibrations. The ultrasonic generator produces electrical oscillations in the 20 or 35 kHz range for this from the 50-Hz mains alternating current. A converter is used to turn the electrical oscillations into mechanical ones in the same frequency. The weld tool, called the sonotrode, transfers the vibrations to the joining partner. The sonotrode couples with the joining part facing it and makes it oscillate longitudinally. The other joining part is held in a structured anvil and does not move. The sonotrode's coupling surface must also be structured, as otherwise the top joining partner would not move, which is to say no relative motion would be generated.
The oxide coating at the joining sites is broken up by the intensive friction and the two joining parts are fused together with a molecular bond under simultaneous exposure to pressure. The decisive aspect of the welding is not the heat produced, which is far below melting point, but the relative motion of both joining partners. As a result of the low process heat, there is no negative effect on the substance's material structure. The joining partners' maximum material thickness is 2 to 3 mm for copper sheet. The power requirement is between 1,200 and 6,200 watts, depending on the application.
Visualization assists process monitoring
The system control checks the process parameters and visualizes them. This graphical display of parameters on the machine screen, which includes amplitude, energy, weld depth and weld force, is turning out to be an important instrument to ensure process stability. A process window must be determined for each application to balance out material and production tolerances. All the upstream cell production process steps must be taken into account at this stage. It is important to reduce rejects to a minimum, especially in the case of expensive battery cells. When determining the welding parameters, i.e. taking the application, material and production environment into account, it is essential to think holistically. Which is why it is important to get the ultrasonic technology suppliers involved in product development as early as possible.
Herrmann Ultraschall sees fine parameterization as offering great opportunities to further improve the production quality and service life of sonotrodes. Correlations can be observed between process stability and particle reduction, and between energy inputs, a stable converter, and the weld tools' service life.

Formation & Aging

Key figure-based evaluation and process quality relationships of the formation result of lithium-ion batteries

Louisa Hoffmann
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As is well known, the formation is an important process step in the production of lithium-ion batteries due to the growth of the solid electrolyte interphase (SEI) on the anode surface during initial charging. This layer is an indispensable component of the cells and has direct effects on cycling stability as well as on performance at high charge and discharge currents. At the same time, the formation is the most time-consuming process step. Therefore, the prediction of the cell performance during the formation as well as directly after this step through the application of tests is of great interest to the cell manufacturers. Hence, it is possible to derive correlations and in the next step optimize the formation.
The general purpose of the poster is to show which key figures can be obtained from the measurement data of the formation process in order to be able to make statements about the quality of the cells. In this context, the following indicators are often mentioned: the loss of capacity during the first cycle and the self-discharging rate during the ageing period following formation. Further examples of relevant indicators are the voltage efficiency of the charging and discharging cycle and the increase of the internal resistance during formation and ageing. In order to obtain statistical data on the distribution of the formation key figures, about 200 industrial scaled 9 Ah battery cells had undergone the same formation procedure and were evaluated using the same method.
In addition, a quick test directly after the formation is presented, which allows further information about the cell properties to be obtained. This end-of-line test is based on the process quality relationships determined from the statistical data and thus enables the targeted prediction of cell quality immediately after the formation.

Fast Charging Formation

Robin Drees
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The formation of lithium-ion batteries is the most time-consuming process step during the production. Common formation methods consist of several charging and discharging cycles with relatively low currents in order to build up a durable Solid Electrolyte Interface (SEI) on the anode. The SEI has a significant impact on the performance and aging of the battery cells. Aiming at cheaper production costs and better properties of lithium-ion batteries, the optimization of common formation methods is necessary. This contribution is focused on developing optimized fast charging procedures by means of parameter studies and model-based design. Therefore, self-made battery cells with NMC622/G are characterized with a three-electrode setup in order to parametrize the developed battery model. The output of the battery model are optimized fast charging profiles that are used for the formation of self-made 5 Ah pouch cells afterwards. Different test-methods and the cycling of the cells are investigated in order to validate the optimized formation procedure.

Cell & Pack Housing, Design & Saftey

Development of a scalable bipolar battery design for multiple battery chemistries

Lukas Wilhelm
Fraunhofer UMSICHT

Electrical energy storages for large-scale stationary storages require high-voltage and high-energy battery modules that consist of numerous single cells connected in series. Since every single cell is sealed and packaged separately (monopolar battery design) each cell has a large share of inert materials, which leads to a decrease in volumetric energy density [1, 2].
A bipolar battery design offers several advantages compared to conventional battery modules, such as a compact and stackable battery design, low internal resistance, high current densities and lower manufacturing costs [1, 3].
This project focuses on the development of a bipolar battery stack design for multiple battery chemistries. By using flexible, polymer based bipolar plates and a polymer based framing, the bipolar battery stack can be sealed using plastic welding, without the need of age-sensitive rubber seals.
An overview about project focal points and the developed bipolar battery stack as well as first results will be presented.
I want to present this project at the IBPC, because it includes a key topic the battery community is interested in: development of a compact, scalable and stackable cell design for multiple battery chemistries which is cheap to manufacture due to less components and low material costs.

High power load test for battery saftey elements

Philip Dost
Ruhr-Universität Bochum

Battery cells are not defeatable and therefore require reliable safety elements. In order to ensure reliable operation, assemblies related as well as system related load tests are required. This way the assemblies' reaction to a short circuit can be assessed. A special designed test bed allows tests with continuous load of up to 12 kA at 1 kV, while performing synchronous measuring of all desired voltage and current values at 1 MHz. In addition the temperature of system components can be monitored. In order to fit the trajectory of the current to real testing conditions, it can be pre-defined.
The configurable test bed allows scalable load conditions and automated analyses of the reaction of the safety components.

Modelling and Simulation of a Battery Cell Abuse Tests with Finite Element Method

Shraddha Suhas Kulkarni
TU Braunschweig | Institute of Engineering Design (IK)

High energy and power density make Li-ion batteries ideal for their use as traction batteries in vehicles. On the other hand they become more susceptible to explosion in case of accidents. To ensure the crash safety of the Li-ion batteries, they must undergo a series of mechanical, thermal and electrical abuse-tests. In our study we have simulated two of such mechanical abuse test configurations namely- the ball indentation test and the cylindrical compression test of a battery cell using Finite element method. We have verified the importance of a casing of the prismatic cell for the mechanical integrity of the battery cell. A parametric study involving the variations in casing wall thickness and fillet radius of the cell casing is also performed. The outcomes of simulation models show good agreement with the available literatures. Our poster shows detail information about the methodology employed for crash simulations.

The Influence of Different Cell Capacities on the Results of Nail Penetration Tests of Lithium Ion Batteries

Stefan Doose, Alexander Hahn
TU Braunschweig | Institute for Particle Technolgy (iPAT)

Nowadays lithium ion batteries (LIB) became one of the key technologies for energy storage. The most important application is energy supply for mobile devices as well as for battery electric vehicles (BEV), hybrid electric vehicles (HEV) and plug-in hybrid vehicles (PHV) because of their high energy density and their advanced stage of development. Therefore, LIB's are not simply rated by their performance parameters but also by issues of safety.
With respect to the interaction of electrical and chemical hazards as well as emergence of fire and explosions, the thermal runaway represents the main risk potential related to the extended use of LIB's. During thermal runaway, exothermal chemical reactions trigger further exothermal reactions, leading to the release of flammable and toxic gases plus particles. For safety studies a thermal runaway can be provoked by direct heating, overcharging or short circuit events. Such events can be analyzed via temperature and voltage monitoring, as well as measurements (qualitative and quantitative) of gaseous products and post mortem studies.
This study presents results of nail penetration tests in a custom-made battery cell investigation chamber. This chamber allows the determination of parameters which influence the response of battery cells to internal short circuit experiments. The response is analyzed via measurement of cell voltage, temperatures, as well as camera recording. Infrared gas species are identified and analyzed by Fourier transform infrared spectroscopy (FTIR). The cells investigated in this study are manufactured, formed and electrochemically characterized in the Battery LabFactory Braunschweig. Cells of different capacity are tested using a conductive nail material to determine the minimum required capacity to trigger a thermal runaway while using constant cell parameters. Subsequently cells with the capacity resulting in thermal runaway are manufactured with different separators to investigate and compare gaseous reaction product quantities, explicit temperature changes and development of the thermal runaway.

Electrode, Cell and Module Diagnostics During Production

A novel method to measure the swelling of water-soluble PVDF binder system and its electrochemical performance for Lithium-Ion Batteries

Christina Toiga
University of Bologna

Water-soluble CMC/PVDF binder systems were used to prepare graphite anodes and compared mechanically and electrochemically with CMC/SBR binder systems. The effect of crystallinity of PVDF binder on the mechanical and electrochemical performance of the anodes is studied. A contact free method easy to operate and equipped with high accuracy was developed by using capacitance measurement. The swelling of graphite electrodes was controlled and showed different results for different binder crystallinities (no swelling of binder with high crystallinity vs. 12 % for medium crystallinity and 17 % for low crystallinity binder). The discharge capacity depends on the crystallinity of the binders and half-cells delivered a capacity in the range of 230 – 360 mAh/g. The binder with medium crystallinity in particular exhibited the best mechanical and electrochemical performance and showed an excellent C-rate stability with specific capacities up to 10 C. Full cell tests showed good cycling stability over 180 cycles. The water-based PVDF binders seem to be a promising alternative to solvent-based binders.

On the Correlation between Contact Resistance and Electrode Cutting Technique: an Electrochemical Impedance Spectroscopy Study

Dr. Gilberto Carbonari, Verena Müller, Dr. Rares-George Scurtu, Dr. Michaela Memm, Dr. Margret Wohlfahrt-Mehrens
ZSW – Zentrum für Sonnenenergie- und Wasserstoff-Forschung

The interfaces study in lithium-ion batteries (LiBs) plays an important role in improving the performance of the aforementioned. In this regard, Electrochemical Impedance Spectroscopy (EIS) has already proven to be a very useful characterization technique. Nonetheless, EIS spectra interpretation of LiB electrodes is not straightforward because of the many phenomena occurring within the composite electrodes. In consequence of this fact, an optimal fitting model is necessary, together with the attribution of a physical meaning to the model parameters. As already shown by several groups, a Transmission Line Model has been applied with very good results as regards its application to porous electrodes. In recent times, many LiBs production processes use laser-based techniques such as laser-cutting and-ablation. Laser cutting make possible the production of virtually any electrode shape and thus the manufacturing of tailored cell formats in order to fill any available space in the final product (laptops, smartphones, cars). Laser ablation is another widely used technique, mainly for the coating removal and structuring of LiB electrodes. Since the laser parameters must be carefully adjusted based on the electrode composition (active material, binder, conductive agent and current collector combination), a method is needed for finding the optimal settings. In this work, EIS has been used on graphite and NMC 811 industrial-grade electrodes to compare different cutting techniques like mechanical notching, laser ablation and laser cutting. Using symmetrical coin cells in blocking conditions, we show that we can quickly relate the electrode edges quality with the presence of a contact resistance (Rcont) in the high frequency region of Nyquist plot.

Methods for evaluating the quality of lithium-ion batteries

Jan Niedermeier
Aalen University, Materials Research Institute

The demand for effective quality control measures of Li-ion batteries (LiB) is becoming more important than ever with the increasing usage of LiB for commercial and car applications. This paper examines three image inspection techniques regarding the production-relevant inspection features and their suitability for a general quality control of LiB. Digital radioscopy (DR) and computed tomography (CT) form the non-destructive counterpart to materialographic preparation with subsequent light microscopic analysis. The avoidance of defects on a microstructural level, such as the contamination of foreign inclusions in the electrode coatings, primarily requires an understanding of their cause and origin. In order to address this question effectively, image analysis methods are required to identify foreign particles. On the basis of digitized cross section levels of LiB, 'Machine Learning' (ML) methods were trained to automatically detect and quantify defects and other specific features. Based on that, a comparison of different battery cells was carried out. One aim was to compare different production batches of a specific 18650 format cell, trying to quantify abnormalities. From our analysis, we found several metallic and non-metallic particles as well as voids and agglomerations.

The effect of expander formulation on the electrical performances of the Lead-acid cell

Samir Briche
MAScIR Foundation

Nowadays, there are several technologies of lead-acid batteries. This multitude of technologies is mainly the result of improvements and developments that the battery had undergone for more than 160 years since the invention of the first lead-acid battery, which are driven by the development of the automotive sector, which constantly imposes new technological requirements for lead-acid battery.Whatever the technology, hard sulfation is one of the most important failure that affects the negative plate. Hard sulfation is an irreversible chemical process that leads to the formation of large non-conductive lead sulphate ($PbSO_4$) crystals, which leads to the passivation for electrochemical activity of negative plate. As a result, hard sulfation becomes the most discussed failure mode in lead–acid batteries, because it affects cyclability, charge acceptance, and capacity. [1].

To overcome this inconvenience, additives are added to prevent the deposition of a continuous lead sulfate passivating layer in the negative plate during battery discharge [2]. These additives are commonly called "Expander"and become essential for the manufacture of negative plate of lead-acid batteries, because without them the battery performance would be significantly impaired [3].

