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36th ANNUAL March 25-28, 2019

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# International Battery SEMINAR & EXHIBIT

ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

Fort Lauderdale Convention Center | Fort Lauderdale, FL

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## CONFERENCE PROGRAMS

### R&D STREAM
- Next-Generation Battery Research
- Lithium-Ion Development & Commercialization

### MANUFACTURING STREAM
- High Performance Battery Manufacturing
- Lithium-Ion Development & Commercialization

### APPLICATIONS STREAM
- Battery Power for Automotive Applications
- Battery Power for Consumer Electronics
- Alternative Applications in Energy Storage

### ENGINEERING STREAM
- Battery Safety
- Battery Management Systems

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## PLENARY KEYNOTE PRESENTATIONS

**1000, 2000, 3000 .... N Cycles from Li-Ion Cells: How Large Can N Be?**
*Jeff Dahn, PhD, NSERC/Tesla Canada Industrial Research Chair, Dalhousie University*

**Battery System Engineering Challenges and Opportunities for the Cell, Pack and System**
*James Lim, PhD, Battery System Engineering Manager, Google*

## PLENARY KEYNOTE PANEL DISCUSSIONS

**What Innovations/Advancements Do OEMs Need to Enable Near-Term, Large-Scale Production?**
*Moderator: Celina Mikolajczak, Director, Engineering, Energy Storage Systems, Uber*

**Solving the Innovation Barrier for Production of Improved Li-Ion**
*Moderator: Brian Barnett, President, Battery Perspectives*

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**Sherry Johnson**
*Senior Manager, Business Development*
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## Sample List of 2018 Delegates

**Amazon**, Sr Battery Engineer, AWS

**Apple Inc,** Sr Reliability Engineer, Battery Reliability

**Argonne Natl Lab,** Dir, Argonne Collaborative Ctr for Energy Storage Sci

**BASF Corp,** Managing Dir Battery Materials, N America

**BMW Grp,** Engineer, Advanced Battery Technology

**Boeing Co,** Design & Analysis Engineer

**Boston Scientific,** Senior Engineer, R&D

**Crown Battery Mfg,** President

**Dell EMC,** Sr Engineer Dev, Battery Team

**DuPont,** Sr Research Chemist, Safety & Construction

**Duracell Inc,** CTO, R&D Facebook, Hardware Engineer

**Federal Aviation Administration,** Dir Hazardous Materials Safety Program

**Fitbit Inc,** Principal Battery Engineer

**Ford Motor Co,** Sr Researcher, Advanced Energy & Storage Grp

**General Motors Company,** GM & Dir R&D, R&D Chemical & Materials Systems Lab

**Google Inc,** Sr Hardware Engineer, Power & Battery Grp

**Great Wall Motor Co Ltd,** Tech Dir, Solid Electrolyte

**Heraeus Battery Technology GmbH,** Head of Innovation, Heraeus New Businesses Battery

**Huawei Technologies,** Battery Technical Expert, 2012 Labs

**Intel Corp,** Sr Technologist, Battery

**Johnson Controls Power Solutions,** Advanced Market & Technology Strategist

**LG Chem Power Inc,** President & CEO

**Maxwell Technologies Inc,** Sr Dir Applications & Systems Engineering, Applications & Systems Engineering

**Mercedes Benz,** Sr Systems Engineer, HV Battery Technology & Powertrain & eDrive

**Microsoft Corp,** Battery Mech Eng, Surface Batteries

**Motorola Solutions Inc,** Principal Staff Engineer & Cell Technologist

**NASA Jet Propulsion Lab,** Principal Tech Staff & Scientist & Team Lead, Battery

**Natl Renewable Energy Lab,** Chief Energy Storage Engineer, Transportation & Hydrogen System Ctr

**Nissan Motor Co Ltd,** Electric Vehicle System Lab

**Panasonic Boston Lab,** Dir

**Paraclete Energy Inc,** CEO

**Phillips 66,** Mgr Global Specialty, Specialty Coke Technology

**Polaris Battery Labs,** CEO

**PPG Industries,** Mgr New Bus Dev, Battery Coatings

**Robert Bosch Battery Systems LLC,** Dir Engineering, Engineering

**Samsung Electronics Co Ltd,** Sr Scientist

**SharkNinja,** Principal Battery Engineer

**Sony Corp,** Exec Alumnus

**Stanley Black & Decker Inc,** Dir Global Battery Technology, Global Battery Technology

**Subaru Corp,** Chief, Engineering 2

**Sunwoda Electronics Co Ltd,** Sr Engineer R&D, Material Dev

**Texas Instruments Inc,** Head of Algorithm Dev, Battery Power Systems

**Toyota Research Institute of N America,** Principal Scientist

**Trojan Battery Co,** Dir, Global Product Solutions

**Uber, Dir Engineering,** Vehicle Systems

**Volkswagen Grp of America Inc,** Sr Scientist & Project Lead, Grp Research

**Volvo Car Corp,** Cell Component Owner, Traction Battery Control & Calibration

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# CONFERENCE AT A GLANCE

| | MONDAY | TUESDAY - WEDNESDAY MORNING | WEDNESDAY AFTERNOON - THURSDAY |
|---|---|---|---|
|  R&D Stream | TUTORIALS & TRAINING SEMINAR | Next-Generation Battery Research | Lithium-Ion Development & Commercialization |
|  Manufacturing Stream | | High Performance Battery Manufacturing | Lithium-Ion Development & Commercialization |
|  Applications Stream | | Battery Power for Automotive Applications | Battery Power for Consumer Electronics<br>Alternative Applications in Energy Storage |
|  Engineering Stream | | Battery Safety | Battery Management Systems |

**Don't Miss the Plenary Sessions!**

# Plenary Keynote Presentations

**March 26-28, 2019** | FORT LAUDERDALE, FLORIDA

## TUESDAY, MARCH 26
## 1:25 - 2:30 PM

### 1000, 2000, 3000 .... N Cycles from Li-Ion Cells: How Large Can N Be?

*Jeff Dahn, PhD, Professor of Physics and Atmospheric Science, NSERC/ Tesla Canada Industrial Research Chair, Dalhousie University*

Our laboratory has developed many methods to help rank the lifetime of cells in relatively short duration experiments (coulombic efficiency, isothermal microcalorimetry, etc.) so that cell developers and users can move rapidly to find next generation chemistries. In this presentation I will describe another powerful method and give examples of how it has been useful in developing outstanding cells that last many thousands of charge-discharge cycles and last many years.

### Battery System Engineering Challenges and Opportunities for the Cell, Pack and System

*James Lim, PhD, Battery System Engineering Manager, Google*

Designing and verifying a well-balanced battery for safety, reliability, performance, availability, and cost requires strong cross-functional team interactions during system integration and product launch. The opportunities are being able to provide viable options, evaluate tradeoffs, and deliver battery solutions associated with next generation products.

## WEDNESDAY, MARCH 27
## 1:45 - 2:55 PM

### Shep Wolsky Battery Innovator Award

### PANEL DISCUSSION: What Innovations/ Advancements Do OEMs Need to Enable Near-Term, Large-Scale Production?

*Moderator:*

*Celina Mikolajczak, Director of Engineering, Energy Storage Systems, Uber*

*Panelists:*

*Mohamed Alamgir, PhD, Research Director, LG Chem*

*Micheal Austin, Vice President, BYD US Operations (BYD America-IT, BYD Motors, BYD Energy)*

*Craig Rigby, Vice President Technology, Power Solutions, Johnson Controls*

*Bob Taenaka, Technical Specialist, Battery System Development, Ford Motor Company*

*Timothy Arthur, PhD, Principal Scientist, Materials Research Department, Toyota Research Institute of North America*

## THURSDAY, MARCH 28
## 4:40 - 5:45 PM

### PANEL DISCUSSION: Solving the Innovation Barrier for Production of Improved Li-Ion

*Moderator:*

*Brian Barnett, President, Battery Perspectives*

*Panelists:*

*Michael Fetcenko, Director, Global Licensing, BASF Battery Materials, BASF*

*Tobias Glossman, Senior Engineer, Mercedes-Benz Research and Development North America*

*Bruce Miller, Technology Strategist, Dell*

*Donald R. Sadoway, PhD, John F. Elliott Professor of Materials Chemistry, Department of Materials Science and Engineering, Massachusetts Institute of Technology*

*Paul Schiffbanker, Product Manager Battery Systems, AVL*

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# Tutorials & Training Seminar*

**Monday, March 25, 2019** | FORT LAUDERDALE, FLORIDA

## MONDAY, MARCH 25 | 8:00-10:00 AM

**TUT1: Battery Safety and Abuse Tolerance Validation**
*Shmuel De-Leon, CEO, Shmuel De-Leon Energy, Ltd.*

**TUT2: Materials Selection and Design for Batteries with High Energy Density, Ultralong Cycle Life and Excellent Safety**
*Yi Cui, PhD, Professor, Department of Materials Science & Engineering, Stanford University*

**TUT3: Technoeconomic Analysis of Battery Material Development and Manufacture**
*Thomas D. Gregory, Owner, Borealis Technology Solutions LLC*

**TUT4: 21st Century Battery Raw Materials**
*Andy Miller, Senior Analyst, Benchmark Mineral Intelligence*
*Simon Moores, Managing Director, Benchmark Mineral Intelligence*

## MONDAY, MARCH 25 | 10:30 AM-12:30 PM

**TUT5: Li-Ion Cell Design and Manufacturing: Processes, Equipment and Quality Control**
*James Kaschmitter, CEO, SpectraPower*

**TUT6: Advances in Solid State Batteries**
*Venkataraman Thangadurai, PhD, Professor, Chemistry, University of Calgary*

**TUT7: Value of LIB Secondary Use & Recycle**
*Jack Lifton, MS, Vice President, Business Development, Resource Conservation and Recycling Corporation, Pty Ltd.; CEO, Jack Lifton LLC*
*Steve Tolen, President/CEO, Indie Power Systems*

**TUT8: Aligning Intellectual Property Strategies with R&D and Commercial Goals – Part 1 of 2**
*Daniel Abraham, PhD, Vice President, Science and Business Strategy, MPEG LA*
*Matthew Rappaport, President, Intellectual Property Analytics, IP Checkups, Inc.*
*Lisa Salley, President, Energy Systems & Safety Institute*
*Victor A. Cardona, Partner, Heslin Rothenberg Farley and Mesiti*

## MONDAY, MARCH 25 | 2:00-4:00 PM

**TUT9: The Rechargeable Battery Market: Value Chain and Main Trends 2018 - 2028**
*Christophe Pillot, PhD, Battery Survey Manager, Avicenne Energy, France*

**TUT10: Improving the Energy Density of Batteries with Silicon-Based Anodes**
*Dee Strand, PhD, CSO, Wildcat Discovery Technologies*

**TUT11: Lithium Battery Transport Regulations: New Developments Impacting the Storage and Packaging of Lithium Batteries and a New Lithium Battery Hazard-Based Classification System for Shipping**
*Christopher Egloff, Vice President, Sales, Americase, Inc.*
*George A. Kerchner, Executive Director, PRBA – The Rechargeable Battery Association*

## WEDNESDAY, MARCH 27 | 5:45-7:45 PM (DINNER INCLUDED)

**TUT13: Advanced Battery Design and Selection Criteria for Medical Device Applications: From Implants to Surgical Tools**
*Yevgen Barsukov, PhD, IP Development Manager, Battery Management Systems, Texas Instruments, Inc.*
*Gaurav Jain, PhD, Technology Director, Technical Fellow, Medtronic*
*Iacovos (Jake) Kyprianou, PhD, Senior Science Health Advisor, FDA*
*Robert Rubino, Senior Director, Research and Development, Integer*

## MONDAY, MARCH 25 | 8:00 AM-4:00 PM

**TS1: Lithium-Ion Battery Cell and Pack Technology**
*Bob Spotnitz, President, Battery Design LLC*
*Kevin Konecky, Battery Systems Consultant, Total Battery Consulting, Inc.*

*Separate registration or Best Value required for Tutorials and Training Seminar. See website for further descriptions.