In order to enhance electrical performances of SLI (starting, lighting, and ignition)automotive lead acid battery particularyinitial charge acceptance, we focused on negative active material (NAM) by adding new expander formulation. For more applicability, this studywas done on 12 V commercial batteries, in collaboration with the Moroccan battery manufacturer ELECTRA BATTERIE (Afrique Cables Company).

Three expander formulations were developed by varying black Carbone/barium sulfate ratio. Thereafter, the physicochemical characterizations were carried out in order to evaluate their structure and composition of negatives plates.The electrical tests were carried out at Afrique Cable Company. Several tests with different batteries were made including the effective capacity, the cold cranking amps 'CCA', the electric voltage drop after 10 seconds of discharge and initial charge acceptance test, and all this according to the standards.

[1] Henry A. Catherino, Fred F. Feres, Francisco Trinidad .Sulfation in lead–acid batteries, Journal of Power Sources 129 (2004) 113–120.
[2] RobabKhayatGhavami, FatemehKameli, Ali Shirojan, Amir Azizi. Effects of surfactants on sulfation of negative active material in lead acid battery under PSOC condition, Journal of Energy Storage 7 (2016) 121– 130.
[3] David P. Boden, Jeff Arias, Frank A. Fleming. The Effect of Organic Expander Materials on the Performance, Life, Surface Area and Crystal Structure of Negative Electrodes in Valve Regulated Cells, Journal of Power Sources 95 (2001) 277–29

Production of Solid Polymer Batteries and All Solid State Batteries

Automated Assembly Station for All-Solid-State Batteries

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The future materials used in All-Solid-State Batteries place high requirements on the cell assembly process. The material properties (e.g. mechanically sensitive and limp electrodes, high reactivity with for example moisture and nitrogen) require an appropriate composition and particle-free ambient process atmosphere, as well as almost stress-free handling. In order to investigate the effect of the aforementioned influences on the electrodes material and the resulting electrochemical performance of the All-Solid-State Batteries, a test rig will be set up. In the experimental setup, the composition of the process atmosphere can be measured and controlled. In addition, the suitability of different handling procedures can be investigated and evaluated in the controlled environment using different measurement techniques.

Influence of rotational speed of a drum collector electrospinning setup on polymer electrolytes

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Solid polymeric electrolytes for lithium ion batteries are currently in the focus of research facilities around the world. Especially the advantages of those electrolytes regarding safety, flexibility and energy density make them attractive for diverse applications. Unfortunately, solid electrolytes suffer from poor ionic conductivities. One approach to solve this challenge is the microscopic structuring of the polyethylene oxide based electrolytes.

In our study, we develop electrospinning methods to achieve such structures. A setup using a rotating cylinder as a collector and nozzles as emitters is used. The rotational speed of the collector is varied between 100 and 500 rpm. It is found, that the morphology of the resulting fibers strongly depend on the collector speed. It is demonstrated that both nonwovens and orientated fibre structure can be generated with the same equipment by modification of the collector speed. The dependency with respect to the surface speed is characterized and quantified by using both optical and scanning electron microscopy.

It is shown that improved alignment of the fibers is a function of those parameters . The ionic conductivity of these structures is investigated using impedance measurements with respect to the usage in solid state cell production.

Influences of process parameters on the conductivity of polymer electrolyte based all-solid-state cathodes

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All-solid-state batteries are seen by many as a promising technology for future battery generations. They are expected to improve the safety, the fast charging properties and the achievable volumetric energy density [1]. Over the last years there has been a lot of research on the development of great solid ionic conductors [2]. In terms of processing of all-solid-state batteries the overall conductivity can be influenced independently of the investigated battery system as it is a function of the manufactured structure [3,4]. It remains a topic of current research to build all solid state batteries using scalable process technologies and to achieve the requirements of sufficient ionic and electronic conductivity.

The chemical processes within a battery cell are limited by the slowest electrical transport mechanism. The structure directly influences the electrochemical properties like ionic and electronic conductivity, as well as residual porosity. Therefore, it is important to investigate structural changes within the process. A solvent free process chain is developed for manufacturing of polymer electrolyte based all-solid-state cathodes. In a first step, a granulation is performed to homogeneously distribute the cathode components and adjust the carbon agglomerate size. The impact of granulation intensity and granulation time on the structure and the resulting electrical conductivity is investigated. Next, the granule is processed to a dense compound by extrusion. A following calendering step is applied to compress the extrudates to the targeted layer thickness. The calendering degree, temperature and speed is varied and the resulting structural changes are analyzed. Afterwards, the cathode is laminated on a current collector and the effect of different lamination temperatures and current collector surface coatings on the boundary resistance and adhesive strength will be shown. Lastly, the electrochemical performance of the manufactured cells is characterized.

References

[1] Kato Y, Hori S, Saito T, Suzuki K, Hirayama M, Mitsui A, Yonemura M, Iba H and Kanno R 2016 Nat. Energy 1 16030
[2] Review on solid electrolytes for all-solid-state lithium-ion batteries, Masashi Kotobuki Shufeng Song, Man OnLai LiLu, 2018 Journal of Power Sources 389 198-213
[3] Froboese L, Titscher P, Westphal B, Haselrieder W and Kwade A 2017 Materials characterization 133 102–11
[4] Kwade A et al 2018 Nature Energy 3, 290-300

Development of a scalable manufacturing process for sulfide-based solid-state batteries

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All solid-state lithium-ion batteries (ASSBs) have drawn a lot of research focuses towards its application on electric vehicles. Substituting liquid electrolyte for a solid superionic conductor, the volumetric energy density of lithium-ion batteries can be increased and the safety concern is reduced. Moreover, it has been reported that ASSBs could provide superior power density compared to conventional lithium-ion batteries [1,2]. Among the candidates of solid electrolytes, sulfide-based glass-ceramics reach sufficiently high ionic conductivities up to 10-3 S/cm [2,3]. Most research on ASSBs has been conducted by pressing powder into pellet form [3,4]. However, this process is difficult to realize in large-scale production.
Therefore, we are developing a manufacturing process for cathodes and separators including dispersing, coating, drying and compacting steps. At first, we are mixing pulverized raw materials and solvent using a dissolver to get a homogenous suspension. After that, the slurry is coated on a current collector by a film applicator, whose heated plate enables immediate drying at different temperatures. Following, cathode and separator sheets are compacted for increasing the energy density and decreasing the porosity by a laboratory press. Subsequently, the components were characterized in terms of their mechanical, structural and electrochemical properties. The process parameters were optimized for high conductivities, capacities and cycling stability.

References:

[1] Kato et. al, Nature Energy 2016,1, 16030
[2] W. G. Zeier, J. Janek, Nat. Energy 2016, 1, 16141
[3] Zhang et. al, ACS Appl. Mater. Interfaces 2017, 9 (21), 17835–17845
[4] K. Takada, Acta Mater. 2013, 61, 759

Syntheses of nickel-rich active materials and sulfide solid electrolytes for ASSB cathodes

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In recent years, All-Solid-State-Batteries (ASSB) have gained importance for energy storage systems, because of their potentially superior characteristics compared to conventional lithium ion batteries. In order to produce cells with competitive properties, such as high energy density as well as high thermal, and mechanical stability, the choice of materials at the beginning of the value-added chain of a battery is a main key. Thus, the focus of our work is to evaluate and establish new process strategies to produce and pre-treat active materials as well as solid electrolytes.
For example, producing nickel-rich active materials for ASSB systems is a current topic in research and industry. We have the goal to establish and optimize a new precipitation process to synthesize such active materials. Using a stirred media mill with suitable setting parameters for optimized flow characteristics and residence times should result in an efficient process, which can easily be scaled up for industrial application. Furthermore, processes will be developed to modify the surface of active materials to especially enhance their conductivity and to increase the chemical stability against solid electrolytes.
Sulfides have attracted broad interest as solid electrolytes due to their high Li+ conductivity and compliant mechanical properties. Their synthesis can be performed by high energy ball milling. However, the reaction mechanisms are still not well understood. Therefore, it is highly important to acquire extensive knowledge of the process-product interactions.
Our main aim is the upscaling of the mechanochemical syntheses of sulfidic electrolytes while optimizing the process by systematic variation of parameters, such as grinding media ratio, grinding media size or temperature. The starting point for this development is the synthesis of sulfidic glasses in planetary ball mills, which is currently taking up to 25 hours for complete amorphization. Based on the obtained insights, the synthesis procedure will be adapted for the upscaling in suitable mill types such as vibrating mill and stirred media mill.
The combined work on the scale-up of active material and solid electrolytes should enable high performance and low cost cathodes and thus facilitate the industrial production of ASSB.

Coatable, fully amorphous PEG based polymer electrolyte for lithium ion battery with adapted adhesion properties for graphite electrodes

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High molecular weight polyethylene glycol (PEG or PEO) is used as standard material for today's lithium ion batteries. The inherently good lithium ion conductivity of the PEG is based on an ion hopping mechanism of the repetitive units of ethylene oxide. Disadvantages of the PEG solid electrolyte are a relatively high crystalline proportion of the polymer which on one hand reduces the ionic conductivities, and on the other hand has a melting point between 50-60°C. At this higher temperature range the PEG solid electrolyte experiences an increased volume work in the battery which negatively affects the interphases to the electrodes by partial detachment. In this study we investigated a more competent blending system that allows commercially available short-chain PEG acrylates or methacrylates with dissolved lithium conductive salts (LiTriflat) to be completely armorphically deposited on a graphite electrode by a UV light coating procedure. The anode with solid electrolyte coating produced in this way was technically measured in a cell structure with a NMC electrode as cathode by means of impedance spectroscopy. In order to measure the best ionic conductivities, it was necessary to adapt the blending system with adhesion-enhancing acrylates. For this purpose, an acrylate component SR001 was synthesized in a two-stage reaction and, as an additive in the blend, the concentration was attuned so that the connection to the graphite electrode and the ionic conductivities were ideally adjusted. At room temperature reproducible ionic conductivities between 1.2-1.6 10-5 S/cm were measured. The thermal properties of the solid electrolyte were determined using DSC and show completely armorphic behavior and temperature resistance up to over 200°C. Financial support by the German Federal Ministry of Economic Affairs and Energy is gratefully acknowledged. (Project Batt3D: 03ET6111B)

Towards a solid state nickel / iron battery

Wolfdietrich Meyer & Dario Gomez Vazquez

A not negligible factor in the manufacture of electrical energy storage devices is not only the theoretical, such as practical capacity per volume or kilogram, but the mass supply and associated cost of the corresponding metals that convert electrical energy into chemical storage energy. To avoid competing with lithium ion technology for stationary electronic memories, we are exploring the possibilities of developing a solid state nickel/iron battery to store a battery that can store high currents quickly and safely. In order to suppress the hydrogen evolution reaction (HER), which occurs at the charging voltage as an unwanted side reaction, we are working on a low-water electrolyte system that can provide stoichometric amounts of water only for the desired cell chemistry. We synthesized polymeric polyelectrolyte membranes and processed membranes, which were investigated for their hydroxide ion conductivity by impedance measurements and resistance avoidance experiments. The electrodes were prepared by pressing the metall hydroxides within an conductive foam and a battery setup was investigated in liquid KOH bath.

Recycling & Sustainability

A conceptual framework for sustainability assessment of battery-based propulsion systems in aviation

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The aviation industry is facing significant challenges to achieve its self-imposed goals towards the reduction of environmental impacts and to comply with the global environmental policies that seek to limit the temperature increase, as laid out in the Paris Agreement. Due to the high fuel demand of aircraft during flight operation and the associated emissions, the aviation sector was responsible for 850 million tons of CO2 emissions in 2017, which represents 2.6% of the total global amount.

The development of novel aircraft based on electric propulsion is a key strategy to achieve emission reductions in the aviation sector despite the continuously growing demand for air travel. A potential configuration of the propulsion system is based on an electric propeller with a battery system for energy storage.

While the environmental assessment of batteries has been the focus of many research studies, important socio-economic aspects have been neglected so far. This is rather critical, because positive environmental effects during operation may be accompanied by negative socio-economic effects occurring in the upstream and downstream stages of the life cycle.

As known from the automotive sector, materials for the production of battery-based powertrains require more energy to be produced and are more difficult to recycle compared to conventional powertrains. At the same time, social challenges during the life cycle arise and become increasingly important for customers. For instance, batteries often consist of critical and rare materials that are mined in countries with a high risk of child labor and poor working conditions. It is essential to consider the socio-economic dimension as part of a comprehensive sustainability assessment and to extend the classic environmental sustainability assessment.

Therefore, a methodological framework for the Life Cycle Sustainability Assessment (LCSA) of battery-based propulsion systems in aviation is developed. The concepts of Life Cycle Assessment, Life Cycle Costing, and Social Life Cycle Assessment are used to define a framework, especially for the use of batteries in an electrified propulsion system, which can be used as guidelines for the LCSA in aviation.