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R&D STREAM

# Next-Generation Battery Research

Advances in Material, Chemical, and Electrochemical Engineering

March 26-27, 2019 | FORT LAUDERDALE, FLORIDA

## MONDAY, MARCH 25

**7:00 am – 3:00 pm Tutorial and Training Seminar* Registration Open**

**7:00 – 8:00 am Morning Coffee**

**8:00 am – 4:00 pm Pre-Conference Tutorials and Training Seminar***

**4:00 Close of Day**

** Click here for Tutorial and Training Seminar details. Separate registration required for Tutorials and Training Seminar.*

## TUESDAY, MARCH 26

**7:00 am Registration and Morning Coffee**

## NEXT-GENERATION CHEMISTRIES & MATERIALS: SAFETY

**8:05 Organizer's Opening Remarks**

*Mary Ann Brown, Executive Director, Conferences, Cambridge EnerTech*

**8:10 Chairperson's Remarks**

*Jigang Zhou, PhD, Staff Scientist, Innovation Division, Canadian Light Source, Inc.; Adjunct Professor, Materials Engineering Department, Western University*

**8:15 FEATURED PRESENTATION: Li-Ion Battery Aging: Lessons Learnt on the Way to the Future**

*M. Rosa Palacín, PhD, Professor, Solid State Chemistry, Institute of Materials Science of Barcelona (ICMAB-CSIC); Associate Editor, Chemistry of Materials*

The talk reviews origins and methodology to study performance degradation upon Li-ion battery lifetime. Ageing is unavoidable and ultimately rooted in diverse interrelated chemical processes, the extent of which is mostly determined by battery material components and operation conditions (charge/discharge rates, voltage operation limits and temperature).

**8:45 Novel Advanced Diagnostics at BatteryX**

*Jigang Zhou, PhD, Staff Scientist, Innovation Division, Canadian Light Source, Inc.; Adjunct Professor, Materials Engineering Department, Western University*

BatteryX uses non-destructive characterizations to monitor complex structural and chemical changes that occur in the battery. This leads to deeper practical understanding of batteries' synthesis, surface engineering, device design, and failure mechanisms. We review the platform and newest research at BatteryX such as *in situ* nanoscale chemical imaging of composite electrode to integrate the fine understanding of interphase structure with degradation and safety.

**9:15 The Evolving Lithium-Ion Battery Technology Landscape**

*K.M. Abraham, PhD, President, E-KEM Sciences*

The state of the art of Li-ion batteries will be presented. While conventional ones utilize liquid electrolytes, there is increasing effort to build all-solid-state Li-ion batteries to overcome safety hazards of present technology. Their prospects will be discussed. As the energy density of present technologies approaches its upper bound, new lithium battery chemical couples are needed for next-generation ultra-high-energy density rechargeable batteries. Our efforts in this direction will also be presented.

**9:45 Networking Coffee Break**

## NEXT-GENERATION CHEMISTRIES & MATERIALS: ELECTRODES

**10:15 Chairperson's Remarks**

*Dee Strand, PhD, CSO, Wildcat Discovery Technologies*

**10:20 Synthesis of Sulfur-Based Cathodes and Effects on Li-S Battery Performance**

*Perla B. Balbuena, PhD, Professor, Department of Chemical Engineering, Texas A&M University*

The success of the Li-S battery is highly dependent on controlling important issues such as those derived from the solubility and migration of long-chain polysulfides. We address the importance of the sulfur-carbon chemistry and its effect on the discharge and charge reactions. We demonstrate that certain cathode architectures can significantly reduce the generation of long-chain polysulfides, and we discuss possible chemistries that can accomplish this effect.

**10:50 Synthetic Design of Surface Stabilized High-Ni Cathodes for Lithium-Ion Batteries**

*Feng Wang, PhD, Materials Scientist, Sustainable Energy Technologies, Brookhaven National Laboratory*

High-Ni layered oxides are among the most promising cathode candidates for next-generation lithium-ion batteries due to high theoretical capacity, which, however, has been difficult to realize due to surface instability related issues. Herein, we report a structure tracking-aided approach that enables synthetic control of structure and stoichiometry, both in the bulk and locally within individual particles. Examples of applying the approach to developing surface-stabilized high-Ni layered oxide cathodes will be given.

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**11:20 Anomalous Segregation in Lithium-Rich Layered Oxide Uncovers New Theoretical Design Rule for Stable Cathode in Lithium-Ion Battery and the Development of Artificially Intelligent TEM Characterization for Battery Diagnostic**

*Huolin Xin, PhD, Assistant Professor, Department of Physics and Astronomy, University of California, Irvine*

Here we report the TEM, X-ray, and first-principle investigation of a promising high-capacity lithium-rich 3*d*-4*d* transition-metal layered compound. The incorporation of 4*d* transition metals here offers an uncharted phase space for mechanistic exploration as compared to the well documented 3*d* transition metal (TM) oxides. The revealed mechanism allows us to provide predictive guidance for the future design of lithium-rich as well as stoichiometric layered cathode materials.

**11:50 New Coatings and Materials that Enable Performance and Safety for Next Generation Batteries and Drivetrains**

*Sponsored by* PPG

*Calum Munro, Senior Scientist, Science and Technology, PPG Industries*

Electric vehicle growth is demanding unique solutions for lithium ion batteries, battery packs and electrified drivetrains. The electric vehicles of the near future will require lightweight environmentally friendly solutions for batteries, battery pack sealing, thermal management and safety performance.

**12:20 pm Grand Opening Networking Luncheon in the Exhibit Hall**

*Sponsored by* Tektronix

**1:25 Plenary Keynote Program (Click here for details.)**

**2:30 Dessert Break in the Exhibit Hall with Poster Viewing**

## NEXT-GENERATION CHEMISTRIES & MATERIALS: ELECTRODES

**3:15 Chairperson's Remarks**

*Wu Xu, PhD, Chief Scientist, Energy and Environment Directorate, Pacific Northwest National Laboratory*

**3:20 Accelerating Development of High-Nickel Cathodes**

*Dee Strand, PhD, CSO, Wildcat Discovery Technologies*

High-nickel cathodes can deliver improved energy density relative to today's materials. However, these materials suffer from poor lifetime and durability. Variations in electrode composition can impact the performance of the material. This presentation highlights parameters that can accelerate implementation of high-nickel cathodes in applications. The presentation focuses on approaches other than compositional changes to the NMC811 to improve cycle life in high-loading electrodes.

**3:50 Nanoscale Material Design of Zinc Anodes for High-Energy Rechargeable Aqueous Batteries**

*Nian Liu, PhD, Assistant Professor, School of Chemical & Biomolecular Engineering, Georgia Institute of Technology*

Zn-based batteries are a safe alternative to Li-ion due to compatibility with aqueous electrolyte. However, the Zn anode in aqueous electrolyte is historically not deeply rechargeable. We have identified the root causes for the lack of rechargeability to be passivation of ZnO discharge product, and dissolution of zincate intermediate, and addressed the rechargeability issue of aqueous Zn anodes via nanoscale material design.

**4:20 FEATURED PRESENTATION: Advancing Lithium-Metal Batteries**

*Wu Xu, PhD, Chief Scientist, Energy and Environment Directorate, Pacific Northwest National Laboratory*

Advancement of rechargeable lithium-metal batteries requires protecting and stabilizing the lithium-metal anode as well as maintaining the stability of cathode materials. The electrolyte plays a key role in these functions by forming high-quality lithium/electrolyte and cathode/electrolyte interface layers. Three major approaches, including electrolytes, protective membranes and three-dimensional lithium structures, will be discussed.

**4:50 Welcome Reception in the Exhibit Hall with Poster Viewing**

**5:50 Interactive Breakout Discussion Groups (See website for details.)**

**6:50 Close of Day**

## WEDNESDAY, MARCH 27

**7:15 am Registration and Morning Coffee**

## NEXT-GENERATION CHEMISTRIES & MATERIALS: SOLID STATE

**8:25 Chairperson's Remarks**

*Marshall A. Schroeder, PhD, Materials Science Engineer, Electrochemistry Branch, US Army Research Laboratory*

**8:30 FEATURED PRESENTATION: 6V Solid-State Li-Ion Electrolytes Derived from Li-Stuffed Garnets**

*Venkataraman Thangadurai, PhD, Professor, Chemistry, University of Calgary*

Solid-state (ceramic) Li-ion electrolytes exhibiting high ionic conductivity and electrochemical stability window, and chemical stability with metallic Li offer development of advanced safe and high-energy density Li batteries.

**9:00 FEATURED PRESENTATION: Rational Design of an All-Solid-State Li-Ion Battery**

*Puru Jena, PhD, Distinguished Professor, Physics, Virginia Commonwealth University*

Development of the next-generation Li-ion batteries would require advanced materials for electrolytes, anodes, and cathodes. This talk deals with a rational design approach for the development of all-solid-state Li-ion batteries that includes halogen-free electrolytes as well as those based on anti-perovskites, a new 3D Dirac nodal-line semi-metallic graphene monolith for anodes, and a high-pressure phase of Rutile-like CoO2 for cathodes.

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**9:30 Manufacturing Technology of All-Solid-State Thin-Film Li Secondary Battery for IoT/AI Applications**

*Sponsored by* ULVAC

*Akiyoshi Suzuki, Engineer, ISET, ULVAC, Inc.*

All-Solid-State Thin-Film Lithium Secondary Batteries (Li-TFB) are key to enabling technologies for standalone sensor devices which are essential for IoT/AI applications. A detailed explanation will be given on the vacuum technologies such as sputtering and evaporation for the manufacturing of Li-TFB, in which we have successfully established reliable hardware and process technologies as mass-production technology for manufacturing Li-TFB.

**10:00 Coffee Break in the Exhibit Hall with Poster Viewing**

## NEXT-GENERATION CHEMISTRIES & MATERIALS: ELECTROLYTES

**10:45 Deploying Machine Learning to Accelerate Materials Design in Electrolytes and Beyond**

*Austin Sendek, PhD, Founder and CEO, AIONICS*

Machine learning offers an exciting new route for accelerated materials design and discovery. We train predictive models on materials performance data to enable rapid screening of thousands of candidate materials, often discovering promising new materials several times more efficiently than trial-and-error searches. In this talk, I focus on our work in screening solid electrolytes, which has identified dozens of new compositions for solid-state batteries.

**11:15 Carbonate-Free, Sulfone-Based Electrolytes for High-Voltage Lithium Batteries**

*Marshall A. Schroeder, PhD, Materials Science Engineer, Electrochemistry Branch, US Army Research Laboratory*

The effects of solvation, concentration, and salt anion chemistry on the performance and properties of sulfone-based electrolytes were explored in detail with experimental measurements, testing with aggressive cell chemistries, quantum chemistry calculations, and molecular dynamics simulations. These results suggest sulfone-based electrolytes offer a promising alternative to the state-of-the-art carbonate systems, and warrant further exploration for enabling safer, high-performance lithium batteries.

**11:45 Liquefied Gas Electrolytes for High-Energy and Safe Lithium Batteries**

*Cyrus Rustomji, PhD, CTO, South 8 Technologies, Inc.*

The use of novel Liquefied Gas Electrolytes has demonstrated excellent stability with traditional 4-V cathodes, high coulombic efficiency of >99% on dendrite-free Li metal anodes, excellent temperature window, and demonstrated safety features inherent to the electrolyte chemistry. Compatibility with both traditional manufacturing and materials will allow this technology to be rapidly deployed into EVs, grid storage, and aerospace energy storage applications.

**12:15 pm Networking Plated Luncheon**

*Sponsored by* EVE 亿纬锂能

**1:15 Dessert Break in the Exhibit Hall with Poster Viewing**

**1:45 Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

**3:40 Close of Conference**

R&D STREAM | MANUFACTURING STREAM

# Lithium-Ion Development & Commercialization

**Delivering Higher Performance**

**March 27-28, 2019 | FORT LAUDERDALE, FLORIDA**

## WEDNESDAY, MARCH 27

**1:45 pm Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

## MODELS, PROTOTYPES & SCALE-UP FOR MANUFACTURING

**3:40 Organizer's Opening Remarks**

*Mary Ann Brown, Executive Director, Conferences, Cambridge EnerTech*

**3:45 Chairperson's Remarks**

*Seung-Wan Song, PhD, Professor, Department of Chemical Engineering & Applied Chemistry, Chungnam National University*

**3:50 Materials and Manufacturing of Sodium-Ion Batteries**

*Emma Kendrick, PhD, FIMMM, FRSC, Professor & Chair, Energy Materials, Department of Metals Metallurgy and Materials, University of Birmingham*

This talk addresses some of the manufacturability questions around sodium and compares to what we know about lithium-ion batteries. In particular, it discusses the process for making the inks and electrodes, and the formation process at the end of the manufacturing chain.