Sustainable supply chains for lithium-ion batteries: Integrated assessment of environmental and socio-economic hotspots

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As key components in electric vehicles and stationary energy storage systems, lithium-ion batteries are associated with considerable benefits in their use phase. However, the production of the batteries and their components, as well as the extraction of the raw materials, such as lithium, cobalt, nickel, manganese, and graphite, lead to significant environmental and social impacts. Due to the complexity of the supply chain and the global dispersion of the production processes, the sustainability of lithium-ion batteries is difficult to evaluate. An important challenge is the consideration of regional differences with regard to technology, the environment, markets, and society. Therefore, a quantitative modeling approach that facilitates the sustainability assessment of global supply chains is developed. The novel approach is used to analyze the environmental, economic, and social impacts of lithium-ion batteries from both a global and a regional perspective. The objective of this poster is to give an overview of the assessment results for selected sustainability indicators. In particular, the contributions from individual processes are analyzed, and the influence of alternative supply chain configurations is discussed. Modifications regarding the sourcing of raw materials or the location of cell production have the potential to change the environmental impacts of the battery (e.g., climate change, acidification, eutrophication) by up to 30% in both directions compared to a global average supply chain. For social indicators (e.g., risk of corruption, risk of child labor), the variations are even higher. These results open promising research opportunities to advance the design of sustainable supply chains.

Characterisation of lithium-ion battery stacks in terms of second use applications

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Electromobility becomes more and more popular, resulting in an increasing amount of vehicles with an electric power train. With lithium-ion-batteries as the heart of this power train, their amount increases as well. However, it is assumed that these automotive traction batteries reach their first life end of life (EoL) at a state of health (SoH) of approx. 80 % at the latest. As the batteries are removed without further investigation of their actual performance or ageing progress, the battery most likely has a remaining useful life. This assumption has led to a growing interest in second-use applications recently, for example stationary storage systems. Consequently, the necessity of determining a battery's condition accurately arises. This work aims at meeting the aforementioned necessity with a focus on stack level by developing a methodology that allows identifying battery specific parameters such as the SoH and inner resistance, for example.

Previous research has concentrated on investigations on cell level, while only little effort has been devoted to examining stacks and systems. Regarding these, differences between stacks with homogenously and heterogeneously aged cells need to be considered. Therefore it is unclear, whether examining on cell level is necessary to determine a battery stack's condition or if it is sufficient to examine the stack only. Moreover, the battery's ageing progress highly correlates to the former load profile. For this reason it is either necessary to know about the battery's history or to find characteristic parameters which indicate the future aging behaviour.

With these objectives in mind, testing procedures for characterising lithium-ion cells serve as basis in order to adapt these to measurements on stack level as well: capacity tests and inner resistance tests as well as the electro-chemical impedance spectroscopy. Concerning the latter, it is no proven testing procedure for battery stacks thus far and is therefore another objective of this work.

Lithium-ion-batteries with a nickel manganese cobalt/carbon (NMC/C) chemistry are main subjects of the investigations.

In order to draw conclusions from a stack with well-known history to unknown stacks, the procedure is as follows: at the beginning, cells are cycled based on the load profile in the worldwide harmonised light-duty vehicles test procedure (WLTP). Since this procedure is destined for whole battery systems, the cycle has to be adapted for tests on cell level. More precisely, the procedure is adjusted such that the cell's maximum current and voltage limits are observed.

Afterwards, the cells are characterised by capacity tests and inner resistance tests and then put up to a stack. Determining the stack's characteristics in correlation to its cells is the aim. For this reason, the capacity and inner resistance as well as the voltage characteristics dependent on the state of charge of the stack are determined on the one hand. On the other hand, the cells' voltage and current characteristics are tracked as well.

Additionally, battery stacks at their first life EoL with unknown history are tested similary: after a first capacity test and determination of the inner resistance, the stacks are cycled and continuously characterised in order to reveal their aging trend. Eventually, the findings on both types of battery stacks (i.e. with unknown history or known history) are compared with focus on the correlation between cell parameters and stack parameters. Furthermore, connections between parameters at the begin of life, the aging trend and the end of life are examined.

Recycling 4.0 – Mapping digitalisation onto the Circular Economy for Li-Ion Batteries

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The manufacturing of electric vehicles creates high environmental impacts and battery production is the major contributor. Adequate end of life treatment of batteries may mitigate the environmental impacts by providing alternative material sources and by substituting impactful primary material production. Industrial digitalisation promises to deliver effective solutions for improving the recycling sector – even for complex cases such as for Li-Ion batteries, which show a large variety of cell chemistries,-formats and sizes and no prolific standards as of yet. The reason is that Li-Ion batteries are comparatively new products as the transformation of the mobility sector towards electric drivetrains has started just recently within the last decade. Up until now, it is uncertain which potentials and challenges result from combining digitalisation approaches with the Circular Economy (CE) and thus, from transferring Industry 4.0 to recycling operations. The present poster identifies digitalisation technologies and solutions, which support CE and maps them on recycling and remanufacturing operations.

The mapping is demonstrated for different recycling process chains for Li-Ion batteries to evaluate the individual digitalisation potential. Through the comparison of different recycling process chains, challenges and strengths regarding digitalisation are identified. This may be used for the engineering of future, large scale recycling or retro-production systems for automotive Li-Ion batteries.

ProZell
Kompetenzcluster
zur Batteriezellproduktion

ProZell - Competence cluster for battery cell production – Influences of production steps and parameters on cell performance and quality Challenges and goals

In the Competence Cluster for Battery Cell Production (ProZell), German research institutions work together to strengthen the national battery cell production. The aim of the research cluster is to build the scientific base for the establishment and sustainable further development of internationally leading battery cell production in Germany. The economic efficiency of cell production is highly relevant in this context. The focus and overriding goal of the competence cluster is therefore to increase cell performance, especially energy density, while simultaneously reducing the energy-related cell price (€/kWh).
Due to the complex and interdisciplinary value chain, a targeted and structured combination of national competencies in the field of battery cell production has been achieved. The identification of influencing variables that cause relevant changes in intermediate product properties as well as cell performance, quality and costs is the main focus of the cluster research.
The joint development of understanding along the entire production process is goal-oriented and valuable for this purpose. The cross-linking of the specific knowledge, the special equipment and the competence of the various research institutions in joint projects is the central concept of the cluster. An accompanying project strengthens cooperation and networking within the entire cluster and ensures a structured bundling of knowledge in a results database. In addition, an advisory committee with representatives from industry and science, which accompanies the cluster projects throughout the entire project duration, ensures that the cluster is united with industry.
Contents and main areas of work The continuous production of battery suspensions by extrusion, in addition to increasing the energy density through the targeted structuring of high-capacity electrodes and the use of silicon is a major focus in the field of electrode production. The simulative description of the dispersion process at various levels of detail and the use of innovative technologies for solventfree electrode production is also promoted in the cluster in order to implement optimized process and production routes. In addition, interactions between process control and product properties are investigated in detail, especially for calendaring and post-drying of electrodes.
Within cell production, special attention is paid to the optimization of filling and wetting processes, taking into account all essential cell components. The energetic optimization of cell formation is investigated together with the upstream process steps, so that both cause-effect relationships and causes of energy loss can be identified in the process. The investigations regarding cell stack formation focus above all on the special requirements of high-energy electrodes. Cross-process projects in the cluster develop innovative quality assurance concepts to reduce fluctuations and reject rates and optimize the interlinked production processes with regard to an appropriate definition of production tolerances. A results database brings together the key findings of the project work in a transparent manner.
Application, use of results and contribution to energy storage The properties of electric vehicles and systems for the electrochemical storage of energy as well as their respective customer benefits correlate directly with the properties of the battery cells used. A better understanding of influencing variables along the entire process chain, including the production environment, is therefore essential. The establishment of an economical and sustainable battery cell production is the central milestone on the way to establishing Germany as a leading market and provider of electro-mobility. The fundamental challenge for competitive battery cell production is to increase cell performance while simultaneously reducing the energy-related cell price (in € per kWh).
The knowledge gained in the competence cluster should form the essential basis for the development of economically producible battery cells, i.e. battery cells with a significantly improved performance-cost ratio. The results provide a scientific basis for achieving and continuously expanding the sustainable, international technology and cost leadership of all German industries involved in the value chain of cell production.

The 12 partners of the ProZell research cluster include universities and research institutions: TU Braunschweig, RWTH Aachen, TU Dresden, Ulm University, TU Munich, Landshut University of Applied Sciences, Karlsruhe Institute of Technology, TU Dortmund, German Aerospace Center, Fraunhofer-Gesellschaft, Center for Solar Energy and Hydrogen Research Baden-Württemberg and Helmholtz Institute Ulm. The ProZell cluster was funded by the Federal Ministry of Education and Science (BMBF) with more than 16 million euros in the first three years of Phase.
The successful ProZell concept, which serves as a model for the establishment of further competence clusters by the BMBF, has been continued in a second funding phase since 1 October 2019. In addition to the individual production steps of the battery cells, the cost and environmental assessment, the development of a digital twin of the battery cell and the recycling of battery cells will form further focal points. To this end, new partners and locations will be added and a significantly higher funding volume will be available.

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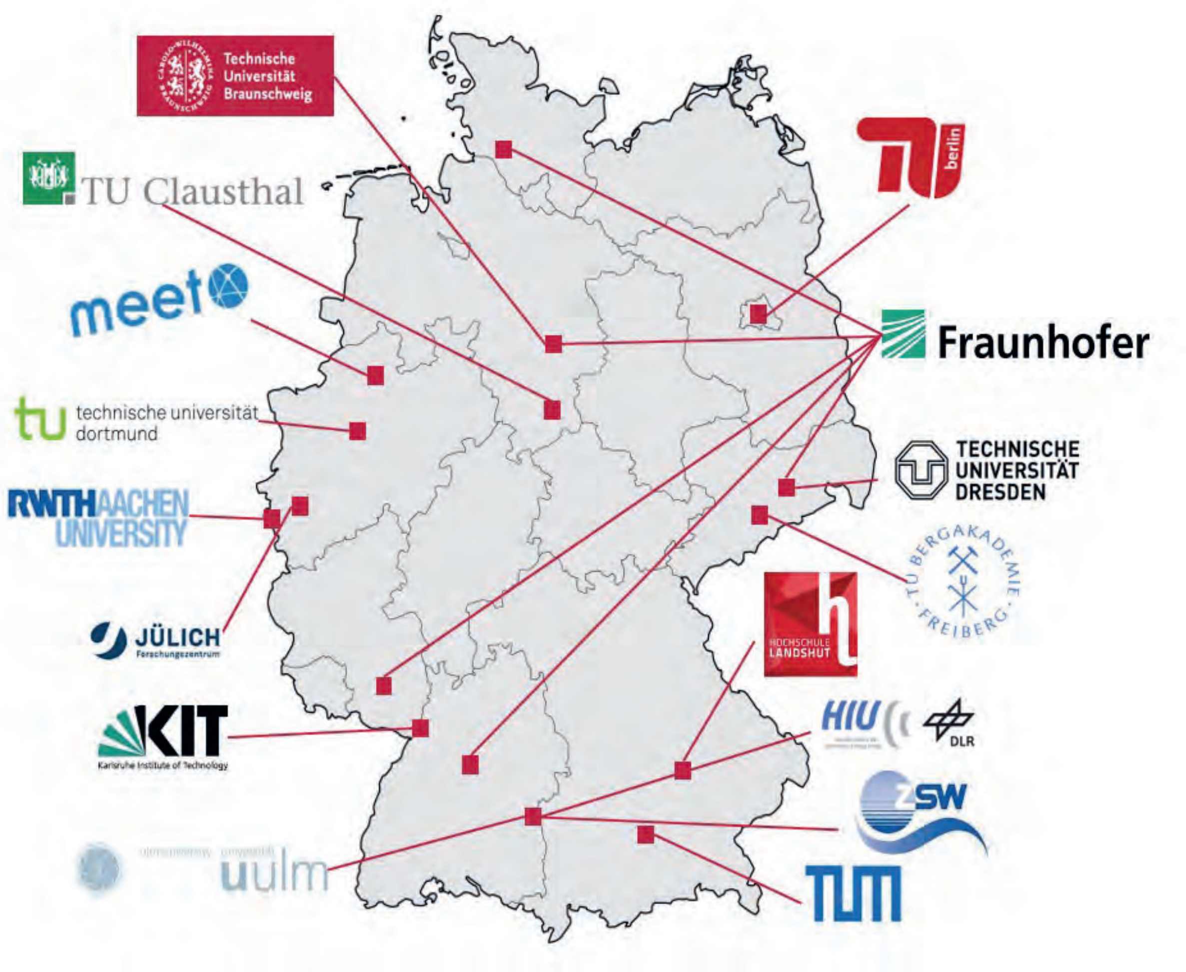

PRESENTATION ABSTRACTS

Electrode Production

Production Process for overcoming the limited rate capability of ultra-thick electrodes for LIB

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For the application of Lithium-ion batteries in products with growing market like electric vehicles and portable devices, important requirements are a high energy density and low production costs of the cells. Both of them can be fulfilled by making the electrodes ultra-thick [1]. However, ultra-thick electrodes are compromised by limited rate capability [2], low adhesion and crack formation [3].
In this contribution, processes in the manufacture of Li-ion electrodes are shown that address these drawbacks and lead to improved properties of ultra-thick electrodes. Occuring challenges of the processes and corresponding counter measures are explained via the case of ultra-thick NCM 622 cathodes (50 mg/cm2) produced in pilot scale, yielding a triple areal capacity compared to state of the art cathodes.
The large impact of the dispersion procedure on the structure and electrochemical properties of ultra-thick electrodes [4] is elucidated in depth. Additionally, simultaneous two-layer slot die coating of suspensions with different binder content is shown to be a process, in which the usually unwanted binder migration [5] is systematically utilized to implement a more homogeneous vertical binder distribution in the electrode than commonly reached within the same drying time. By each of the two improved processes, the mechanical properties and processability as well as rate capability of the electrodes are improved. For example, two-layer slot die coating yielded 30 % higher capacity of an ultra-thick cathode at 1 C compared to single layer slot die coating. Further examples include the drying procedure and the targeted adjustment of pore size distribution. Some of the improved processes are also advantageous for thinner electrodes, others exploit their potential especially in ultra-thick electrodes and at higher c-rates.

References

[1] H. Zheng et al.; Electrochim. Acta 71 (2012), 258–265
[2] M. Singh et al.; J. Electrochem. Soc. 162 (2015), A1196–A1201
[3] Z. Du et al.; J. Power Sources. 354 (2017), 200–206
[4] L. S. Kremer et al., Energy Technol. (2019), DOI 10.1002/ente.201900167
[5] S. Jaiser et al.; J. Power Sources 318 (2016), 210- 219

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Coating, Drying and Solvent Recovery – Material Throughput and Effects on Pilot and Mass Production of Battery Electrodes

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Dürr Megtec

Coating, drying and recovery of solvent technologies and special requirements in pilot and mass production of battery electrodes are discussed in this presentation.
Especially the mass throughput of different machine sizes impact greatly the cost of operation and are surprising when building up a pilot facility.
This includes material cost and energy consumption in the electrode production and NMP recovery.

Challenges in the prelithiation of electrodes within lithium ion cell production

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Nowadays, lithium-ion batteries are the technology of choice for many applications in the field of consumer electronics and electric mobility. In order to meet the sophisticated requirements for electric vehicles, the lithium-ion technology has many challenges to overcome related to energy density, lifetime and overall costs. New materials, electrode designs and production processes for lithium-ion cells are currently subject to scientific investigations and represent a significant factor to increase storage capacity and energy density as well as cycle life. One reason why lithium-ion cells do not reach their maximum theoretical capacity is active lithium loss (ALL). ALL occurs mainly due to formation of solid electrolyte interface (SEI) during the first cycle, which permanently reduces the available energy through the consumption of active lithium from the cell. This effect can be compensated by adding additional lithium to the cell during production. Prelithiation is therefore a method of increasing relevance for improving the energy density and cycle life of lithium-ion batteries.
To date, various prelithiation techniques have been evaluated, including electrochemical and chemical prelithiation, prelithiation with additives or prelithiation by direct contact with lithium metal. However, none of these techniques could be developed into an industrial process that allows upscaling and integration into lithium-ion cell production. This presentation will address challenges faced by various prelithiation methods in their development towards a series-capable process and its integration into cell production. Different prelithiation methods are analyzed and evaluated and the requirements for a s eries-capable process are derived.

High Energy Li-Ion Electrodes prepared via a Solventless Melt Process

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Hutchinson Research and Innovation Center

Electrodes of Li-ion batteries are typically prepared by coating a solution containing the active materials, conducting additive and a PVDF binder dispersed in N-methyl pyrrolidone (NMP) solutions. NMP is toxic, PVDF is expensive and these dispersions typically exhibit sedimentation issues. Therefore, the use of a solventless inexpensive extrusion process for the manufacturing of Li-ion electrodes is highly desirable.
High areal density and high energy Li-ion electrodes were prepared using a high throughput green, solventless melt process leading to electrodes of controlled porosity.
PVDF-free melt formulations were developed for several conventional Li-ion cathodes, namely LFP, NCA, LCO and NMC and Li-ion anodes, namely graphite, LTO and nanostructures silicon. The formulations were based on commercially available and inexpensive elastomeric or thermoplastic binders, conventional conducting fillers and >90 wt% electrode active materials. A large range of loadings could be achieved, from 4 to 40 mg/cm2 single side. Electrochemical performances in half cells (coin cells) and multi-layer pouch cells will be presented. High capacity and cyclability for high loadings of NCA and NMC cathodes and graphite anodes were demonstrated. Areal capacities over 5 mAh/cm2 in coin cells were obtained at a C/5 rate. Cycling at high rates, up to 10 C was demonstrated for LFP electrodes.
The extrusion process and its advantages regarding the associated facilities, throughput, dispersion stability and electrode performances will be detailed in the presentation.

Cellulose-based composite electrodes production on a paper machine

Lars Sandberg
BillerudKorsnäs AB

We are developing electrodes from cellulose fibers coated with a conducting polymer to form a composite material. These composites are redox active with a capacity of roughly 40 mAh/g, and have the possibility to be used in symmetric setup for metal-free energy storage to power electronics with low power consumption (suitable for a disposable packaging) or to be coupled with a number of other battery electrodes for higher energy densities (to reduce the environmental footprint of the batteries).
The first production has been carried out on a pilot paper machine. Confirming run-ability on a paper machine is an important milestone towards the production of the cellulose-based composite electrodes.
Several applications are possible with this electrode material. One is within Internet of Packaging, that is, digitization of packaging. Intelligent and active packaging provides both sustainable solutions that create and protect products, and offers new experiences for consumers. Another application is large-scale and cost-effective energy storage in the field of Smart Grids.

Continuous Suspension Production: Influencing electrode properties via extrusion process design

Matthias Haarmann, E. Wiekmann, W. Haselrieder und A.Kwade
TU Braunschweig | Institute for Particle Technolgy (iPAT)

Dispersing and drying processes have a large impact on production costs and electrode performance of lithium-ion batteries. Furthermore, batch dispersion processes are limited according throughput and batch related quality variations. Therefore, continuous production of battery suspensions, for example in a twin screw extruder, is an interesting field of research.
A major advantage of extrusion processing evokes by the high solids contents, easy scalability and minor limitation in viscosity. This in turn leads to an overall more efficient electrode production because drying time and drying energy are reduced. On top of that, dispersing of small amounts of conductive additives like carbon black in high amounts of active material are challenging. For the production of cathode (NCM 622) slurries with industry relevant high active material content, process parameters such as screw speed, solids content and the process design are investigated. Slurry characterization is done by rheological analyses and determination of carbon black particle size. Moreover, produced electrodes are characterized and by tensile strength, electrical conductivity, mercury porosity and electrochemical performance. The results show the influence of process parameters on slurry and electrode properties as well as on the resulting electrochemical properties.

Continuous mixing process for LIB electrode slurries contributes to cost-effective cell manufacturing

Philipp Stoessel
Bühler AG, Grinding & Dispersing, Market Segment Battery Solutions

The present production methods for LIB electrode slurries are largely relying on batch or quasi-continuous processes. However, for the expected LIB market growth, these methods will no longer fulfill the requirements of the industry. Therefore, Bühler has developed a novel process for fully continuous electrode slurry production. The technology is based on twin screw mixing which combines raw material handling (simultaneous short time constant dosing of all liquid and solid components of the recipe), pre-mixing, kneading, fine dispersing and degassing in a single continuous device. This new process provides a very high productivity per mixing line (up to 2'500 L/h), eliminates batch-to-batch variation and ensures high slurry yield. Furthermore, the operating costs (e.g. labor, energy consumption) can be significantly reduced in comparison to the conventional batch mixing in planetary mixers.
In this presentation, we will elaborate on the processing of binder/thickener materials in the Bühler continuous mixing process. Two approaches are commonly followed: (1) batch-wise dissolution of the binder/thickener in the appropriate solvent and feeding of the binder solution into the twin-screw mixer ("wet process"); (2) direct dosing of the polymer powder into the mixer ("dry process"), which clearly simplifies the LIB slurry mixing. We will discuss both methods in depth and present various analytical findings such as slurry rheology, high-resolution SEM images of electrodes and electrochemical properties of half-cells.

Advantages and Limitations of Intermittent Coating

Ralf Diehm
Karlsruhe Institute of Technology (KIT), Institute of Thermal Process Engineering (TVT) - Thin Film Technology (TFT)

Lithium-ion batteries are one of the most important technologies for energy storage in electric mobility. Limiting factors are the high costs of the energy storage systems, especially the costs of the battery cells. One way of reducing the costs of lithium-ion battery-cells is to increase the manufacturing process throughput. To gain advantages in cell stacking and energy density, in-termittent coating of the electrodes is often used in industry but limits the production speed.
In this work, we investigate the mechanisms of intermittent slot die coating of non-Newtonian battery slurries. As a non-stationary coating process, intermittent coating has additional limita-tions in the process window and the coating quality. The coating edges are not only influenced by process properties such as coating speed, valve speed and slot-die design, but also by materi-al parameters such as solids content and additive composition in the slurry. The application weight and thus the wet film thickness also plays a role in the edge forming process.
The results showed the relation between coating speed, wet film thickness, slurry viscosity to the quality of the starting and stopping edges. The ramping time is identified as one of the most critical parameters for the quality of the starting and stopping edges and therefore the quality at higher web speeds.

Composite electroforming: a novel production method for binder-free and conducting carbon-free battery electrodes with unique properties

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Aalen University, Research Institute for Innovative Surfaces (FINO)

State-of-the-art sulfur electrodes consist of a multicomponent mixture, which contains, in addition to the sulfur active material, electrically conducting carbon particles to improve conductivity and binder material to stabilize the mechanical integrity of the cathode [1,2]. Since 2012, our group is investigating novel binder-free and conducting carbon-free electrode concepts [3,4,5] enabled by the method of composite electroplating.
Here we especially focus on the new method of composite electroforming, which is a combination of two industrially well-established electroplating processes, namely electroforming and composite electroplating.
A broad overview of our activities and latest results on the newly established method of composite electroforming, which has proofed to be a powerful tool for the production of high performance battery components, is given. Results are shown for the active materials sulfur and lithium intercalation compounds like NMC, each incorporated into a nickel metal matrix. The new types of composite electroplated battery cathodes offer, especially due to their highly structured and adjustable surface, various advantages in terms of efficiency, capacity, energy density and cycle stability.
Furthermore, from the perspective of industrialization, technical and economical aspects of a continuous production process are highlighted.

References:
[1] A. Manthiram, Y. Fu, S.-H. Chung, C. Zu, Y.-S. Su,Chem. Rev. 2014, 114, 11751-11787.
[2] H.-J. Peng, J.-Q. Huang, X.-B. Cheng, Q. Zhang, Adv. Energy Mater. 2017, 7, 1700260.
[3] T. Sörgel, S. Meinhard, Ş. Sörgel; "Folienverbundmaterial", EP 3114721 B1.
[4] C. Erhardt, Ş. Sörgel, S. Meinhard, T. Sörgel, J. Power Sources 2015, 296, 70-77.
[5] Ş. Sörgel, O. Kesten, A. Wengel, T. Sörgel, Energy Storage Mater. 2018, 10, 223-232.

Strategies to improve energy and power density of Li-ion batteries by virtual electrode design

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Technologically, a significant increase in energy density is a declared development goal for lithium-ion batteries. Recent progress in battery research is currently driven by the automotive industry and in order to reach their requirements for next-generation electric vehicles regarding safety, life-time, energy density, and fast charging further progress is inevitable. Additionally, a reduction of material and production costs is needed to improve the price competitiveness.
An attractive strategy to decrease the share of inactive materials is to increase the mass loading of the electrodes [1], [2]. This concept provides a high theoretical capacity and energy density. However, it also shifts the transport limitations of shuttling lithium ions in the electrolyte to lower C-rates and reduces the rate capability and practical capacity of the cell [2], [3]. In order to enable a fast charging of batteries structuring techniques are investigated. A promising concept is the laser perforation of electrodes which creates a hierarchical pore network with macroscopic transport pathways between anode and cathode. In this contribution we will present a study of an improved electrode design concept using laser perforation with the goal to optimize energy and power density of Li-Ion battery electrodes and cells. As a first step, negative and positive electrodes consisting of synthetic graphite and nickel-rich NCM622, respectively, were manufactured in a continuous process. After coating and drying, the electrodes were calendered and finally perforated with a dot-shaped pattern using a focused laser beam. In a next step reconstructions of the electrodes were created with the help of synchrotron tomography and a 3D stochastic microstructure generator [4], [5]. Furthermore, stochastic structure models were developed on the basis of the tomography data, which make it possible to investigate different structural scenarios. The resulting microstructures serve as input to electrochemical simulations within our software BEST [6] and good qualitative agreement between the simulations and experimental data can be reported.
Our simulations confirm the beneficial effects which are found in the experiments. The impact of several design parameters including hole diameter, distance, and shape were investigated in order to find optimal conditions. Our study shows that this simulation-based approach is a powerful and efficient tool for the analysis and design of structured electrodes for Li-ion batteries.