**4:15 Recent Developments on High Voltage LNMO Spinel**

*Sponsored by* HALDOR TOPSOE

*Jonathan Højberg, PhD, Principal Scientist, Advanced Materials, Haldor Topsoe A/S*

This talk presents the LiNi0.5Mn1.5O4 high voltage spinel material TBM-129 developed by Haldor Topsoe A/S to have good powder properties, high tap density and low degradation. Batteries based on LNMO have high energy density and are significantly cheaper compared to cells with high-nickel tri-metal cathode materials like NCA and NMC811.

**4:30 Development of a New Class of Graphitic Anode Materials Optimised for Fast Charge and Low Temperature Performance**

*Sponsored by* talga

*Sai Shivareddy, Battery Program Manager, Talga Technologies Limited*

**4:45 Microscale Half-Cell Modeling of Graphite Electrodes at High C-Rate**

*Francois Usseglio-Viretta, PhD, Battery Researcher, Transportation & Hydrogen System Center, National Renewable Energy Laboratory (NREL)*

Electrochemical fields are computed for tomography-based and numerically generated 3D volumes of graphite electrodes during charge over a range of different C-rate. Analysis is focused on determining the onset of lithium plating, evaluating the field in-plane heterogeneity, and determining the size of the Representative Volume Element (RVE). Impact of various particle size and of particle alignment on fields heterogeneity and lithium-plating is also investigated.

**5:10 Visualization of Electrolyte Filling Process for Hard Case Prismatic Lithium-Ion Cells by Neutron Imaging**

*Wolfgang Weydanz, PhD, Senior Scientist, Automotive Electronics, eBike Systems, Robert Bosch GmBH*

The process of filling electrolyte into lithium ion cells is time consuming and critical to the overall battery quality. However, this process is not well understood. A powerful tool for visualization of the process is neutron imaging. The filling and wetting process of the electrode stack can be clearly visualized *in situ*. Results showed that wetting of the electrode stack takes place slowly but rather steady in a mostly isotropic manner from the outside towards a center point of the hard case cell. Vacuum can assist the process and accelerate it by about a factor of two.

**5:30 Dinner Tutorial Registration***

**5:45 – 7:45 Dinner Tutorial***

**Click here for Tutorial details. Separate registration required.*

**7:45 Close of Day**

## THURSDAY, MARCH 28

**7:30 am Registration Open**

**7:45 Interactive Breakout Discussion Groups with Continental Breakfast (See website for details.)**

**8:45 Session Break**

## PROCESSES TO IMPROVE ELECTRODE PERFORMANCE

**9:00 Chairperson's Remarks**

*Emma Kendrick, PhD, FIMMM, FRSC, Professor & Chair, Energy Materials, Department of Metals Metallurgy and Materials, University of Birmingham*

**9:05 Direct Regeneration of Degraded Cathodes to Reduce LIB Cost and Enhance Materials Sustainability**

*Zheng Chen, PhD, Assistant Professor, Department of NanoEngineering, University of California, San Diego*

The development of next-generation energy storage devices and systems for electric vehicles (EVs) relies on materials with significantly improved performance and lower cost. The increase of lithium-ion battery (LIBs) consumption will result in the resource shortage and price increase of lithium and precious transition metals; the wastes generated from disposal of used batteries can cause severe environmental pollution. This talk will introduce a potential strategy to recycle and regenerate spent LIBs using a "non-destructive" approach, which will lead to new electrode materials that can show the same level of performance as the native materials.

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**9:35 Electrode and Cell Processing Considerations of Ni-Rich/Low-Co Cathodes for Lithium-Ion Batteries**

*David L. Wood, III, PhD, Senior Staff Scientist, R2R Manufacturing Group, Energy & Transportation Science Division, Oak Ridge National Laboratory*

Ni-rich, or low-Co, layered active materials are promising candidates for next-generation cathodes for lithium-ion batteries. However, these materials present processing challenges such as compatibility with water during aqueous electrode formulation and unoptimized SEI/CEI formation conditions during cell assembly. This presentation focuses on ORNL advancements in both areas, where aqueous processing conditions and fast formation protocols are being developed for the example material LiNi0.8Mn0.1Co0.1O2 (NMC 811).

**10:05 Research Progress of Advanced Polymer Lithium-Ion Battery in Highpower**

*Sponsored by*

*Dalin Hu, President, Research Institute, Highpowertech International, Inc.*

In this presentation, Li-ion battery will be introduced. Now, HPJ focus on 3C battery, especially small battery used in Bluetooth & wearable device, and large battery used in Notebook. The R&D also focuses on these two directions, which is mainly fast charge and high ED battery. We will introduce the detail of 4.45V fast charge and high ED battery, and briefly introduce the development of high ED battery with SiOx anode and 4.48V LCO system.

**10:35 Coffee Break in the Exhibit Hall with Poster Viewing**

**11:20 Correlating Nanoporous-Carbon Structure with Li-Ion Anode Energy Storage Properties**

*Michael P. Siegal, PhD, Principal Member, Technical Staff, Department of Nanoscale Sciences, Sandia National Laboratories*

Li-ion intercalation into graphitic anodes has a specific capacity close to its theoretical limit. We study nanoporous-carbon, a binderless material that provides control of the interplanar spacing between graphene sheet fragments, as a model system to understand the relationship between structural and energy storage properties, demonstrating >100% increases in capacity. Furthermore, nanoporous-carbon can host other species, e.g., silicon, to potentially provide even higher capacity.

**11:50 Multifunctional Binder and Its Interface Chemistry with High-Energy Cathodes**

*Seung-Wan Song, PhD, Professor, Department of Chemical Engineering & Applied Chemistry, Chungnam National University*

The capacity of cathode and energy density of lithium-ion batteries can increase by increasing charge cutoff voltage. This presentation shows how new multifunctional cathode binder permits charge of the batteries to high voltage above 4.2V in commercial electrolyte and mitigates the degradation problems of high-voltage cathodes coated with conventional binder, thus enabling well-performing high-energy density Li-ion batteries.

**12:20 pm Lithium Manganese Iron Phosphate: The Next-Generation Olivine Cathode Material for Li-Ion Batteries**

*Shih-Chieh Liao, PhD, Chief Technical Advisor, Research & Development, HCM Co., Ltd.*

We have developed lithium manganese iron phosphate (LMFP) cathode material with an average working voltage of 4.0V and discharge capacity of 150 mAh/g. The LMFP cell had the energy density >135 Wh/kg and excellent life >5000 cycles. The energy density of LMFP cells can be further increased by blending the LMFP with the NMC. In addition, Ni-rich NMC cells exhibited much improved safety, rate capability and cycle life by blending the NMC with the LMFP.

**12:50 Sponsored Presentation** *(Opportunity Available)*

**12:50 Walking Luncheon in the Exhibit Hall with Poster Viewing or Plated Luncheon in the Exhibit Hall Foyer** *(Sponsorship Opportunity Available)*

**1:50 Dessert Break in the Exhibit Hall with Poster Viewing**

## ENGINEERING HIGH(ER) ENERGY ELECTROLYTES

**2:20 Chairperson's Remarks**

*Kevin L. Gering, PhD, Distinguished Staff Scientist, Energy Storage Technologies, Idaho National Laboratory*

**2:25 Continuous Flow Processes – A Platform for Manufacturing Advanced Electrolyte Materials**

*Kris Pupek, PhD, Group Leader, Process R&D and Scale-Up, Materials Engineering Research Facility, Argonne National Laboratory*

New electrolyte materials are required to enable HV/HE and safer batteries. In the quest for such a material, researchers design, synthesize and evaluate more and more complex molecules. The complexity of the structure is translated into increased difficulty in synthesis and production cost. Argonne launched a program to evaluate emerging synthesis technologies to facilitate at-scale delivery of new materials and to address the cost issue.

**2:55 Electrolyte Characterization and Design Using a Fast Chemical Physics Platform, with Emphasis on Low-Permittivity Systems Amenable to High Cycling Rates**

*Kevin L. Gering, PhD, Distinguished Staff Scientist, Energy Storage Technologies, Idaho National Laboratory*

Complexity of electrolyte formulations grows as more demands are placed on them within contemporary batteries. Advanced models are needed to characterize, screen, and optimize electrolytes while reducing the cost burden of laboratory measurements. The move toward reduced EC systems requires new evaluations of low-permittivity electrolytes and underlying mechanisms within the permittivity domain and related ion association. Basis/benefits of INL advanced electrolyte model (AEM) are discussed.

**3:25 High-Voltage, 1000Wh/L+ Batteries Enabled by Compositionally Distinct Electrolytes (Anolytes & Catholytes)**

*Naoki Ota, CTO, R&D, 24M Technologies*

**3:55 Understanding Materials Processing Effect on Surface Energy and Electrolyte Wettability of Lithium-Ion Battery Electrodes**

*Jianlin Li, PhD, R&D Staff, Energy & Transportation Science Division, Oak Ridge National Laboratory*

This presentation discusses a method in characterizing electrode surface energy and electrolyte wettability for lithium-ion batteries.

**4:25 Networking Refreshment Break**

**4:40 Plenary Keynote Program (Click here for details.)**

**5:45 Close of Conference**

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MANUFACTURING STREAM

# High Performance Battery Manufacturing

Advanced R&D for the Global Production of Safe, High Energy Batteries

March 26-27, 2019 | FORT LAUDERDALE, FLORIDA

## MONDAY, MARCH 25

**7:00 am – 3:00 pm Tutorial and Training Seminar* Registration Open**

**7:00 – 8:00 am Morning Coffee**

**8:00 am – 4:00 pm Pre-Conference Tutorials and Training Seminar***

**4:00 Close of Day**

** Click here for Tutorial and Training Seminar details. Separate registration required for Tutorials and Training Seminar.*

## TUESDAY, MARCH 26

**7:00 am Registration and Morning Coffee**

## INNOVATION AND DESIGN FOR MANUFACTURING

**8:05 Organizer's Opening Remarks**

*Craig Wohlers, Executive Director, Conferences, Cambridge EnerTech*

**8:10 Chairperson's Remarks**

*Franz Josef Kruger, PhD, Head of Business Unit TreoPore, Treofan Germany GmbH & Co. KG*

**8:15 FEATURED PRESENTATION: Li-ion Progress and Ceramic Coated Separator**

*John Zhang, PhD, Senior Technical Executive Officer, Asahi Kasei Separator*

One of the critical and important changes for Li-ion batteries is the separator change: from THICK polyolefin film to Ceramic Coated THIN polymer films, which greatly enhanced battery energy density, battery safety and battery performance. This presentation will share the creation, the functions, the mechanisms and the process of modern CERAMIC COATED separators for high energy density Lithium batteries.

**8:45 Nickle Metal Hydride - Older Technology Gets New Life**

*Dennis Malec, Senior Applications Engineer, Panasonic Corporation of North America*

When NiMH came out as a replacement for the environmentally unfriendly NiCd chemistry, it quickly got overshadowed by Lithium Ion. However, with all the safety, transportation concerns, and materials availability/costs of Li Ion, NiMH is again being considered in applications where size and weight are not as critical. New formulations allows this chemistry to be considered in products previously off limits to its capabilities. I'll explore this revitalized chemistry, and show how our NiMH factory is still developing new cells to meet tomorrows demands.