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References:

[1] B. Delattre, R. Amin, J. Sander, J. De Coninck, A. P. Tomsia, and Y. Chiang, "Impact of Pore Tortuosity on Electrode Kinetics in Lithium Battery Electrodes: Study in Directionally Freeze-Cast LiNi0.8Co0.15Al0.05O2 (NCA)," J. Electrochem. Soc., vol. 165, no. 2, pp. A388–A395, 2018.
[2] M. Singh, J. Kaiser, and H. Hahn, "Thick Electrodes for High Energy Lithium Ion Batteries," J. Electrochem. Soc., vol. 162, no. 7, pp. A1196–A1201, 2015.
[3] T. Danner, M. Singh, S. Hein, J. Kaiser, H. Hahn, and A. Latz, "Thick electrodes for Li-ion batteries: A model based analysis," J. Power Sources, vol. 334, pp. 191–201, 2016.
[4] D. Westhoff, J. Feinauer, K. Kuchler, T. Mitsch, I. Manke, S. Hein, A. Latz, and V. Schmidt, "Parametric stochastic 3D model for the microstructure of anodes in lithium-ion power cells," Comput. Mater. Sci., vol. 126, pp. 453–467, 2017.
[5] S. Hein, J. Feinauer, D. Westhoff, I. Manke, V. Schmidt, and A. Latz, "Stochastic microstructure modeling and electrochemical simulation of lithium-ion cell anodes in 3D," J. Power Sources, vol. 336, pp. 161–171, 2016.
[6] A. Latz and J. Zausch, "Multiscale modeling of lithium ion batteries: thermal aspects," Beilstein J. Nanotechnol., vol. 6, pp. 987–1007, 2015.

Batch and continuous production of Electrode Masses in the Laboratory and GWh Production Scale

Stefan Gerl
Maschinenfabrik Gustav Eirich GmbH & Co. KG

Due to increasingly cheaper batteries, but also due to political requirements such as CO2 regulations in Europe or mandatory quotas for car manufacturers active in China, more and more cell factories in the GWh range are being planned and built worldwide.
The preparation of coating masses for the electrodes is at the very beginning of the manufacturing chain for cells and has a significant influence on the quality but also on the costs. In addition to high flexibility for changing recipes, ever higher throughput rates with slurries are required. The classical preparation processes with dissolvers and Planetery Despa mixers, which have been established over decades, are increasingly reaching their performance limits today due to their long preparation times and limitations in size. For GWh factories, sometimes dozens of machines have to be operated in parallel, supplied with raw materials and the finished coating mass removed. The logistics required for the distribution and collection of the materials alone, as well as the cleaning of these numerous machines and plant equipment, represent a major challenge. Established but also new cell manufacturers are therefore looking for alternative, more cost-effective processing methods. With its MixSolver® and EvacMix® vacuum mixer, Eirich offers an innovative processing solution allowing slurry preparation in minutes instead hours that has already found its way into production in cell factories in the GWh range.
As the market is increasingly demanding continuous mixing systems, Eirich has actually developed a suitable solution in the form of the "Eirich Conti Feeder Process", which combines the advantages of batch processing with use of the very short preparation times with the continuous supply of coaters. In addition to high-precision metering of all raw material components, traceability of individual batches, maximum flexibility with regard to adaptation of operating parameters to optimise electrode properties, in-line rheometry by use of the mixing tool for quality assurance, the coater is supplied fully continuous with coating slurry of the highest quality and reproducibility.
The lecture presents the functionality of the Eirich MixSolver®, shows up the excellent scale-up capability, as well as different system concepts and machine designs for batch and continuous operation, based on different 2 GWh customer projects from existing and under erection production systems.

Cell Assembly

High Power Battery Cells

Andreas Würsig
Fraunhofer ISIT

Vehicles with internal combustion engines are usually equipped with a lead-acid accumulator as an electrical energy storage device. It is not uncommon for two batteries to be used in larger upmarket cars. The requirements on the storage device, namely starter operation and supply of the on-board electronics, are very different. In starter operation, very high currents must be provided at short notice, even at very low temperatures. To operate the on-board electronics, the battery is continuously discharged over a longer period of time. To meet both requirements in vehicles with a single battery, the battery must be significantly oversized, as the starter function is essential. A further reason for the oversizing of the lead accumulators used today is that the service life of the lead accumulator is strongly dependent on the discharge depth. The higher the discharge depth under operating conditions, the shorter the battery life. An oversized battery reduces the depth of discharge and prolongs the battery life. In order to reduce the size and weight of the battery for starter operation, Fraunhofer ISIT has developed an extremely robust high-performance battery. The aim was to select suitable materials and develop a manufacturing process that guarantees a long service life and safety and at the same time offers the potential for very good resilience. Electrochemical energy storage devices with lithium titanate as anode material and lithium manganese oxide as cathode material meet these requirements. A separator developed by Fraunhofer ISIT was also used for the high-performance cells. The result was a 3.3 Ah battery cell, which can be discharged over a short period of time with over 200 A. The Fraunhofer ISIT technology thus enables a discharge of up to 60 C and the cells can be charged up to 20 C. Charging is possible below-10°C. These parameters qualify the cells for numerous applications where both very high current loads and long-term energy supply are required. In addition to the starter batteries, these include cells for a 48 V on-board power supply, but also for aviation and shipbuilding.

Influences of increasing coating thicknesses and calendering degrees on single sheet stack formation

Hannes W. Weinmann
Karlsruhe Insitut of Technology

Due to increasing energy and power densities, new fields of application for lithium-ion battery cell technology are constantly emerging. However, the energy and power densities that can be achieved on a laboratory scale are often limited by the industrially available production equipment.
The growing demand, especially for high-energy cells, also reveals a deficit in production technology. The systems currently available on the market are often unable to process corresponding materials, which increasingly poses challenges for cell manufacturers. Unfortunately, many products that can be manufactured on a laboratory scale currently fail due to their manufacturability on an industrial scale.
Within the HighEnergy project, the wbk- Institute of Production Science has dealt with the processability of thick-film electrodes and is also conducting research with respect to the influence of increasing degrees of calendering on the subsequent process steps, especially with regard to the formation of single sheet stacks.
The aim of this presentation is therefore to give an overview on influences of increasing coating thicknesses and calendering degrees on the stacking process and to demonstrate various process interactions. In particular, the material guidance and alignment, the separation and the positioning of the individual sheets on a cell stack will be examined more closely. Different requirements which the materials place on the production process will also be examined, e.g. how different web tensions depending on the calendaring degree lead to different levels of dimensional accuracy in single sheet cutting. Finally, it will be shown how these versatile findings can be integrated and how they lead to a process model. This model forms the basis for a statement about the processability of novel or changing materials.

Customizing of Lithium-Ion Cells – From First Prototypes to Flexible Series Production

Jan Diekmann
CustomCells

The progressive increase in energy density and the associated decline of the costs per kWh leads to an increase in the useful application possibilities of lithium ion cells. In addition to the requirements for available energy and currents, the demands with regard to temperatures and, in particular, installation space are also increasing. In addition to that, the cell numbers for many applications are not in the mass market range, but are still required in high quality and recurrently.
To tailor the cells to the corresponding applications all components of the cells are adapted from active materials for anode and cathode to the tab design. The shape of the cells also plays an important role.
In addition to these adaptations and their influence on cell performance, an approach for the realization of a flexible automated serial cell production for small and medium quantities is presented. For the design of automatically producible cell designs, not only the shape is decisive, but also the use of different electrochemically active materials.

High throughput joining process within productivity increased assembly of electrode-separator-composites for lithium-ion-batteries

Solmaz Sezer
TU Berlin

Lithium-ion batteries' production trend goes to large scale cell formats, which have a limited productivity due to their demanded handling tasks. These handling tasks were avoided in conventional production processes through utilization of pre-stacked laminated electrode-separator-composites to increase the productivity through easier handling of rigid intermediate products. This approach requires an additional pre lamination process and an interconnection to the main stacking process. A direct interconnection between the lamination and the main stacking process is not possible due to limited throughput of conventional lamination machines. To avoid time-consuming sequential lamination tasks, a novel process featuring a continuous separator feeding-speed and a high-speed synchronous joining by gluing of discrete electrodes has been developed, hereby enabling for a significant decrease of cycle-times in electrode-separator-composite assembly and thus reducing manufacturing costs. A suitable adhesive and application device have been identified for the high throughput joining process. The feasibility of this procedure has been proven through initial pre-validation using a developed test bench. By using a fast-setting and highly viscous adhesive, the footprint of the developed joining device can be reduced significantly compared to state-of-the-art laminating apparatus.

Scaling up new materials to mass cell production – challenges, experience and process solutions

Stefan Rößler
ZSW - Zentrum für Sonnenenergie- und Wasserstoff-Forschung

Since established in 2014, the Research Production Line (FPL) at ZSW Ulm provides close-to-production conditions for LIBS in PHEV-1 format in order to support the transfer of laboratory-research results to mass-production. High standards are set regarding quality, automation as well as reproducibility and continuously optimized during the large amount of conducted orders for cell production on the FPL over the last years.
The demand for a higher process yield, innovative materials and higher energy density bring new requirements to the process chain of cell production. In particular when shifting materials from Gen2b (NMC622 / C) to Gen3a (NMC811 / C-Si) we encounter new process routes, requirements and differently structured process-chains.
In this respect, the ZSW will share data of the past scaling-up of these new materials to a mass production level of PHEV1-hardcase cells and discuss the advantages and challenges of the new materials and impacts on established processing technology.

Agile battery production – a novel concept for the manufacturing of battery cells flexible in format and material

Tobias Storz
KIT - wbk Institute of Production Science

Despite the wide range of applications and requirements, standardized cells are used for a lot of products. Standardized cells can't fit all the different needs of the various battery driven products. Our hypothesis states that product manufacturers will demand batteries adapted to their requirements for electric properties and installation space. This will result in a growing variety of battery cells regarding dimensions, format and materials. This trend is already visible in batteries for consumer electronics like smartwatches and smartphones.
To keep up with varying customer requirements, cell manufacturers will need suitable, flexible machinery to avoid large reconfiguration costs for every new type of cell.
As a solution, an agile type of cell production equipment will be developed at KIT. Inspired by modern combustion engine

manufacturing, the production system will consist of redundant robot cells of different types. Every type of robot cell will be responsible for a defined set of production steps and will be equipped with easily exchangeable production modules accordingly. Thus, the robot cell consists of the robot as a central handling, various production modules that execute the production processes and a microenvironment casing that ensures optimal climatic conditions for each production step.
The production modules will be designed to use kinematic, tool-independent processes if possible and quick tool change if necessary to ensure flexibility.
By adding or removing robot cells, the production system is scalable in ramp-up and ramp-down of products. Since a wide range of cells can be manufactured by the flexible equipment, the investment costs can be recovered over multiple product lifecycles.
As a first step towards agile production, wbk is in the process of developing and building a robot cell for battery cell assembly that covers the production steps stacking, contacting and sealing. It will feature a microenvironment and a robot for handling the cell (stack). Being part of the ongoing project "SmartBatteryMaker", two material systems (NMC622/ graphite and LFP/ graphite) and two different cell formats (rectangular and trapezoidal) will be able to be processed in the robot cell without the change of tools.
To achieve "plug & work" properties in the production modules, a service-oriented machine control will be adopted.
After giving a detailed description of the agile production in general, the presentation will give an overview of a planned project to adapt the concept of agile manufacturing to battery production. Furthermore, concepts and the state of the "SmartBatteryMaker" production cell will be presented. "SmartBatteryMaker" is the first step at KIT and wbk towards a flexible, agile production of battery cells.

Battery Production 4.0

Challenges and Answers in Battery Production

Jan Köhler
Siemens AG

Since the 15th of June 2019 the usage of E-Scooters in Germany is officially allowed by law. Maybe you thought about buying one, tried out the rent in one of the major cities or are already a long-time E-Bike driver. It is out of question that these new vehicles will significantly increase the demand of batteries in the whole European market. Nevertheless, the major impact will sure have the electric car. To raise battery production Siemens can offer numerous solutions.
The fast-rising curve of needed batteries obviously leads to several challenges which have to be addressed by the battery production companies. The large consumption of raw materials like cobalt make it crucial to think about a resource optimized battery production. By the use of simulation, we are able to validate recipes, virtually develop the best cell design and optimize the arrangement of the cells within a battery pack. It is needless to say that we have to accelerate the go to market process of those new designs. It is urgent to implement a faster machine development. This can be done by optimizing the mechanical design, generating parameters and configuration data automatically and using libraries for faster engineering. But it is obvious that the high demand of batteries cannot be met by one single pilot line. The upscaling process has to be coordinated in less time. The solution is again simulation leading to an invest reduction and optimized productivity. Siemens also stands for a high grade of production transparency and process stability. With standardized machine models and a coordinated production process a fast machine integration is achieved in less time. The reflection of the simulation on reality together with continuous monitoring and optimization make it finally easy to detect incorrect behavior early on and guarantee a high level of production quality.
Siemens wants to be your partner to meet future challenges in battery production.

IoT adapted to future Battery Factories

Klaus Eberhardt
Exyte Management GmbH

This presentation will explore how to integrate an IoT (Internet of Things) approach, which combines manufacturing, corporate and facility systems, into a coherent platform for an advanced and cost effective Battery Factory.
Battery production 4.0 methodology should be already implemented during the initial design of the factory. Advanced design of high tech factories starts today with a 5D BIM model (Building Information Modeling). This includes not only the 3D design, but adds information on schedule and costs as the 4th and 5th dimension to the design. This allows checking any impacts on design changes on costs and scheduling. Since the BIM architecture contains as-built documentation of the building & facility systems, it can be used during the entire fab's life cycle. In combination with a comprehensive MES (Manufacturing execution System) model, this allows advanced process control, virtual site walks, life cycle analysis as well as financial modeling.
Examples for the design of a generic 6-8 GWh/a Battery factory will be given and the impact on process control and cost savings will be discussed.
Key takeaways:

- Site requirements (area, utility consumption, generic functional layouts) for a cost effective 6-8 GWh/a Battery Production Factory will be given
- Principles of the BIM (Building Information Modeling) adapted to a Battery factory will be shown
- The main challenges from a Factory design point of view discussed
- Benefits for a Battery production 4.0 will be highlighted

Simulating Process-Product Interdependencies in Battery Production Systems

Matthias Thomitzek
TU Braunschweig | Institute of Machine Tools and Production Technology (IWF)

Battery production requires a highly complex manufacturing process chain consisting of different process steps. Both product and process parameters deviate throughout the whole process chain. Shape and scale of those distributions heavily affect subsequent process steps and final battery quality. Multi-level Simulation can be used to predict the impact of different distributions. In the paper, a concept is presented describing how process parameters and its distributions influence structure of intermediate products, which in turn affect battery performance. The former transition is realized through an agent-based process chain model approach while the latter uses an extended pseudo-2-dimensional battery model.

Cost Optimization in Battery Cell Manufactruing through Simulation

Michael Stalder
Bern University of Applied Sciences

In the coming years, the demand for lithium-ion batteries will increase rapidly due to the adoption of the technology for electric vehicles and stationary energy storage devices. Many manufacturers are building capacity to meet this demand. To be competitive, battery cell manufacturers must design and optimize their production lines for cost efficiency.
Cost models for lithium-ion batteries have been studied in detail by various authors [1–5]. In this contribution, such cost calculations were integrated into a simulation model for battery cell production, so that costs for the specific production line design can be analyzed in detail.
A holistic model has been developed to cover product characteristics, aspects of demand and work planning such as product mix and lot size, product and material flow, and machine and process characteristics. To get the complete picture, a worker model, inventories and machine arrangement are included. Further, the product quality flow is modeled such that costs caused by scrapped parts can be analyzed. Cost calculations are integrated into a bottom-up approach at process level. Costs at process level are further divided into two dimensions: Cost types and process/machine states. The model has been

implemented in a discrete event simulation environment.
The simulation model allows to study and optimize both costs and process flow of battery cell production lines jointly. Cost inefficient processes or machines can be identified easily due to the detailed cost breakdown at process level and alternative configurations can be compared.
This is shown by exemplary application of the simulation model to the pilot production line at Bern University of Applied Sciences, as the industrial application on production lines in industry cannot be shown here. This contribution shows the advantages of simulating and optimizing production processes before building a production line.

[1] R. J. Brodd and C. Helou, "Cost comparison of producing high-performance Li-ion batteries in the U.S. and in China," Journal of Power Sources, vol. 231, pp. 293–300, 2013.
[2] R. E. Ciez and J. F. Whitacre, "Comparison between cylindrical and prismatic lithium-ion cell costs using a process based cost model," Journal of Power Sources, vol. 340, pp. 273–281, 2017.
[3] A. Kwade et al., "Current status and challenges for automotive battery production technologies," Nature Energy, vol. 3, no. 4, pp. 290–300, 2018.
[4] P. A. Nelson, K. G. Gallagher, I. Bloom, and D. W. Dees, "Modeling the Performance and Cost of Lithium-Ion Batteries for Electric-Drive Vehicles," Laboratory, Argonne National, 2011.
[5] J.-H. Schünemann, Modell zur Bewertung der Herstellkosten von Lithiumionenbatteriezellen. Göttingen: Sierke-Verlag, 2015.

Smart Manufacturing of battery cells: The concept of Traceability

Soumya Singh
Fraunhofer IPA

Dynamic and intelligent manufacturing is a major factor for Industry 4.0. Increasing efforts have been applied for the past years to optimize state-of-the-art battery manufacturing processes. The concept of smart factory envisions an environment of connected, responsive and adaptive manufacturing. Though the concept has not yet found broad application in industry, it is considered an important outcome of Industry 4.0. A smart factory production facility relies on smart manufacturing. Smart manufacturing is not a recent research, but has in fact been an ongoing process ever since traditional manufacturing came into picture. It is important to note that once implemented, a smart manufacturing process or smart factory cannot be considered as the "end state", given the rapid pace of technological development and varying customer needs. Rather, it represents an ongoing evolution, a continuous journey toward building and maintaining a flexible and self-adaptable manufacturing system. The current battery manufacturing industry cannot be converted to a smart manufacturing process through a "one and done" factory modernization approach.
The initial steps towards smart battery manufacturing have already been undertaken. The concept of adopting and implementing smart manufacturing solutions as a whole can be complicated to implement but starting with small manageable components and then scaling to other operations can help in realizing a smart manufacturing system. One of such steps is 'Traceability'. According to ISO 9000 (2005), traceability is the ability to trace the history, application or location of that which is under consideration. In terms of smart battery manufacturing, traceability can be defined as the ability to access and process the identity and attributes of a physical production unit or batch throughout the process chain. This implies, not only tracing the location of a component, but also includes the possibility to trace:

1. The changing compositions of raw materials
2. Intermediate component properties
3. Production process and environment knowledge
4. Final product properties

This presentation aims to bring traceability under the bigger umbrella of smart manufacturing for battery production.

The application of traceability at the factory level helps in creating a dynamic and intelligent production environment. Due to diverse influencing factors coming from raw materials, production processes and intermediate product properties, intelligent and real-time traceability is currently not a common practice in the battery manufacturing industry. Through this presentation, we want to dive into the following research questions in terms of implementation of traceability in battery production lines:

1. Which traceability method should be used for a certain process step? How can the identified traceability method be applied in the manufacturing process?
2. How can the real time usage of data be made accessible in the battery manufacturing process? (GUI on a machine or cloud based server, app, computer tool)
3. What is the level of statistical confidence that we want to achieve?
4. What is the nature of information and the environment in which data has to be collected?
5. How can a traceability process be made self-adaptable?

Here, we will outline the implementation of a concept for traceability in the smart manufacturing process of battery cells. For developing the concept of traceability for the above mentioned properties, we identify the relevant traceability data for each production step and then process them in order to define the following: state of raw materials, their changing compositions, intermediate component properties, state of production process and environmental knowledge. Additionally, an interactive system is proposed so that the processed results can be visualized in real-time directly in a spatial context and be available to the users in a battery production plant.
The benefit of a traceability system depends mainly on how it is been used and has been designed and not by its mere existence. The benefits of having such a system is availability of real time data for the users as a basis for product quality and process improvement and lastly, self-optimization and self-adaptation of battery manufacturing processes to new conditions. Through the implementation of a traceability concept we aim to build a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time.

Data- and Expert-Driven Analysis of Cause-Effect Relationships in the Production of Lithium-Ion Batteries

Thomas Kornas
BMW Group

The development of lithium-ion batteries (LIBs) is characterized by a unique level of complexity in the manufacturing process. In particular, cause-effect relationships (CERs) between process parameters have a strong influence on the quality of a manufactured cell. First approaches for a discovery of CERs in LIBs were expert-based and thus afflicted with a high degree of uncertainty. Recent publications show a tendency to analyse CERs by means of data-driven approaches.
In the presentation an interdisciplinary data analytics framework will be provided in order to combine expert- and data-driven approaches using human-computer interaction (HCI). Moreover, the framework aims to improve data analysis with the help of expert knowledge and, conversely, sharpen the knowledge of experts through data analysis. Implementation and validation of the framework was conducted using the data of an assembly line for prismatic LIBs at the BMW Group in Munich.

Formation & Aging

Shortening Cell Manufacturing time: A comparative study of 2 methods

Albert Gröbmeyer
Keysight Technologies

Li-Ion cells will gradually discharge even when they are not connected to anything. This loss of stored energy leads to lower-than-desired available capacity. And when cells are assembled into multiple-cell battery packs, differing rates of cell self-discharge leads to cell imbalances within the battery. Typical battery management systems will discharge all the cells to the level of the lowest cell, decreasing effective battery life.
Today, self-discharge is determined by measuring how the open circuit voltage of the cells changes over time. The issue is that it can take weeks for the open circuit voltage to change enough to tell whether the self-discharge of the cells you suspect have unacceptable self-discharge beyond acceptable limits or not.
For the R&D engineer, the extra weeks it takes to complete the self-discharge measurement, adds extra weeks and months to get the design to market. For manufacturing, the extra weeks means that manufacturers are being forced to hold large numbers of cells as work-in-process inventory. This negatively impacts their work-in-process inventory metrics, and it causes them to devote floor space to that inventory ... and pay for that inventory.
In this presentation, Keysight will share a new way of looking at Li-Ion Cell Self-Discharge. This new, revolutionary method eliminates weeks or months of cell storage time required to discern good vs. bad cell self-discharge performance.
Data will be presented to providing direct comparison the traditional open circuit voltage method and the new direct self-discharge method. This data will help the cell designer and the cell user to better understand the pro's and con's of each method. This will give cell manufacturers another means to improve cell quality and yield.

A modeling perspective on the multiscale nature of SEI formation

Fridolin Röder
TU Braunschweig | Institute of Energy and Process Systems Engineering (InES)

The formation of the solid-electrolyte-interface (SEI) during the first charge/discharge cycles of a lithium-ion battery has been extensively investigated in model and experiment in the last decades. These studies enabled a significantly better understanding of the physico-chemical processes. However, the formation protocols are often determined based on experience or trial-and-error experiments rather than a profound model based prediction. This yields an extensive effort for the development of optimal procedures while investigating new materials and electrodes.
The SEI is formed on electrochemically active surfaces due to decomposition of various electrolyte components. The process depends on local conditions and surface properties on molecular scale. Local conditions vary in time and space due to mass and charge transport processes on electrode scale. Because of their interdependency, scales cannot be modeled separately, but require a dynamically coupled multiscale model [1] as applied in the presented work. The presented results illustrate the multiscale nature of SEI formation at a generalized example [2]. Further, they provide explanations for the impact of formation protocol and electrode properties on the molecular structure of the surface film [2,3].
In order to enable a knowledge based optimization of the formation, a close collaboration between physical chemistry on the one hand and electrochemical and process engineering on the other hand is needed. The presented model is shown to be a suitable platform to close the gap and enable a model based prediction and optimization of the SEI formation in future.

[1] F. Röder, R. D. Braatz, U. Krewer, Computers & Chemical Engineering 2018, 121: 722-735
[2] F. Röder, V. Laue, U. Krewer, Batteries & Supercaps 2019, 2, 248 –265
[3] F. Röder, R. D. Braatz, U. Krewer, Journal of The Electrochemical Society 2017, 164(11), E3335-E3344

Efficient and Easy to Scale up CELL FINISHING - ...from Laboratory Cell to Mass Production

Jan-Steffen Lang
PEC

The talk on "Efficient and Easy to Scale-up Cell Finishing" describes a easily and efficiently scalable plant concept for the third production area of lithium-ion battery cells, which starts after electrode production and cell assembly and leads from formation to final aging. The key factors for high-quality cell production and simple scaling from manual laboratory production to semi-automatic pilot production and fully automated series/mass production are considered. The presentation concludes with a summary of what makes a good cell manufacturing solution.

Cell & Pack Housing, Design & Saftey

Safety Assessment and Design Optimization of Battery System using Simulation Techniques

Muhammad Ammad Raza Siddiqui, Shraddha Suhas Kulkarni, Filip Vysoudil, Jan-Aut Deeken, Nico Selle, Prof. Dr.-Ing. Thomas Vietor
TU Braunschweig | Institute of Engineering Design (IK)

An extraordinary safety of the battery system is essential, as the crash of vehicle may lead to the risk of short circuit and subsequent “Thermal Runaway”. The safety of battery can be examined through crash analyses to investigate failure phenomenon as well as to develop the new design concepts in order to avoid the Over-Engineering. The presented method enables an early safety assessment of the prismatic battery cell under several mechanical abuse tests using Finite Element Method (FEM). The simulation models of ball indentation and cylindrical compression tests are developed in order to evaluate the significance of casing in the mechanical integrity of the battery cell. A parametric study involving the variations in wall thickness reveals that the casing can provide significance stiffness to the cell. However, the round at the edges of casing has no effect on overall strength, therefore fillet of sizeable radius may lead to cost effective manufacturing.