**9:15 Trends in the Development of Li-Ion Battery Technology and Industry**

*Haokun Deng, PhD, Director of Project Management, EVE Energy Co., Ltd.*

Since 2017, there's been dramatic change in technical solutions and industrial development in li-ion batteries within only one year. Fast charge technology, long cycle life, reliability, quality and safety performance have drawn more attention than before. In battery industry, the big become bigger, and the occupation of market of these big companies tends to focus on several points, and business brought by huge auto companies across overseas due to their global supply chain strategy. The presentation focuses on these points which are about to become hot topics in 2-3 years.

**9:45 Networking Coffee Break**

**10:15 Chairperson's Remarks**

*Jeff Norris, PhD, CEO, Paraclete Energy*

**10:20 Improving Electrode Manufacturing and Battery Performance through Innovative Coating Technology**

*Stuart Hellring, PhD, Senior Scientist, PPG*

Electrode coating formulation technology has a significant impact on cell performance. In addition, electrode manufacturing complexity can be improved by applying coatings with effectively designed formulations. With well-designed binder and solvent systems, electrode coating performance can be optimized to maximize production and performance.

**10:50 Enabling Improved Battery Performance for High Volume Manufacturing**

*Subramanya Herle, PhD, Director, DMTS, Office of the CTO, Applied Materials*

Enhancing battery performance is very critical for various applications. New materials and deposition technologies are needed to enable the battery roadmap. Increasing cell voltage, safety, active material capacity and decreasing inactive material weight/volume are very important attributes for meeting the energy density roadmap. In this talk, we will explore a deeper understanding of what is happening in the anode, and how that affects overall battery performance.

## ADVANCES IN CELL MANUFACTURING

**11:20 Low Voltage for 48V Applications and High Energy Density Applications for Traditional and Beyond Lithium Ion Technologies**

*Patrick Hurley, PhD, CTO, A123 Systems, LLC*

A123 is well known as a developer and manufacturer of lithium ion cells based on our proprietary lithium iron phosphate cathode material along with Nickle Manganese Cobalt. This presentation will share A123's expanded product portfolio for current

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transportation application demands, as well as provide a detailed technology road map for Traditional and Beyond Lithium Ion Cell Chemistries.

**11:50 Pattern Coating of Battery Electrodes by Slot-Die** *Sponsored by* FRONTIER

*Scott Zwierlein, Coating Process Engineer, Coating and Drying Equipment, Frontier LLC - a Delta ModTech Company*

The ability to coat electrode material in discrete rectangular patches is becoming more and more useful in the energy storage industry. Exposed current collector surrounding all sides of an electrode allows for more design options and versatility in battery fabrication. The goal of this presentation is to describe the process of applying electrode slurries to substrate in discrete rectangle via roll to roll, Slot Die Coating.

**12:05 pm Cycling Characteristics of Silicon Enhanced and Boronated Lac Knife Natural Flake Graphite in Lithium Ion Batteries** *Sponsored by* FOCUS GRAPHITE

*Joseph Doninger, PhD, Director of Manufacturing and Technology, Focus Graphite Inc.*

In 2017 Focus Graphite introduced its silicon enhanced Lac Knife graphite for use in high energy lithium ion batteries. This presentation includes the results from further cycling studies on the silicon enhanced graphite and introduces the initial work conducted on boronating Lac Knife graphite to improve high power performance.

**12:20 Grand Opening Networking Luncheon in the Exhibit Hall** *Sponsored by* Tektronix

**1:25 Plenary Keynote Program (Click here for details.)**

**2:30 Dessert Break in the Exhibit Hall with Poster Viewing**

## ADVANCES IN CELL MANUFACTURING

**3:15 Chairperson's Remarks**

*John Zhang, PhD, Senior Technical Executive Officer, Asahi Sasei Separator*

**3:20 Youlion Enters the GWh Factory Competition**

*Huanyu (Henry) Mao, PhD, Chairman & General Manager, Suzhou Youlion Battery Ltd., China*

Youlion Battery Inc., founded 2014 in Suzhou, has started their fully automated production of prismatic (VDA format) cells in their first 1 GWh facility. With their already existing production line for cylindrical cells, this brings up their total production capacity to 1.5 GWh per year, with definitive plans for expansion up to 2.5 GWh. It will be demonstrated that Youlion cells and battery packs surpass most stringent automotive performance and safety requirements.

**3:50 Development of 48V Start-Stop Power Batteries**

*Lingdi Cao, PhD, Vice President, Lishen Research Institute, Tianjin Lishen Battery Joint-Stock Co., Ltd.*

**4:20 Li-Ion Battery Manufacturing Cost Scenarios**

*Franz Josef Kruger, PhD, Senior Advisor Automotive, Roland Berger GmbH*

The main cost drivers for the production of li-ion cells are related to raw material costs for lithium, nickel and cobalt. The presentation shows the development of total cell production costs based on raw material cost forecasts as well as the impact of actual and future cell chemistries.

**4:50 Welcome Reception in the Exhibit Hall with Poster Viewing**

**5:50 Interactive Breakout Discussion Groups (See website for details.)**

**6:50 Close of Day**

## WEDNESDAY, MARCH 27

**7:15 am Registration and Morning Coffee**

## ADVANCES IN CELL MANUFACTURING

**8:25 Chairperson's Remarks**

*Huanyu (Henry) Mao, PhD, Chairman & General Manager, Suzhou Youlion Battery Ltd., China*

**8:30 New Markets and New Electrochemistry at Saft**

*Thomas Greszler, Cell Development Manager, North America, Saft*

Saft is entering a new, dramatic growth stage including expansion into new markets and applications; our strategy and plans will be discussed. In addition, Saft continues to invest and develop new electrochemistry including advanced LTO, Mn-phosphate, and solid-state; recent advancements will be shown. Finally, Saft capabilities for space and defense, including both very high power and world-class high energy density pouches will be presented.

## ADVANCED BATTERY RAW MATERIALS

**9:00 Lithium Market Volatility: A Case Study in Battery Raw Material Price Risk**

*Andy Miller, Senior Analyst, Benchmark Mineral Intelligence*

This talk will cover lithium's price rise & fall: China vs. the rest of the world. In addition, supply challenges in the era of the lithium ion battery, the cathode demand outlook and battery raw material price risk will be presented.

**9:30 Discussion with Data, Validates Paraclete's SM-Silicon/3590™ as the Highest Capacity, Cycle Stable** *Sponsored by* PARACLETE ENERGY

*Jeff Norris, CEO, Paraclete Energy*

Performance and electrochemistry data validating Paraclete's SM-Silicon/3590™ will be discussed as well as its product architecture describing how cycle stability is achieved and the roadmap for its Fast Charge product will be covered. SM-Silicon/3590™ is a drop-in precursor that has an ICL and tap density similar to graphite. SM-Silicon /3590™ at 3,590 mAh/g is priced at up to 5x less than composites available today at only 450 mAh/g.

**10:00 Coffee Break in the Exhibit Hall with Poster Viewing**

**10:45 Cathode Materials: Where All Battery Raw Material Challenges Meet: Threat or Opportunity?**

*Robert Privette, Business Development Manager, North America, Rechargeable Battery Materials, Umicore USA Inc.*

Exponential growth of Li Ion industry has caused major concerns about the availability of Cobalt, Nickel and Lithium. All these supply challenges meet at the cathode maker level. In this presentation, we will separate hype from funded concern and discuss different routes to provide security of supply.

## INNOVATIONS IN RECYCLING BATTERY MATERIALS FOR MANUFACTURING

**11:15 Technology, Timing, and Team: Choosing the Right Ones for Li-Ion Recycling**

*Tim Grejtak, Energy Storage Analyst, Lux Research*

The Li-ion battery recycling industry today is fragmented, with multiple companies pursuing multiple process technologies. What is the timeline for recycling demand? Which methods are best positioned to succeed as Li-ion battery chemistry evolves? Who are the key players today and what should investors and suppliers look for in the future? By combining technical expertise with a focus on early-stage innovation, Lux Research will answer these questions and provide a valuable perspective on battery recycling.

**11:45 The Path to Cost Effective Lithium Ion Battery Recycling**

*Jeffrey Spangenberger, Materials Recycling Group Leader, Argonne National Laboratory*

End-of-life lithium ion batteries in electric and hybrid-electric vehicles are just now starting to reach their end-of-life. The recycling infrastructure that these batteries are expected to go through will likely cost the end user money. Argonne National Laboratory is working to develop ways to reduce cost and increase revenue to improve the economic outlook of responsible end-of-life lithium-ion battery management. This presentation will provide a summary of the work.

**12:15 pm Networking Plated Luncheon**

*Sponsored by* EVE 亿纬锂能

**1:15 Dessert Break in the Exhibit Hall with Poster Viewing**

**1:45 Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

**3:40 Close of Conference**

## Student Fellowships Now Available

Full time graduate students and PhD candidates presenting a poster can now attend the International Battery Seminar for only $299. Please see the website for details.

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APPLICATIONS STREAM

# Battery Power for Automotive Applications

Advanced Engineering for High Performance Vehicle Batteries

MARCH 26-27, 2019 | FORT LAUDERDALE, FLORIDA

## MONDAY, MARCH 25

**7:00 am – 3:00 pm Tutorial and Training Seminar* Registration Open**

**7:00 – 8:00 am Morning Coffee**

**8:00 am – 4:00 pm Pre-Conference Tutorials and Training Seminar***

**4:00 Close of Day**

** Click here for Tutorial and Training Seminar details. Separate registration required for Tutorials and Training Seminar.*

## TUESDAY, MARCH 26

**7:00 am Registration and Morning Coffee**

## OEM APPLICATION-DRIVEN DEVELOPMENT

**8:05 Organizer's Opening Remarks**

*Craig Wohlers, Executive Director, Conferences, Cambridge EnerTech*

**8:10 Chairperson's Remarks**

*Brian Cunningham, Engineer, U.S. Department of Energy*

**8:15 Trends and Needs in Automotive Electrification and Identification of Electrochemical Reactions from Open-Circuit-Potential Data in Traction Batteries**

*Mark Verbrugge, PhD, Director, Chemical and Materials Systems Laboratory, General Motors*

First, we will provide a brief overview of automotive electrification trends and needs, with a focus on battery systems. Following this overview, we will examine methods to determine when various electrochemical reactions are occurring in a battery, which is especially important when it comes to avoiding lithium plating during overcharge of a lithium ion cell.

**8:45 Battery Life Requirements for Electric Vehicles**

*Bob Taenaka, Technical Specialist, Battery System Development, Ford Motor Company*

With the push towards greater and greater EV range for an electric vehicle, there is a reduction in the cycle life required of their battery cells. Additionally, power consumption for ancillary features such as climate control and LiDAR systems can significantly affect vehicle range and therefore battery lifetime capacity throughput. This paper will highlight these factors and their potential impact to battery life requirements.

**9:15 Test and Validation Harmonization for Automotive Large Battery Packs**

*Rakesh Nahta, PhD, Senior Technical Specialist, FCA Fiat Chrysler Automobiles*

Automotive traction batteries are complex systems requiring sophisticated testing and validation processes during their development. Harmonization of a validated test approach can provide benefits for test simplification, the generation of a common dataset and greater overall economy. A method to harmonize validation testing will be highlighted and two case studies will be presented.

**9:45 Networking Coffee Break**

**10:15 Chairperson's Remarks**

*Brian Cunningham, Engineer, U.S. Department of Energy*

**10:20 Lithium-Sulfur Batteries for Transportation**

*Tobias Glossman, Senior Engineer, Mercedes-Benz Research and Development North America*

The Li-S system has been the focus of battery research for many years. Significant progress has been made; however, commercialization on a large scale has not been observed. One well-known issue is the system's difficulty in competing with Li-ion in regards to volumetric energy density on cell level. The promises of Li-S remain: a long term cost benefit and the possibility to present an alternative to cobalt containing batteries. This presentation will cover all the angles of Lithium-Sulfur for transportation applications.

**10:50 Requirements and Challenges for Next Generation Automotive Batteries**

*Ann-Christin Gentschev, PhD, Senior Advanced Battery Technology Engineer, BMW Group*

This presentation will outline the opportunities and limitations of various material concepts from a car manufacturer's point of view. In particular, it will address open issues that need to be solved in the future development of electric energy storage technologies for automotive applications. Some main challenges will be addressed with examples from BMW research projects.