Separator finite-element modelling for improving the prediction quality of short circuits within Li-ion cells caused by mechanical loads

Patrick Kolm
VIRTUAL VEHICLE Research Center

To increase the current quality of mechanical simulation results and the virtual short-circuit prediction of battery cells, detailed simulation models for cell components are necessary.
In order to avoid internal short circuits, the electrodes are electrically and spatially separated from each other by using a separator which occupies a key safety-relevant position. The separator failure is assumed to be an important indicator of an internal short circuit. Therefore, the shown research activity focuses on the improvement of mechanical separator modelling. By using a meso-mechanical modelling approach the simulation model can predict mechanically induced short circuits within the cell components based on physical parameters. This model scale describes the material behavior of the battery components on homogenized single layer levels. To generate the input parameters for such material models the cell components go through various mechanical tests (e.g. tensile and compression tests) with different boundary conditions. By direction-dependent testing of dry or wet-produced separators at different speeds it is possible to differentiate between their orthotropic or isotropic mechanical behavior. Depending on the production process and separator type orthotropy can be weaker or stronger.
By varying the separator type or even single parameters (thickness, etc.) in the meso-mechanical cell model, influences on the mechanical behavior – especially the mechanically induced short circuit behavior – can be easily investigated. This model can be used for decision support in early design stages based on the cells field of application and can help to reduce expensive prototyping and testing. The separator model can further be used for component or cell production simulation purposes.

Li-Ionen battery protection and automotive requirements

Volker Buchmann
Hugo Benzing GmbH&Co.KG

We are all familiar with the smart phones and defects of Li-Ionen packs. But what happened if a battery is more than 100 times larger?
Which kind of influences do we have?
The biggest challenge today is the automotive market. Simple guards can't meet the demands of harsh reality.
The requirements due to the environmental are tough.
High temperature ranges, varying air pressure, car under water for longer time, chemical fluids and human liquids, vibration and others have to be predicted for all products which could be effected in the thermal runaway.
The fuel fire test is important to find the right material.
But, what are the right materials?
Therefore, rigorous testing attempts to simulate reality as much as possible.
But, hows knows them?
We as Hugo Benzing are in contact with the premium car manufacturers to develop safety parts to avoid the critical and unplanned explosion of the battery. We can't avoid the thermal runaway, but we are producing venting devices to digas the battery to save the inhabitants in the vehicle or in houses. Additional we are producing pressure compensation devices and combination of both applications in one part. We developed safety parts for low and high voltage batteries and we are producing them.
It is my pleasure to pass on the many years of knowledge to all interested people.

Electrode, Cell and Module Diagnostics during Production

Stochastic 3D modeling of the three-phase microstructure of electrodes in Li-ion batteries by means of synchrotron tomography

Benedikt Prifling
Institute of Stochastics, Ulm University

Due to their outstanding electrochemical properties, as for example a high energy density, lithium-ion batteries are one of the most promising technologies for storing electrical energy. It is well known that the microstructure of the electrodes significantly influences their electrochemical performance. In particular, the amount and spatial distribution of binder and conductive additives has a strong impact on the functionality of the battery. Thus, one of the goals in state-of-the-art battery research is to optimize the manufacturing process of anodes as well as cathodes such that a preferable morphology of the carbon-binder domain (CBD) is obtained. In the present talk, we investigate how adapting the mixing process can change the spatial distribution of binder and conductive additives leading to improved electrochemical properties. For this purpose, we combine stochastic microstructure modelling with spatially-resolved transport simulations. More precisely, we first generate the system of active particles and insert the CBD in such a way that the gradient observed in 2D EDX images is reflected. The combination of this partially data-driven stochastic modeling approach with numerical simulations of electrochemical properties allow us to correlate the 3D microstructure with its functionality. In addition, we present a fully data-driven approach based on k-means clustering for reconstructing the three phases (active material, CBD and pores) from 3D tomographic image data obtained by synchrotron tomography. This allows us to characterize the microstructure of battery electrodes in detail by computing phase-based image characteristics. This valuable information is crucial for a deeper understanding of the microstructure and facilitates the development of an optimized manufacturing process leading to electrodes with preferable electrochemical properties.

In-line measurement of wrinkle formation and strains for NMC 622 cathodes while calendering to derive a suitable counteraction

Benjamin Bold
Karlsruhe Institute of Technology KIT

The characteristics of battery cells, such as energy density, power density and capacity, are determined by the material and influenced and adjusted during the production. Within the electrode production, calendering is an essential process step for adjusting the volumetric energy density. The higher the compaction during calendering, the higher is the achieved energy density, taking into account the limits of the material.
Nevertheless a high compression leads to defect patterns which are wrinkles at the coating edge and wave formation in the coating area. This is the starting point for the presentation and it will be explained, how the wrinkles and the waves in the coating are formed during calendering and why the effects depend on the material.
The main part of the presentation shows how the wrinkles and the wave formation of the electrode are detected and measured in-line while calendering. The wrinkles are described geometrically by their length, width and angle. The wave formation is determined by measuring the strains of the electrode in three-dimensional space. In relation to the parameter description, the self-designed measuring system and its evaluation algorithm based on image processing is explained.
This measuring system is applied in a series of experiments within the BMBF project PErfektZELL for the investigation of NMC 622 cathodes on the industrial calender at the wbk Institute of Production Science at KIT Battery Technical Center. Therefore, the results of a statistical test planning are presented and the dependencies between the wrinkle description and the material strains to the process parameters are shown.
Finally, the results lead to conceptual solutions of effective countermeasures in order to reduce the effects of wrinkles and wave formation.

DEM-based simulation of the mechanical and electrical behavior of lithium-ion battery electrodes

Clara Sangrós
TU Braunschweig | Institute for Particle Technology (iPAT)

Bearing in mind the particulate nature of lithium-ion electrodes, this work proposes a discrete element method (DEM) simulation approach to describe both the behaviour of the particles and the additive-binder matrix. In particular, the calendering manufacturing process was under study via this simulation method, which was able to capture the elasto-plastic behaviour of the electrode by combining both particle and binder stiffness. As a consequence, a comprehensive understanding could be acquired regarding the interaction among all components and how it may affect the structural and mechanical properties of the whole electrode. Additionally, a closer look at the microstructure via this method can assist to comprehend electrode properties such as the electrical conductivity, the ionic conductivity or the mechanical stability. In fact, a post-processing tool was implemented to determine the electrical conductivity based on the DEM-generated structures and their connectivity. Based on a pathfinding algorithm and Kirchhoff´s circuit laws, it was feasible to assess this electrode property assuring a reasonable computational cost.
Within the framework of this research, lithium-ion battery cathodes were simulated via DEM to investigate their behavior during the calendering process and to assess their resulting electrode properties. By combining the numerical approach with experiments, the proposed simulation method can give insight into the overall electrode structural, mechanical and transport properties in view of predicting and designing improved materials.

Analysis and monitoring of the percolating network of battery electrode films during the drying process using eddy current technology.

Dr.-Ing. Sebastian Reuber, Marcel Wild, Arnaud du Baret de Limé, Martin Schulze, Martin Oemus, Prof. Dr.-Ing. Henning Heuer, Dr.-Ing. Mareike Wolter, Prof. Dr. Ing. habil. Alexander Michaelis
Fraunhofer IKTS, Dresden

In the battery cell production, electrode drying after the coating process represents an important production step in which the properties of the electrodes are determined. As the evaporation of the solvent and sedimentation of the solids and binder components progresses, the slurries' particles form over several steps a porous, electrically conductive electrode structure. This formation of the electrode morphology is strongly sensitive to negative influences and must not take place too quickly to prevent e.g. binder migration. As a consequence, the coating speed in the cell production is ultimately determined by the drying speed. In order to guarantee the quality of the electrodes and increase the coating speed in battery production, IKTS is developing an inline sensor system based on eddy current sensors for the monitoring of the drying process.
The eddy current method is based on electromagnetic induction. The body to be tested (here: battery electrode films) is placed in the magnetic field (primary field) of a coil. As a result, eddy currents are induced due to the electrical and magnetic properties of the electrode material. These cause a second magnetic field (secondary field), which counteracts the primary field according to Lenz´s Law. This secondary field is measured with a second coil or another magnetic field sensor. In the example of the battery electrode films, the change in electrode morphology or the formation of electrically conductive paths by means of conductive carbon black leads to an altered eddy current density and thus influences the secondary field to be measured.
Within the framework of test series with a single sensor, strong correlations between the evolving percolating network and the eddy current signals were identified. LTO on an aqueous basis in combination with an aluminum current collector was used for the electrode. With a wet layer thickness of 300 µm, it could be shown that after a certain drying time, a significant impedance change in the electrode film occurs. At this point, the conductive target structure of the particle system is considered mostly formed. Following this significant change, the measured impedance of the secondary coil remains constant, which indicates that the structure of the electrode is completely established. If several sensors were integrated, it would be possible to control and optimally adjust the coating speed for different materials in production.
An area scan of the electrode film can be realized with a sensor array specially developed at the Fraunhofer IKTS. This makes it possible to make a statement about coating thickness, coating homogeneity, coating defects, etc. In this way, the manufacturing process can be specifically optimized in one of the first production steps. In the first test series with different electrode materials, an almost linear behavior between dry film thickness and eddy current signal could be demonstrated.

Production of Solid Polymer Batteries and All Solid State Batteries

Production Technologies for Sulfide-based All Solid State Battery Electrodes

Benjamin Schumm
Fraunhofer IWS

While promising results on lab-scale all solid state battery electrodes are published with increasing number, there are only few publications on production methods for this new battery technology. We succeeded in solving key challenges in processing cathode and anode production for all solid state battery cells, which will be presented in this contribution.
Sulfide-based solid electrolytes offer outstanding ionic conductivity even at room temperatures, when compared to ceramic and polymer solid electrolytes. Moreover, these materials allow shallow contact to active materials upon mechanical pressing due to their relatively high ductility. However, in order to realize an Ah-class cell, powdered raw materials have to be transferred into sheet-type electrodes. Since sulfide based solid electrolytes suffer in terms of ionic conductivity when processed in liquid slurries, new production methods have to be found. We could enable the IWS solvent-free electrode production method in order to obtain high-quality NCM/LPSCl electrode sheets from a scalable powder-to-roll roll process.
By using ultra-low PTFE-binder contents of down to 0.1 wt.% parasitic porosities could be minimized.
On anode side very thin Lithium metal layers are required in order to compensate irreversible lithium losses upon cycling. So far, only costly PVD methods are available for realizing the desired film thicknesses of 1-5 µm The IWS melt deposition process has been applied for metallic lithium electrode deposition. The process is based on lithiophilic interface layers allowing the wetting of molten lithium on the current collector substrate. We succeeded in efficient and scalable roll-to-roll processing of 1-30 µm thin lithium films with process speeds up to 3 m/min.
By combining these two scalable roll-to-roll methods, an all solid state battery pouch cell with practically relevant cell dimensions of 9 cm2 was realized showing stable cycling for >100 cycles.

Laser cutting of novel battery materials for all-solid-sate batteries

Johannes Kriegler
Technical University of Munich - Institute for Machine Tools and Industrial Management

The all-solid-state battery (ASSB) is regarded as a promising technology for sup-plementing the currently dominating lithium-ion battery with liquid electrolyte. However, the existing cell fabrication concepts require upscaling from laboratory to an industry-relevant level. To fulfill the required process rates in ASSB production the shaping of the electrode and electrolyte layers is one of the key production processes. Novel cell concepts additionally require the processing of composite electrodes, e.g. consisting of solid electrolyte and cathode material, which poses challenges for a homogenous cutting process. Therefore, in this work the laser cutting of LATP as solid oxide electrolyte and me-tallic lithium as anode, which comprise one possible novel material systems, is addressed. The challenges of processing these materials by mechanic die cutting processes are highlighted to motivate for the non-contact laser process. To qualify the laser cutting of LATP and metallic lithium the effects of relevant process pa-rameters like laser power, pulse repetition rate and pulse duration were investigat-ed. Conclusions are drawn about their influence on quality characteristics, such as the cutting edge quality. Based on the results, two pulsed laser systems with dif-ferent specifications are compared. Also taking into account the economic effi-ciency, their suitability for an industrial application is assessed. Building on the process characterization for the individual materials, the laser processing of com-posite electrodes and multilayer systems and the challenges occurring are ad-dressed. The presented work confirms the potentials for laser cutting of the mate-rials used in the industrial production of ASSB.

Scalable manufacturing processes for all-solid-state batteries

Peter Michalowski, Sabrina Zellmer
TU Braunschweig | Institute for Particle Technology (iPAT)

All-solid-state batteries (ASSB) are considered as one candidate for so-called post-lithium batteries. Substituting liquid electrolyte for a solid superionic conductor prom-ises increased volumetric energy density, higher rate capability and an improved safety. The different classes of solid electrolytes – oxides, polymers and sulfides – possess advantages and disadvantages regarding e.g. cost, processability and elec-trochemical properties. There are already impressive results with electrolytes show-ing ionic conductivities up to 10-3 S/cm. However, to guarantee efficient operation the single components of the battery must be coordinated with one another. In this regard, the interfaces between the different components of the ASSB are of im-portance and ways to optimize them need to be investigated. Eventually, for eco-nomic feasibility scalable processes for the fabrication of ASSBs have to be devel-oped and studied.
To reach this goal, the examination of the whole value-added chain is essential. This starts with the synthesis of the materials followed by their functionalization. As an example for the latter, we present the coating of cathode active material with thin layers of various oxides by CVD and PVD techniques. Similar methods can be ap-plied to the lithium metal anode, which is an integral part of all ASSBs. Afterwards, the effect of these treatments is evaluated by structural and electrochemical characterization of single components and full cells.
Furthermore, we present scalable manufacturing processes for composite cathodes and separators based on polymer and

sulfide solid electrolytes. This includes the granulation, extrusion and calendaring for polymer-based as well as the dispersing, coating and compaction for sulfide-based films. The resulting components were characterized in terms of their mechanical, structural and electrochemical properties. Consequently, the process parameters could be optimized for high conductivities, capacities and cycling stability.

From Li-ion Batteries to All-Solid-State Batteries: A Life Cycle Comparison

Stefan Blume
Fraunhofer IST

All-solid-state batteries (ASSB) are expected to constitute the next generation of electrochemical energy storages for mobile applications. Their application promises several advantages such as improved safety and energy density. However, a commercial production of ASSB with a significantly better performance than state of the art Li-ion batteries has not been established yet. Due to many uncertainties along the entire product life cycle, technical advantages, economic feasibility as well as environmental benefits of ASSB cannot be guaranteed with today's knowledge. On the way towards large-scale production, various aspects such as resource availability, raw material costs, scalability of production processes or recyclability of used batteries require further investigation. This presentation gives an overview about several challenges to be solved along the life cycle of ASSB, emphasizing differences and similarities to the production of conventional Li-ion batteries.

Recycling & Sustainability

Recycling 4.0 - A System of Systems approach to support Circular Economy

Mark Mennenga
TU Braunschweig | Institute of Machine Tools and Production Technology (IWF)

The all-time high demand for electrochemical energy storages in vehicle applications requires sustainable solutions to ensure future electric mobility. In this regard, Circular Economy (CE) can contribute to mitigating the high environmental consequences from the manufacturing of traction batteries by providing alternative material sources and by substituting impactful primary material production. Although different strategies exist that support circular economy, it is still connected with sub-optimal processes, such as losses in collection systems or recycling process inefficiencies. A promising approach to addressing these inefficiencies, is the digitalization of the CE. Digitalization can help to gather, process and share relevant live cycle data of a used battery system and provide this data along the supply chain to support CE. From a systems perspective, this digitization of CE creates a superior system, which connects different other systems along the supply chain, which are diverse in technology, context, operation, geography, and conceptual frame (e.g. connection of manufacturing and recycling). Typically, these kinds of systems which are themselves consisting of multiple autonomous embedded complex systems are called System of Systems (SoS). An SoS bundles the capabilities and resources of different systems and, because of intelligent collaboration, offers more or different functionality than the sum of the individual systems it consists of. From an engineering perspective, an essential question is how an SoS can be designed in such a way that desired properties are achieved and that chaotic behavior and undesired properties are avoided. This requires a systematic design and control of such higher level SoS so that sustainability is promoted. The presentation will therefore, discuss the foundations and methodological approaches of Systems of Systems Engineering (SoSE) in relation to the digitalization of the CE. Based on the methodological framework of SoSE, a recycling 4.0 approach will be developed and a relation to the case of Li-Ion batteries will be given.

Innovative Production Concepts

Electrospinning as a Key Technology for fast Battery Production Processes

Karl-Heinz Pettinger
University of Applied Sciences Landshut

Within this presentation electrospinning methods are presented as a process step for advanced and fast production of Li Ion cells. Lamination is a key technique for Lithium-ion battery production, since it enables fast production line speed by fixing the mechanical cell components. Lamination has also a positive effect concerning the capacity fading at high C-rates [1]. Unfortunately, this technology is inapplicable for separator and electrode formulations not based on thermoplastic binders. To overcome this disadvantage, electrospinning technology was developed to apply PVDF polymer nanofibers to commercially available polyolefine separators. Within the investigations modified separators and untreated control samples were laminated using temperatures about 5°C around the melting temperature of the used PVDF polymer, which was around 115°C. The experiments showed clearly that the separator/electrode interface can only be laminated by surface modification with electrospinning. With elevated SEM technique information about the distribution of the polymer on the separator surface before and after lamination were gathered. In addition, half cell measurements have been conducted to investigate the rate stability for modified and unmodified separators using 3 electrode setup with both lithium at the counter and reference electrode.

[1] M. Frankenberger , M. Singh, A. Dinter, S. Jankowski, A. Schmidt, K.-H. Pettinger; Laminated Lithium Ion Batteries with improved fast charging capability, Journal of Electroanalytical Chemistry, 837, 2019

Concepts for innovative battery housings and their production

Célestine Singer
Technical University Munich - Institute for Machine Tools and Industrial Management (iwb)

The increase in the energy density of lithium-ion batteries depends decisively on the improvement of the ratio of active to inactive components. In order to reduce the dead volume and weight of prismatic hardcase housings, all components of the housing and their manufacturing processes were systematically investigated. Therefore, requirements resulting from automotive applications were identified. In a potential analysis, the individual components of the hardcase housing were evaluated with regard to the state of the art in product and process design to derive optimization propositions. Referring to the methods of Design for Manufacturing and Assembly, innovative approaches for new housing concepts were developed and simplified assembly processes were induced. Applying new production technologies for selected process steps, e.g. laser welding for the joining of the thin electrode foils at stack level, shows advantages in costs and effort while meeting current test requirements. Based on these findings, an assembly-optimized design and new layout of battery housings can make a significant contribution to increasing energy density at cell and module level in lithium-ion batteries.

Module & Pack Production

The Key to a reliable leak testing process in battery production

Felix Werner
ZELTWANGER Holding GmbH

ZELTWANGER has installed circa 70 – 80 leak testing equipment in the environment of the HV-Batteries. We started in 2012 with the first project with one German car manufacture and developed a unique filling process to test the complete assembled batteries. Therefore, we developed high tech devices, software, adaption and services which allow us to adapt the perfectly tuned overall system to the unique demands of every customer.
The key to a reliable leak testing process might be an easy one. But there are a lot of influencing factors, which must be considered. One factor is the pure test item for sure, which can be the assembled Battery Pack, or the empty Battery Housing, or the DAE, or the cooling circuit, etc. But there are a lot of more influencing factors and the influence on the results around on which we will focus in the presentation.
We will start to analyze the environment of the leak testing spot in the production line.
That means:
Are there influencing environmental factors like vibrations, light irradiation, heat emission, draught, temperature changes, moisture, etc. We will show practically how these factors influence the measurement and what can we do against them.
Afterwards we are focusing to the key process, leak testing.
That means:
What kind of measurement fit with the demands of a battery pack and its components. And what are the most challenging aspects of a battery, which can be considered as a high-volume testing room. That includes the manner of testing as well, which we call the testing concept. We analyze cycle times, develop the right adaptions and the right way to adapt. Which way will the test item go after a leakage detection. How can we identity the place of the leakage. In general, the leak detection includes a totally deferent process and equipment. We will show examples and explain it.
The points above are in the pre-sales phase of a potential project with a customer and deliver the input for the final specification of the leak testing project. Every type of battery is different, every testing environment is different, therefore the pre-sales phase will influence the success of the EoL testing in the production fundamentally.
After starting the project, we are focusing on the integration of the right equipment in the automated assembly line for example.
That means:
How will be the commissioning done at the customer side, which knowledge must be brought to the testing engineer, service engineer, etc. Everybody how is generating test results must get a basic knowledge of leak testing to understand the process, to fix the adaptions, to interprets results, etc. Theoretically analyses are one side of the medals, to evaluate the data during the commissioning the other side. Therefore, the first results will be analyzed with very experienced application engineers from ZELTWANGER. The more precise the analyses of the environment were done, the easier and quicker will be this task. The aim at this phase sound easy to get a reliable process, which deliver results you can trust and record easily. By providing all state-of-the-art interfaces, like OPC/UA (suitable for I 4.0 integration), Profinet, Ether Cat the results can transferred to almost every data system and we support the customer to do that as well.
I hope these abstract create curiosity about leak testing in battery production.

Free configurable, tailored vacuum gripper kit to handle electrodes, separators and cells in nearly any possible design

Harald Kuolt
J. Schmalz GmbH

As mentioned during IPBC 2018, vacuum handling is necessary to cut costs during the production process and to increase the quality of the produced cells and batteries.
As long as shapes of cells are standardized, also gripper solutions can be standardized. So a standard gripper solution could be the easiest way to solve the handling task.
When standard cells are not suitable with the designated space, for example in a car, special shapes of cells are needed, to use as much space as possible for the battery. But if the shape of a cell is changing, a new kind of gripper has to be developed.
During this presentation it will be shown a gripper solution based on a free configurable, tailored vacuum gripper kit. With this solution it is easily possible, to design special grippers to handle electrodes, separators and cells in nearly any possible design, e.g. pouch or cylindrical cells. This gripper kit is optimized for additive manufacturing, so that it can be easily printed, too.
Furthermore, test results and customer solutions based on these kind of grippers will be presented.

Manufacturing Solutions for Battery Module and Pack Assembly Considering the Current Market Development

Lars Ebert, Tobias Grobe
ThyssenKrupp Systems Engineering

The electric mobility has grown over recent years slowly but steadily. The need to meet fleet emission targets has triggered many new projects in e-mobility. Those projects bear a high degree of uncertainty regarding the expected selling numbers. Thus, car manufacturers demand flexible manufacturing lines that can grow with higher production numbers. The initial investment should be at an optimum between investment cost and production rate.
Line builders like thyssenkrupp System Engineering have been approached by such demands and generated ideas to cater those challenges. Changeovers from manual to automatic production, flexible extensions of conveyor lines with additional stations and work distributions as well as the usage of AGVs with a flexible workstation arrangement are the most common solutions to provide such flexibility. Further flexibility can be reached by arranging single closed work cells with the same machine structure and interfaces. Regarding safety, machine builders have to provide fire detection and protection solutions such as sensors and safety boxes.
Battery producers benefit strongly from the expertise of an established line builder and its use of standardized manufacturing concepts and components. Continuous developments provide state of the art solutions to minimize capex cost and optimize production space. Shorter delivery times are an additional advantage of using standardized concepts.

Automated inline inspection of weld seams in battery production

Peter Daniel
VITRONIC Dr.-Ing. Stein Bildverarbeitungssysteme GmbH

The quality standards for weld seams in battery production are most stringent due to very high safety reasons combined with long term utilization. Thus 100% visual inspection is required in addition to electrical end of line tests. As risk is high that relevant defects which often range in tenths of mm are not detected during visual inspection, a suitable automated inspection which guarantees a high reliability level during 24/7 production is preferable.
Laser triangulation has proven to be a particularly reliable and robust method for quality inspection of weld seams. At battery connectors one major challenge is a robust detection of very flat laser welds.

A new high speed and high resolution triangulation sensor together with a new method for the detection of such flat seams used in battery production is discussed in the talk. Special methods for the inspection of circular weld seams are shown which allow a precise inspection according to the quality specifications. All inspections can be integrated into the automated handling without reducing the production speed.
The inspection tool also offers a database for tracking of parts and for fast feedback of main deviations for process optimization.
Sensor and method have been validated in various projects and examples are shown for laser, brazed and MIG/MAG welds of battery cases, busbars and battery modules.

Advanced Laser Technologies for E-Mobility: New Manufacturing Solutions for High-Performance Energy Storage

Peter Kallage
Coherent, Alessandro Baldini (Voltabox AG)

Urban mobility concepts are no longer relying on combustion engines and drive the development of electric vehicles. Main component for this technology is an intelligent integration of batteries into car bodies. With more and more standardised frames structures and increasing vehicle numbers, batteries are getting a mass product. Joining technologies like laser welding are the key to fulfil requirements like repeatability on a high quality level and at the same time a low heat load on the work piece to prevent thermal damage. Even for dissimilar joints between copper and aluminium the laser offers features like flexible seam shaping or fast power modulation.
This presentation will show you the development of an industrial production machine for battery manufacturing from the first idea and process development till the installation in a production environment.

Integrity testing of battery packs

Sandra Seitz
INFICON GmbH

The market for electric vehicles is growing very rapidly. To generate a positive reputation of this technology – besides long drive ranges and short charging times – it will be critical to produce high quality and extremely reliable and safe-to-use drive train technology. One step to achieve this high quality is to perform sufficient leak testing throughout the entire production process – from battery cell manufacturing to final electric car assembly.
In this presentation leak testing of battery packs is described. Leak testing of battery packs is needed to ensure the integrity of the complete pack. Scenarios described include the testing of the pack housing as part of quality control during component manufacturing, pre-testing of cooling components to avoid leakage of cooling liquid as well as end-of-line testing of fully assembled battery packs for ingress protection against water (e.g. IP67). Failure modes will be discussed and recommendations for new standards for leak testing battery packs will be presented. Recommended leak rate thresholds and how these were derived will be explained and proper leak testing methods to test against these specifications will be described.

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