**11:20 Growing NIO's Battery Ecosystem Silicon Valley Style**

*Marc Juzkow, Principal Cell Specialist, NIO*

The leap from cool new EV battery technology to commercial implementation is monumental. NIO is using its Silicon Valley style partner approach to propel advanced materials, components and processes from innovative startups to market. NIO does this as both a development partner through our Silicon Valley facility and our global EV business. We will present several examples of our ecosystem partnerships; highlighting the process, results and challenges addressed. NIO's mission is to shape a joyful lifestyle by offering smart, premium electric vehicles.

**11:50 Optimizing Electric Propulsion for VTOL Aircraft**

*Sponsored by* Uber

*Tushar Swamy, PhD, Senior Cell Engineer, Elevate, Uber*

Electric batteries have become the obvious energy source for transportation vehicles,

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including VTOL aircraft. However, balancing the specific energy, charge rate, and cost per kilowatt-hour are essential to economic viability of electric aircraft. In this presentation we will discuss how Uber is implementing a data infrastructure and battery analytics environment that will enable the company to develop batteries that make VTOLs an affordable form of daily transportation.

**12:20 pm Grand Opening Networking Luncheon in the Exhibit Hall**

*Sponsored by* Tektronix

**1:25 Plenary Keynote Program (Click here for details.)**

**2:30 Dessert Break in the Exhibit Hall with Poster Viewing**

## HIGH-ENERGY BATTERIES FOR HEV APPLICATIONS

**3:15 Chairperson's Remarks**

*Mark Verbrugge, PhD, Director, Chemical and Materials Systems Laboratory, General Motors*

**3:20 Commercial Developments of LMP Technology in Mobility and Stationary Domains**

*Didier Marginedes, Senior Vice President, Director, BlueSolutions – Groupe Bolloré*

BlueSolution's next generation LMP (Lithium Metal Polymer) battery with higher performance intends to play a crucial role in the expansion of urban mobility. These all-solid batteries are dedicated to applications for electric buses which are already in use by such cities as Paris and Brussels. As a result, we have developed key partnerships with major bus manufacturers.

**3:50 Progress and Challenges in the Electrification of Heavy Duty, Long Distance, Mass Transportation**

*Michael Mcdonald, PhD, Sustainable Transportation Specialist, Motor Coach Industries*

Electrification of motor coaches designed for inter-community mass transport comes with a specific set of challenges that differentiate the design parameters from urban transit buses as well as other electric vehicles. MCI is successfully designing and building 100% zero-emissions battery-electric motor coaches for the commuter market, and this presentation will detail the successes and challenges that remain in this unique space with a specific emphasis on battery integration.

## EV MARKET DEMAND

**4:20 Market and Strategic Analysis of the Chinese xEV and Related Batteries – Product, Technologies & Promotion**

*Mark Lu, PhD, Certified Senior Industrial Analyst, Industrial Economics & Knowledge Center (IEK), Industrial Technology Research Institute (ITRI)*

From 2016, the Chinese xEV market has become the largest plug-in vehicle market in the world. This presentation will compare the leading Chinese xEV companies and battery makers' strategies, from the aspects of product, BEV/PHEV/m-HEV technical roadmap and market promotion. As a conclusion, the key issues to consider the Chinese xEV future potential will be listed.

**4:50 Welcome Reception in the Exhibit Hall with Poster Viewing**

**5:50 Interactive Breakout Discussion Groups (See website for details.)**

**6:50 Close of Day**

## WEDNESDAY, MARCH 27

**7:15 am Registration and Morning Coffee**

## INNOVATION AND DESIGN IN NEXT-GENERATION TRANSPORTATION APPLICATIONS

**8:25 Chairperson's Remarks**

*Rachid Yazami, PhD, School of Materials Science & Engineering, Program Director, Energy Storage, Energy Research Institute, Nanyang Technological University, Singapore; Founding Director, KVI PTE LTD*

**8:30 U.S. Department of Energy Electric Vehicle Battery Research Pathways and Key Results**

*Brian Cunningham, Engineer, U.S. Department of Energy*

The U.S. Department of Energy set key technical targets necessary to enable Electric Vehicles (EV) to be as affordable as gasoline vehicles by 2022. A focus of this effort is the development of more cost-effective, longer lasting, and more abuse-tolerant EV batteries. VTO's battery R&D effort includes multiple activities, ranging from battery materials research to battery cell and pack development and testing. This paper will highlight the current battery R&D pathways supported by VTO and key technical results.

**9:00 Review of Battery Electric Vehicles – Regulations, Batteries, Infrastructure, Markets, and Forecasts**

*Timothy Johnson, Director, Emerging Technologies, Corning Incorporated*

The presentation will cover some key developments in the public domain related to battery electric vehicles. Regulations is the US, EU, and China are an important market driver, and key features and options for meeting them will be discussed. A high-level overview of battery technology includes major electrode and electrolyte developments and the impact of these. The infrastructure developments covered include the raw material base and charging developments. Finally, an update on market acceptance and future forecasts will be summarized.

**9:30 Innovating and Delivering EV Battery Performance in the Age of Hype**

*Sponsored by* ENEVATE

*Benjamin Park, PhD, Founder & CTO, Enevate Corporation*

Enevate's will discuss updated data on its single-active-material and proprietary electrolyte and silicon-dominant cells designs for use in electric vehicles. Extreme fast charge with high energy density, low temperature performance and other data will be presented that shows efficacy of the developed technology in addressing the many barriers in customer adoption of EVs.

**10:00 Coffee Break in the Exhibit Hall with Poster Viewing**

**10:45 60 Is the New 20: Challenges as a Result of Increasing EV Battery Capacities**

*Matthias Vetter, PhD, Head of Department, Electrical Energy Storage, Fraunhofer Institute for Solar Energy Systems ISE*

Based on the discussion of cruising ranges, battery capacities of EVs are increasing.

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These developments result in challenges for the EV itself but also for the grid infrastructure. This presentation will highlight these topics and provide alternative approaches.

**11:15 12V and 48 V LMO-LTO Energy Storage for Micro and Mild Hybrids**
*Vaselin Manev, PhD, Senior Technical Director, LTO Technology, XALT Energy*
The presentation will review XALT achievement in development of 12 V and 48 V micro and mild hybrid batteries using LMO-LTO technology. The presentation will also report the progress in development of 12 V start stop LMO-LTO battery under 4.7M contract with USABC, project DE-EE0006250. It will be in particular emphasized in the outstanding high temperature cycle and calendar life performance of XALT LMO-LTO battery technology combined with very good cold cranking performance at -30oC.

**11:45 FEATURED PRESENTATION: New Safe and Long Life Fast Charging Protocols for LIB**
*Rachid Yazami, PhD, School of Materials Science & Engineering, Program Director, Energy Storage, Energy Research Institute, Nanyang Technological University, Singapore; Founding Director, KVI PTE LTD*
We developed two methods for fast charging lithium ion batteries: a "natural charging" method and a "cascade pulse" method enabling full charging between 1h and 10 min without cell' deterioration. In "natural charging" we applied a loop between charger and cell is applied so as the cell can take charge only what kinetically is allowed. In the cascade pulse method several pulses are applied with decreasing rates followed by rest.

**12:15 pm Networking Plated Luncheon**
*Sponsored by* EVE 亿纬锂能

**1:15 Dessert Break in the Exhibit Hall with Poster Viewing**

**1:45 Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

**3:40 Close of Conference**

# SHEP WOLSKY BATTERY INNOVATOR AWARD

The 36th International Battery Seminar & Exhibit is seeking submissions for its **5th Annual Shep Wolsky Battery Innovator Award.** The award seeks to recognize innovative advances of applied battery technology at the chemistry or product level. The award is named after Shep Wolsky, the International Battery Seminar's founder, in recognition of his tremendous contributions to the field over so many years. Judged by a team of leading industry experts, the winner will be announced on Wednesday, March 27 at 1:45pm during the Plenary Keynote Program. The winner will receive a trophy and cash award. Full details including entry forms are available at InternationalBatterySeminar.com.

APPLICATIONS STREAM

# Battery Power for Consumer Electronics

## Increasing Performance & Safety of Batteries for Portable Devices

MARCH 27-28, 2019 | FORT LAUDERDALE, FLORIDA

## WEDNESDAY, MARCH 27

**1:45 pm Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

### OEM APPLICATION-DRIVEN DEVELOPMENT

**3:40 Organizer's Opening Remarks**
*Craig Wohlers, Executive Director, Conferences, Cambridge EnerTech*

**3:45 Chairperson's Remarks**
*Brian Barnett, President, Battery Perspectives*

**3:50 Requirement and Forecast of Li-Ion Battery for Portable Home Appliances**
*Chia-Ying Lee, PhD, Principal Battery Engineer, SharkNinja*
With suitable battery designs to electrify home appliances, new categories of Li-ion battery applications are emerging. However, there are still design challenges that need to be solved by both the battery and appliance companies. To address that, two topics will be discussed during this presentation: 1) The latest development status and battery requirements for cordless vacuums 2) Trend forecasting of Li-ion battery in future home appliances.

**4:20 Battery Innovation Driving Consumer Experience**
*Rick Thompson, Chief Battery Technologist, Dell Technologies*
Expectations for mobile electronics continue to evolve. Battery will remain a core piece of the customer experience. This talk will address components of "worry free" mobile power, device level battery management, and product opportunities for advanced battery technology.

**4:50 Next Generation Battery Management Using AI for Consumer Devices**
*Jeremy Carlson, Battery Technology Engineer, Lenovo*
As battery energy density continues to increase in consumer devices, the need for individualized battery management becomes increasingly necessary. Rather than a one-size-fits-all approach, cloud-based or local AI can deliver an individualized battery experience based on the user's habits. This methodology can be used to increase battery performance and longevity as well as the best user experience for the customer.

**5:20 Dinner Tutorial Registration***

**5:45 – 7:45 Dinner Tutorial***
**Click here for Tutorial details. Separate registration required.*

**7:45 Close of Day**

## THURSDAY, MARCH 28

**7:30 am Registration Open**

**7:45 Interactive Breakout Discussion Groups with Continental Breakfast (See website for details.)**

**8:45 Session Break**

### OEM APPLICATION-DRIVEN DEVELOPMENT

**9:00 Chairperson's Remarks**
*Bill von Novak, Principal Engineer, Qualcomm*

**9:05 Advancement in Power Battery Technology for Consumer Markets**
*Mattias Simonsson, Channel Manager, Stanley, Black and Decker*
The ever increasing need for longer run time and more power keeps pushing the envelope for what can be accomplished with battery technology. A combination of cell construction changes, advancements in chemistry and innovation in battery pack design is enabling batteries to do what previously could only be done with power cords or gasoline combustion engines.

**9:35 Introduction to Medtronic 2nd Generation Rechargeable Battery Technology**
*Hui Ye, PhD, Senior Principal Scientist, Medtronic*
Medtronic's 2nd gen rechargeable Li ion battery Overdrive, released with the Intellis spinal cord stimulators, offers many breakthrough patient-friendly attributes. Overdrive allows recharge from empty to full in less than one hour and offers less than 5% capacity fade after continuous 9 years of operation under most demanding use conditions. This presentation will discuss the design philosophy of Overdrive battery chemistry, and the strategy to test and predict its performance over time.

**10:05 Development of Rechargeable Alkaline Silver-Zinc Microbatteries for Medical and Consumer Devices**
*Sponsored by* ZPOWER
*Timothy Powers Director, Applications Engineering Engineering ZPower, LLC*
Known for its stability and high energy density, silver-zinc batteries have been used by NASA and the military for mission-critical applications for years, including the Apollo missions, submarine torpedoes, and other underwater submersible craft. Innovation by ZPower in the miniaturization of aqueous silver-zinc microbatteries have enabled improvements in cycle life, rendering the technology useable for medical and consumer devices. Rechargeable silver-zinc alkaline batteries by ZPower allow for a reliable and safe alternative, especially with regard to body-worn applications.

**10:35 Coffee Break in the Exhibit Hall with Poster Viewing**

## INNOVATION & DESIGN IN NEXT-GEN CONSUMER ELECTRONICS APPLICATIONS

**11:20 Studying Lithium Ion Battery Behavior to Deliver Better User Experience**

*Kamal Shah, Director, Platform Architecture Management Client Computing Group, Intel Corp; Chairman, Mobile PC Extended Battery Life Working Group, EBLWG*

Mobile devices such as smartphone, laptops, etc. are an integral part of our modern lives. Delivering better user experiences require holistic approach which includes comprehending the battery's ability to support improved user experiences. This presentation discusses motivation to understand battery behavior to support better user experiences, results of some of the experiments on batteries ability to supply power needed, as well as wear out impact and results of experiments based on revised discharge profiles.

**11:50 Adaption of System Design to High Voltage Li-Ion Battery Technology**

*Jeff Bruce, Director, Battery Technologies, Microsoft*

With the continued development and implementation of high voltage chemistries (e.g., above 4.2V), the consumer electronics industry faces new challenges from rapid gas generation and cell swelling. In the era of high-voltage chemistries, many factors could have visible impact on battery degradations, including capacity fading and cell swelling. Here, we discuss cause and effect, some methods of mitigation through system design, and the role that the end user can have in mitigating or prevention of accelerated degradation.

**12:20 pm Charging Lithium Ion Batteries with Qualcomm Quickcharge**

*Bill von Novak, Principal Engineer, Qualcomm*

Rapid charging of lithium ion batteries has recently become possible due to changes in battery design allowing greater than 1C charge rates. However, rapid charging requires sufficient power to achieve those greater than 1C rates – and often charge current is limited by connector design and wire-gauge limitations in charging accessories. This talk will describe how to use Qualcomm's Quickcharge technologies to overcome these limitations and allow very high charge rates with standard device connectors.

**12:50 Walking Luncheon in the Exhibit Hall with Poster Viewing or Plated Luncheon in the Exhibit Hall Foyer** *(Sponsorship Opportunity Available)*

**1:50 Dessert Break in the Exhibit Hall with Poster Viewing**

## INNOVATION & DESIGN IN NEXT-GEN CONSUMER ELECTRONICS APPLICATIONS

**2:20 Chairperson's Remarks**

*Kamal Shah, Director, Platform Architecture Management Client Computing Group, Intel Corp; Chairman, Mobile PC Extended Battery Life Working Group, EBLWG*

**2:25 3D Cell Architecture Enables a High-Capacity Silicon Anode: Over 900 Wh/l Energy Density and 500 Cycle Life**

*Murali Ramasubramanian, Vice President, R&D, Enovix*

A silicon anode can significantly increase the energy density of a Li-ion battery. But silicon swells up to 400% upon initial lithium absorption, has low-formation efficiency, and shrinks-and-swells externally with each charge-discharge cycle. This causes a Li-ion battery to break apart after a few cycles. Enovix has developed unique, patented 3D cell architecture that contains silicon expansion within the cell core and maintains high cell-stack pressure to eliminate external swelling. It also enables an efficient, scalable pre-lithiation process to overcome low-formation efficiency. The result is a smartphone-sized Li-ion battery with packaged energy density over 900 Wh/l and cycle life over 500 produced with commercially available Si powders using a conventional roll-to-roll process.

**2:55 Life-Enhancing Advancements in Batteries for Implantable Medical Devices**

*Robert Rubino, Director, R&D, Greatbatch Medical, Integer*

Active implantable medical devices, such as pacemakers, have been successfully powered by implanted batteries for 60 years. The success of the pacemaker has fueled the development of multiple other types of devices such as defibrillators, sensors, and neurostimulators. In order to enable and improve these life-enhancing devices, power technologies have evolved to provide reliable and improved output resulting in more patient-friendly devices with enhanced functionality.

**3:25 Optical Sensing of Battery Faults**

*Jon Cartlidge, Commercial Manager, Consumer and Industrial Products, Battelle*

In this talk, we will discuss the competing requirements for selecting waveguide materials that meet battery and optical requirements, designing devices for sufficient light transmission, and results from a series of tests. Implications for design in operating commercial scale batteries will be discussed, including design revisions to leverage low-cost components available from the telecommunications and medical device industries.

**3:55 Wearables – Differences in Evaluating Cell Quality When Downsizing Capacity**

*Alexandra Emly, PhD, Manager, Exponent*

Lithium-ion batteries are gaining a stronghold in the wearables market for their energy density and light weight. Although the lower energy also correlates with potentially less catastrophic failures, lower energy also means that out-of-the-box tests used for evaluating safety of larger lithium-ion cells don't work well in accurately evaluating cell safety. This talk will discuss differences to consider when sourcing and vetting small lithium-ion cells.

**4:25 Networking Refreshment Break**

**4:40 Plenary Keynote Program (Click here for details.)**

**5:45 Close of Conference**

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APPLICATIONS STREAM

# Alternative Applications in Energy Storage

## Meeting Evolving and Increasing Energy Storage Demands

MARCH 27-28, 2019 | FORT LAUDERDALE, FLORIDA

## WEDNESDAY, MARCH 27

**1:45 pm Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

## NEW APPLICATIONS DEMAND NEW FUNCTIONS

**3:40 Organizer's Opening Remarks**
*Mary Ann Brown, Executive Director, Conferences, Cambridge EnerTech*

**3:45 Chairperson's Remarks**
*Amy Marschilok, PhD, University Instructional Specialist, Research Associate Professor, Materials Science and Engineering & Research Professor, Chemistry, Stony Brook University; Joint Appointee, Brookhaven National Laboratory*

**3:50 An Argument for Basic Battery Science: Each Time an Application Demands a New Battery Chemistry to Achieve Previously Unrealized Functionality, a New Fundamental Understanding Is Required**
*Amy Marschilok, PhD, University Instructional Specialist, Research Associate Professor, Materials Science and Engineering & Research Professor, Chemistry, Stony Brook University; Joint Appointee, Brookhaven National Laboratory*
Battery science must be explored both fundamentally and with an understanding of application-specific demands, to achieve relevant and previously unrealized functionality of energy storage materials and to facilitate deliberate design of systems with the desired characteristics. This presentation includes case studies to illustrate this point in several applications enabled by electrochemical energy storage solutions.

**4:20 Longevity and Economics of Battery Power for Seismic Nodes**
*Timothy Betzner, PhD, Research Scientist, Systems Division, Fairfield Geotechnologies*
Autonomous seismic sensor nodes, alternatives for traditional geophysical exploration, rest on the seabed for weeks per deployment, recording earth echoes indicative of fossil fuels and minerals. Nodes contain up to 400 commercial lithium-ion cells, which, over eight years, experience unique marine degradation conditions. Capacity testing, AutoLion simulation, and Weibull statistical modeling were combined with node manufacturing history to determine an economic battery replacement schedule.

**4:50 Characterizing and Simulating Batteries for IoT Applications**
*Bradley Odhner, Applications Engineer, Keithley Instruments, Tektronix*
Battery simulation grants designers the ability to repeatably and reliably test their devices under realistic conditions, besides a simple cost savings in the battery budget. Simulating accurately often requires knowledge of how the battery will react to a device's unique current draw and low level continuous current drain. This talk explores the difficulties and solutions of battery simulation.

**5:20 Dinner Tutorial Registration***

**5:45 – 7:45 Dinner Tutorial***
**Click here for Tutorial details. Separate registration required.*

**7:45 Close of Day**

## THURSDAY, MARCH 28

**7:30 am Registration Open**

**7:45 Interactive Breakout Discussion Groups with Continental Breakfast (See website for details.)**

**8:45 Session Break**

## LARGE-SCALE ENERGY STORAGE

**9:00 Chairperson's Remarks**
*Kevin Fok, Director, Operations, LG Chem Michigan, Inc.*

**9:05 KEYNOTE PRESENTATION: Towards Profitable Sustainability: The Liquid Metal Battery**
*Donald R. Sadoway, PhD, John F. Elliott Professor of Materials Chemistry, Department of Materials Science and Engineering, Massachusetts Institute of Technology*
The liquid metal battery offers colossal current capability and long service lifetime at very low cost. The roundtrip efficiency is greater than 80% under daily 4 h discharge (C/4) with fade rates of 0.00009%/cycle, which means retention of >99% of initial capacity after 10 years. There is much to be learned from the innovative process that led to the discovery of disruptive battery technology.

**9:35 Battery Energy Storage Roadmap – Market and Technology since 2008**
*Michael Liu, Director, Energy Storage, BYD America Corp.*
A quick overview on what in the stationary storage industry has evolved since 2018, what industry was looking for back then, and what was available back then. We use some typical examples of the time to provide an idea of how the technology has improved and of increasing markets that are services.

**10:05 Understanding and Formulations of Material Selection for Battery Pack Designs**
Sponsored by wevo
*Terence Kearns, Mr. Business Development Manager, Business Development, WEVO-CHEMIE GmbH*
WEVO Chemical Corporation, years of research and amassed data from customers,

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applications and industry stakeholders, has complied a simpler guide for material selection. Explain the key attributes and boundaries of each chemistry. Considerations for processing and the consequent disparate influences. Formulated into an easy to understand engineering format.

**10:35 Coffee Break in the Exhibit Hall with Poster Viewing**

**11:20 Energy Storage System Deployment and Implementation**

*Kevin Fok, Director, Operations, LG Chem Michigan, Inc.*

This presentation discusses the deployment of energy storage systems and recent trends based on current, in-field experiences. As energy storage systems continue to be installed not only in rural and remote locations, but also in crowded, urban environments, additional considerations need to be factored in. For successful projects, it is critical to understand requirements in the rapidly growing and evolving energy storage market.

**11:50 Solar Flow Batteries: Integrated Solar Energy Conversion and Redox Flow Battery Devices**

*Wenjie Li, Research Scientist, Song Jin Laboratory, Department of Chemistry, University of Wisconsin-Madison*

Practical solar energy utilization systems demand efficient solar energy conversion and inexpensive large-scale energy storage. Combining both functions into a single integrated device represents a more efficient, compact and cost-effective approach to utilize solar energy. We have developed novel and highly efficient hybrid solar-charged storage devices that integrate regenerative solar cells and redox flow batteries (RFBs) that share the same pair of redox couples.

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**12:20 pm FEATURED PRESENTATION: Aqueous Sodium-Ion Batteries**

*Jay F. Whitacre, PhD, Professor, Materials Science and Engineering, Engineering and Public Policy, Carnegie Mellon University; Founder & Chief Scientist, Aquion Energy*

This talk will explore the promise and inherent limitations associated with the inception and scale up of several different neutral pH, aqueous sodium-ion electrolyte battery chemistries. While there are appealing attributes to be considered, techno-economic and supply chain analyses show that achieving solutions with sufficiently low cost is extremely challenging.

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**12:50 Walking Luncheon in the Exhibit Hall with Poster Viewing or Plated Luncheon in the Exhibit Hall Foyer** *(Sponsorship Opportunity Available)*

**1:50 Dessert Break in the Exhibit Hall with Poster Viewing**

## MICROBATTERIES

**2:20 Chairperson's Remarks**

*James J. Watkins, PhD, Professor, Polymer Science and Engineering; Director, NSF Center for Hierarchical Manufacturing, Polymer Science and Engineering Department, University of Massachusetts, Amherst*

**2:25 Thin Film Polymer Electrolytes in Lithium Batteries**

*Wyatt Tenhaeff, PhD, Assistant Professor, Department of Chemical Engineering, University of Rochester*

Carefully engineering the surface chemistry of lithium-ion battery electrodes is necessary for the development of safe, stable, high-energy-density cells. The application of ultrathin film coatings is an important strategy used to mediate electrochemical reactions. This talk describes work in our group using surface-initiated atom transfer radical polymerization and initiated chemical vapor deposition to synthesize polymer thin film electrode coatings to study how polymer chemistry and film morphology influence key electrode processes.

**2:55 Scalable Fabrication of High-Power Lithium-Ion Microbatteries via Imprinting of 3D Electrodes Using Nanoparticle Inks**

*James J. Watkins, PhD, Professor, Polymer Science and Engineering; Director, NSF Center for Hierarchical Manufacturing, Polymer Science and Engineering Department, University of Massachusetts, Amherst*

Microbatteries based on 3D electrode architectures hold great promise but their practical realization is limited by strict material requirements and significant hierarchical processing complexities. We fabricated a fully integrated 3D lithium-ion microbattery using sub-10 nm $LiMn_2O_4$/$Li_4Ti_5O_{12}$ nanocrystals and a novel copolymer gel electrolyte that possess superior capacity retention (40% at 300 C) and high-power density (855.5 $\mu Wcm^{-2}\mu m^{-1}$) comparable to some of the best microsupercapacitors. The microelectrodes are fabricated by scalable solvent-assisted imprint lithography using nanoparticle inks and the battery cell is integrated vertically through layer-by-layer (LBL) assembly.

**3:25 Batteries for Novel Medical Applications Based on Wafer-Level Processing**

*Robert Hahn, PhD, Senior Scientist, Micro Energy Group, Fraunhofer IZM*

Several emerging innovations in the medical and health sector require extremely miniaturized batteries and special form factors. A technology was developed that combines advanced silicon wafer-level packaging and microprint and dispense processes to fabricate thousands of small batteries in parallel on a substrate. While standard lithium-ion electrode materials are used adaptions were made for the electrolyte to reduce the vapor pressure. Special fabrications technologies have been developed like high-speed particle jetting for active materials and electrophoretic deposition for the simultaneous fabrication of separators.

## SUPERCAPACITORS

**3:55 Exploring Threefold Specific Energy in Novel Activated Carbons**

*Bettina Fuchs, Dr. rer. nat., Postdoctoral Researcher, Fuel Cells Fundamentals, Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW)*

We introduce novel activated carbons (AC) with capacities of 146 mAh/g @ 1C and 60 mAh/g @ 850 C load in aqueous-alkaline electrolytes. This outstanding electrochemical performance is linked to the surface chemistry and porosity of the novel ACs. A high-power Ni(OH)2/AC fuel cell with 10 Wh/kg demonstrates their promising application potential.

**4:25 Networking Refreshment Break**

**4:40 Plenary Keynote Program (Click here for details.)**

**5:45 Close of Conference**

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ENGINEERING STREAM

# Battery Safety

## Battery Testing & Regulations

**MARCH 26-27, 2019 | FORT LAUDERDALE, FLORIDA**

## MONDAY, MARCH 25

**7:00 am – 3:00 pm Tutorial and Training Seminar* Registration Open**

**7:00 – 8:00 am Morning Coffee**

**8:00 am – 4:00 pm Pre-Conference Tutorials and Training Seminar***

**4:00 Close of Day**

** Click here for Tutorial and Training Seminar details. Separate registration required for Tutorials and Training Seminar.*

## TUESDAY, MARCH 26

**7:00 am Registration and Morning Coffee**

## NEW BATTERY REGULATIONS & STANDARDS

**8:05 Organizer's Opening Remarks**

*Victoria Mosolgo, Conference Producer, Cambridge EnerTech*

**8:10 Chairperson's Remarks**

*Cynthia Millsaps, President and CEO, Quality, Energy Assurance LLC*

**8:15 Battery Regulations for "Drop-In" Lithium-Ion Batteries**

*Cynthia Millsaps, President and CEO, Quality, Energy Assurance LLC*

In recent years, there are more and more applications moving to Li-ion as a replacement for the older lead acid technology. In many cases, a single battery form factor and design can be used in multiple different "drop-in" applications. However, from a standards point of view, there may be a need to apply more than 1 set of tests to the same battery based on the application it is used in. Also, it is not as clear what/who will be driving the need for standards testing and certification in various regions for these types of batteries.

**8:45 Safer Battery Powered Consumer Products**

*Douglas Lee, Directorate for Engineering Sciences, U.S. Consumer for Product Safety Commission*

**9:15 Advancing Battery Tech Innovations Through Safety**

*Sponsored by* UL

*Michael Sakamoto, Senior Business Development Manager, Consumer Technology Division, UL LLC*

With battery technologies enabling devices that promote mobility, convenience, and innovation for consumers, there has been a rapid and steady emergence of products where battery and its end device design elements have become critical for defining safe use and operation. UL has pursued to look at these devices, and with their public safety mission in mind, have developed industry standards that promote safer design practices. This presentation will cover few of those examples.

**9:45 Networking Coffee Break**

## MITIGATING THERMAL RUNAWAY

**10:15 Chairperson's Remarks**

*William Q. Walker, PhD, Aerospace Technologist, Engineering Directorate (EA), Structural Engineering Division (ES), Thermal Design Branch (ES3), NASA Johnson Space Center*

**10:20 Combining Fractional Calorimetry with Statistical Methods to Characterize Thermal Runaway**

*William Q. Walker, PhD, Aerospace Technologist, Engineering Directorate (EA), Structural Engineering Division (ES), Thermal Design Branch (ES3), NASA Johnson Space Center*

Fractional thermal runaway calorimetry (FTRC) techniques were introduced to examine thermal runaway (TR) behavior of Lithium-ion (Li-ion) cells. Specifically, FTRC considers the total energy released vs. the fraction of the total energy that is released through the cell casing versus through the ejecta material. The original FTRC device was designed to accommodate 18650-format Li-ion cells. This device has been expanded to universally support FTRC testing of additional cell types including 21700-format, D-Cell format, and large prismatic format Li-ion cells. The TR behavior as influenced by cell format, manufacturer, chemistry, capacity, and *in situ* safety features are described in this presentation.

**10:50 Predicting Thermal Propagation Using an Uncertainty Quantification Framework**

*Kevin Marr, PhD, Research Engineer, Mechanical Engineering, University of Texas at Austin*

This presentation will detail an experimental and modeling framework that utilizes an uncertainty quantification (UQ) methodology to predict and evaluate thermal propagation in battery modules. In this framework, small-scale abuse tests of single and multi-cell tests are conducted. Thermal properties and kinetic parameters are estimated using inversion methods and are then used as input parameters to thermal-chemical models to predict the thermal propagation in a full-scale battery.

**11:20 Integrated Multiphysics Modeling for Improving Li-Ion Battery Pack Safety**

*Chuanbo Yang, PhD, Energy Storage Engineer, Vehicle Electrification Group, Transportation and Hydrogen Systems Center, National Renewable Energy Laboratory (NREL)*

Battery CAE tools are effective in evaluating safety design concepts and identify key design parameters preventing cascading failures among batteries. An integrated multiphysics safety modeling framework is developed for large format lithium-ion batteries and applied to provide insights into battery pack behaviors subject to internal short circuits. The impact of the energy released by failed battery cells in the form of gas and ejecta on pack safety is addressed in this numerical approach.

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**11:50 Co-Presentation: Minimizing Risk in Fielded Lithium-Ion Battery Cells with Cell Screening Technology** *Sponsored by* CAMX Power

*Robert Fricke, Senior Advisor, Adjunct Director, CAMX Power*

*Suresh Sriramulu, PhD, Head of Development CAMX Power*

Lithium-ion battery safety events in fielded cells have shown the immense downside associated with a single cell failure. To minimize this risk, CAMX Power's Cell Screening Technology (CST) can efficiently and reliably detect the presence of internal short-circuits in LIB cells. This talk will discuss the current readiness and potential uses of CST, as well as other short-detection technologies currently in development.

**12:20 pm Grand Opening Networking Luncheon in the Exhibit Hall** *Sponsored by* Tektronix

**1:25 Plenary Keynote Program (Click here for details.)**

**2:30 Dessert Break in the Exhibit Hall with Poster Viewing**

## MONITORING SOH/SOC AND PREVENTING THERMAL RUNAWAY

**3:15 Chairperson's Remarks**

*Brett Huhman, PhD, Electrical Engineer, Plasma Physics Division, US Naval Research Laboratory*

**3:20 A Single-Frequency Impedance Diagnostic for State of Health Determination in Li-Ion 4P1S Battery Packs**

*Brett Huhman, PhD, Electrical Engineer, Plasma Physics Division, US Naval Research Laboratory*

A series of experiments were performed to evaluate the performance of a 4P1S battery array using electrochemical impedance spectroscopy to identify key frequencies that may describe battery state of health at any state of charge. The experiment established that discharging batteries in parallel at high C rates resulted in a 75.32% reduction in life compared to operating solo as well as an operating envelope to evaluate battery health. Additionally, a post-mortem analysis of cells from three configurations (baseline, single-cell, and parallel-cell) demonstrated physical damage to the copper current collector in the anode in the parallel-connected cell.

**3:50 Development of a Safe, Lightweight Li-Ion 28V Battery for Navy Aircraft Applications**

*Trung Nguyen, PhD, Vice President, Aircraft Power Sources, EIC Laboratories, Inc.*

Lithium-ion batteries, with their high power and energy density, long cycle life, and low self-discharge rate, are an attractive alternative to meet immediate on-board equipment power needs. In comparison with well-established lead-acid and nickel-cadmium batteries, Li-ion batteries offer significant advantages: decreased weight and increased capacity. EIC Laboratories, in a program sponsored by NAVAIR, has developed and qualified a safe, lightweight Li-ion 28V aircraft battery where potential thermal instabilities are eliminated.

**4:20 SafeCore by Amionx - an Internal Fuse to Prevent Thermal Runaway** *Sponsored by* AMIONX

*Jenna King, CEO, Amionx*

SafeCore by Amionx was designed to combat the major hazards associated with batteries including overcharge, internal short, and high temperature. It is a layer within the cell that acts like a fuse and can be triggered by temperature, voltage, or current. No major capital expenditures are needed to implement SafeCore

**4:35 Increasing Success & Safety applying Lean Methodologies to Battery Testing** *Sponsored by* Associated Environmental Systems

*Beran Peter, CEO,Associated Environmental Systems*

Concepts in Lean Methodologies lend naturally to safer, more efficient, battery testing. By creating a scenario for managing high-density testing in small batches, it increases safety and reduces cost per channel. Safety is increased by limiting propagation in the case of an event. Cost is reduced by utilizing standardized products.

**4:50 Welcome Reception in the Exhibit Hall with Poster Viewing**

**5:50 Interactive Breakout Discussion Groups (See website for details.)**

**6:50 Close of Day**

## WEDNESDAY, MARCH 27

**7:15 am Registration and Morning Coffee**

## TRANSPORTATION SAFETY

**8:25 Chairperson's Remarks**

*Ahmad A. Pesaran, PhD, Manager, Energy Storage Group, Transportation and Hydrogen System Center, National Renewable Energy Laboratory (NREL)*

**8:30 Analysis of Factors that Affect Thermal Failures and Propagation in Lithium-Ion Batteries**

*Steve Hwang, PhD, U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (U.S. DOT – PHMSA)*

Despite seemingly redundant regulatory frameworks designed to overcome unique safety challenges posed by conditions incident to normal transportation of lithium batteries, cell or battery failures are still occurrences of concern. This study focuses on the safety challenges pertaining to cell or battery thermal failures and failure propagation mechanisms.

**9:00 Risk Estimation of Failing Automotive Li-Ion Batteries**

*Christiane Essl, Researcher, Virtual Vehicle Research Center*

In this scientific contribution, the influence of increasing energy density on the chemical reactions and the cell behavior in failure cases will be presented, examples of LIB failures will be provided, and risks will be discussed. Beside the amount and the composition of the evolving gases of a failing Li-ion cell at different energy density, information about the resulting particles will be given.

**9:30 Understanding Regulatory Hurdles to Installing Battery Systems in Buildings - An Overview of Codes & Standards**

*Laurie Florence, Principal Engineer, Commercial & Industrial, EP & T, UL LLC*

This presentation is intended to provide the audience with an overview of the various model codes and standards that will impact the installation of battery systems and battery energy storage systems in the built environment. Critical model codes such as the NEC and the Fire Codes have been updated to better address battery energy storage systems that are being deployed in areas that are subject approval by authorities having jurisdiction (AHJs). These model codes are placing limitation on

sizes, locations and type of systems that can be deployed and often requiring that the systems be "Listed" to an appropriate standard. In addition, to the development of new code criteria, there have been development of safety standards to address these systems and that can be used to list the system in accordance with code requirements. These standards include UL 1973, the ANSI standard for stationary batteries and UL 9540, the ANSI and Canadian National Standard for energy storage systems as well as UL 9540A, which was developed to address large scale fault and fire testing options written into the fire codes.

**10:00 Coffee Break in the Exhibit Hall with Poster Viewing**

## SAFETY OF SECOND LIFE BATTERIES

**10:45 Safety of Aged Pouch Format Lithium-Ion Cells**

*Judith Jeevarajan, PhD, Research Director, Electrochemical Safety, Underwriters Laboratories, Inc.*

The Phase I of our study on aging and safety included the testing of lithium-ion cells of cylindrical format in metal cans that include internal protective features. Pouch format cells do not contain such internal protective features and the safety behavior is very different from the cylindrical format. Results of off-nominal tests such as overcharge and external short on fresh cells and cells that have aged and at various levels of capacity loss will be presented. Results from the destructive analysis of the fresh and aged cells will also be presented.

**11:15 Determining Safety of Second Life Batteries**

*Shriram Santhanagopalan, PhD, Engineer, Transportation and Hydrogen Systems Center, National Renewable Energy Laboratory*

This presentation will detail the NREL methods for determining safety of recycled batteries as well as requirements for recycling.

**11:45 PANEL DISCUSSION: Safety Aspects of Li-Ion Battery Collection, Storage, Shipping for Recycling**

*Moderator: Ahmad A. Pesaran, PhD, Chief Engineer, Energy Storage, Transportation and Hydrogen System Center, National Renewable Energy Laboratory (NREL)*

The panel will discuss the recently launched US Department of Energy's Li-Ion Battery Recycling Prize that intends to significantly enhance collection, storage, sorting, and transporting end of life or spent batteries from various applications (including consumer electronics, electric vehicles, and industrial) for eventual recycling and recovery of critical minerals for reintroduction into the supply chain. This panel will focus on one important aspect of the Prize, which is rendering batteries safe or inert during collection, sorting, storage, and shipping to reduce the cost of recycling of Li-Ion batteries.

**12:15 pm Networking Plated Luncheon**

*Sponsored by* EVE 亿纬锂能

**1:15 Dessert Break in the Exhibit Hall with Poster Viewing**

**1:45 Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

**3:40 Close of Conference**

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ENGINEERING STREAM

# Battery Management Systems

## Engineering Reliability and Robustness

MARCH 27-28, 2019 | FORT LAUDERDALE, FLORIDA

## WEDNESDAY, MARCH 27

**1:45 pm Plenary Keynote Program (Click here for details.)**

**2:55 Refreshment Break in the Exhibit Hall with Poster Viewing**

## NEW OUTLOOKS ON BATTERY MANAGEMENT SYSTEMS

**3:40 Organizer's Opening Remarks**
*Victoria Mosolgo, Conference Producer, Cambridge EnerTech*

**3:45 Chairperson's Remarks**
*Anil Paryani, CEO, CTO, Automotive Power, Inc.*

**3:50 A New Paradigm of Lithium-Ion Batteries**
*Chao-Yang Wang, PhD, William E. Diefenderfer Chair Professor, Pennsylvania State University*

**4:20 Software First Approach to BMS**
*Anil Paryani, CEO, CTO, Automotive Power, Inc.*
There are many types of balancing hardware and software architectures for lithium battery packs. Passive bleed and active (inductive) balancing circuits are considered. For controls, different strategies are employed for EVs vs. HEVs.

**4:50 Strain-Enabled Multi-Physical Models of Li-Ion Battery Cells for Control and State Estimation**
*Bogdan Epureanu, PhD, Professor, Mechanical Engineering, University of Michigan*
This presentation focuses on recent results of creating multiphysical models that enable the use of strain to enhance control and state estimation of battery cells. This model can capture electrical, thermal, and mechanical behaviors of battery cells.

**5:20 Dinner Tutorial Registration***

**5:45 – 7:45 Dinner Tutorial***
** Click here for Tutorial details. Separate registration required.*

**7:45 Close of Day**

## THURSDAY, MARCH 28

**7:30 am Registration Open**

**7:45 Interactive Breakout Discussion Groups with Continental Breakfast (See website for details.)**

**8:45 Session Break**

## BMS MODELING & CONTROLS

**9:00 Chairperson's Remarks**
*Brian Barnett, President, Battery Perspectives*

**9:05 Advances in Methods to Generate Reduced-Order Physics-Based Li-Ion Cell Models for BMS Controls**
*Gregory Plett, PhD, Professor, Electrical and Computer Engineering, University of Colorado, Colorado Springs*
Equivalent-circuit models cannot predict internal cell dynamics and hence cannot be used by next-generation controls to predict the onset of degradation behaviors and therefore mitigate aging. Physics-based models must be used. And, these models must be computationally simplified for practical application. Methods are needed to convert high-complexity physics-based models into reduced-order models. This presentation will show advances in methods to create reduced-order physics-based models. This is an important enabler of using physics-based models in BMS.

**9:35 A Multi-Cell Battery-Management Approach to Ease Performance Restrictions Imposed by Weakest Cell**
*Scott Trimboli, PhD, Associate Professor, Electrical and Computer Engineering, University of Colorado, Colorado Springs*
This presentation describes a novel multi-cell control approach (implemented in the context of an active-balancing architecture) that monitors individual cell behavior and acts to reduce the limiting effect of the weakest cell on overall pack performance.

**10:05 Battery Performance and the Internet of Things**
*Sponsored by* Tektronix
*Wilson Lee, Senior Technical Marketing Manager, Marketing, Tektronix, Inc.*
The Internet of Things affects all aspects of our lives in one way or another. Battery performance – specifically battery life cycle – is a key enabler in this paradigm. Designers are needing to precisely and reliably measure, simulate and model battery life cycles in the presence of very small current requirements. Attendees will come away better being able to meet the challenges on selecting and qualifying low power components, and reliably measuring power consumption.

**10:35 Coffee Break in the Exhibit Hall with Poster Viewing**

**11:20 Improved Cell Behavior Understanding for Better Parametrized Control Models**
*Yatish Patel, PhD, Research Fellow, Department of Mechanical Engineering, Imperial College of London*
Presented is a novel adiabatic experimental procedure which investigates cell heat generation, independent of other parameters such as state of charge and internal cell

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concentration gradients. This facilitates an assessment of the impact of temperature on the cell's performance.

**11:50 Power Electronic-Based Active Battery Energy Management Solutions for E-Transportation and Autonomous E-Mobility**
*Sheldon Williamson, PhD, Associate Professor, University of Ontario*
Fundamental topologies of power electronic converters, specifically utilized for bidirectional current flow in cell balancing applications, will be discussed. The design, implementation, and testing/validation of an active cell equalization circuit for a traction Li-ion battery pack will also be presented.

**12:20 pm Effective Battery Control Instead of Monitoring and Balancing the Death of the Battery**
*Hans Harjung, CEO, e-moove GmbH*
Monitoring and balancing has been state-of-the-art in battery management (BMS) for decades. In fact, this means monitoring the death of the battery. Effective battery control (ebc) is controlling all cells according to their individual state-of-health (SoH) and aging parameters. This leads to a maximum lifetime and performance of the battery pack combined with highest safety.

**12:50 Walking Luncheon in the Exhibit Hall with Poster Viewing or Plated Luncheon in the Exhibit Hall Foyer** *(Sponsorship Opportunity Available)*

**1:50 Dessert Break in the Exhibit Hall with Poster Viewing**

## LIFE & RELIABILITY

**2:20 Chairperson's Remarks**
*Thomas Waldmann, PhD, Accumulators Materials Research, ZSW*

**2:25 TIM Materials for Battery Systems**
*Sponsored by* Henkel
*Sarah Querelle-Halverson, Research and Development Manager, Product Development, Henkel Corporation*
Continued advancement in battery technology has resulted in higher power and energy densities. Comprehensive thermal management at the cell, pack, and module level is needed for reliable, long-term operation. Thermal interface materials (TIMs), comprising a polymer matrix and thermally conductive fillers, are an integral part of the battery system design. Besides thermal transport, TIMs need to have tailored properties that address manufacturing automation, mechanical robustness, and high reliability through accelerated aging. This presentation provides an overview of, and challenges associated with, the development of new TIMs.

**2:55 Instrumented Commercial Lithium Batteries**
*Rohit Bhagat, PhD, Chair of Electrochemical Energy Storage, Institute of Future Transport and Cities, Coventry University*
This presentation focuses on utilisation of embedded reference electrodes, fibre optics and sensors within commercial 18650 lithium-ion cells. These instrumented cells are then used to conduct *in operando* investigations of lithium battery safety by giving real-time information on the internal state of the battery.

**3:25 Lithium Plating: A Critical Side Reaction in Lithium-Ion Cells**
*Thomas Waldmann, PhD, Accumulators Materials Research, ZSW*
This presentation will detail the following: How lithium plating affects lifetime and safety, how to predict lithium plating, how to avoid lithium plating, how to select charging protocols to avoid lithium plating.

**3:55 Special considerations in Battery Management for Industrial Applications**
*Yevgen Barsukov, Head of Algorithm Development, Battery Management Systems, Texas Instruments*
While battery gauging, protection and smart charging are common in both portable and in industrial applications, certain aspects of these functions have higher importance for industrial applications. State of health indication is particularly important because efficient use of the devices in industrial environment requires timely replacement before the device can fail and cause disruption in manufacturing. Since majority of devices use DC/DC converters resulting in constant voltage at the device input, they effectively operate in constant power mode rather than constant current mode. This makes it critical to provide Wh battery remaining capacity based information both for estimating SOC, run-time and state of health. This is particularly important for low temperature operation common in industrial applications, where energy loss of the battery is significant. In addition, high longevity is critical for many industrial applications, because it translates to lower cost of ownership. MaxLife technology allows to extend predictable linear degradation rate and useable functionality of the devices past 80% of traditional capacity loss, as it prevents exponential degradation that usually happens soon after this point. This presentation will cover these topics as well as introduce new Texas Instrument gauge and protector devices that support up to 7 serial cells and are specially suitable for high power industrial applications.

**4:25 Networking Refreshment Break**

**4:40 Plenary Keynote Program (Click here for details.)**

**5:45 Close of Conference**

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# Hotel & Travel Information

## CONFERENCE VENUE:

The Greater Ft. Lauderdale / Broward County Convention Center
1950 Eisenhower Boulevard
Fort Lauderdale, FL 33316

## HOST HOTEL:

Hilton Fort Lauderdale Marina
1881 SE 17th Street Causeway
Fort Lauderdale, FL 33316
Phone: 954-463-4000

**Discounted Room Rate:** $224 s/d
(includes complimentary Wi-Fi in sleeping room)

**Discounted Room Rate Cut-off Date:** February 22, 2019
(Approximately 3 minute walk to Convention Center)

## ADDITIONAL HOTEL:

Embassy Suites Fort Lauderdale
1100 SE 17th Street Causeway
Fort Lauderdale, FL 33316
Phone: 954-315-1325

**Discounted Room Rate:** $234 s/d
**(includes breakfast and complimentary Wi-Fi in sleeping room)**

**Discounted Room Rate Cut-off Date:** February 22, 2019
(Approximately 12 minute walk to Convention Center)

**For more information:**
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# International Battery SEMINAR & EXHIBIT

**MARCH 25-28, 2019**
Fort Lauderdale, Florida

## POSTERS

**The International Battery Seminar & Exhibit encourages attendees to gain further exposure by presenting their work in the poster sessions. To secure a poster board and inclusion in the conference materials, your abstract must be submitted, approved and your registration paid in full by February 15, 2019.**

**Reasons you should present your research poster at this conference:**
- Network with interested attendees and speakers during multiple dedicated poster viewing sessions
- Your poster abstract will be published in our conference materials
- Your research will be seen by leaders from top commercial, academic and government institutes

## ADDITIONAL REGISTRATION DETAILS

**Want to Register by Phone?**

Contact our Registration department at 781-972-5400 or Toll-free in the US 888-999-6288.

**Ways to SAVE!**

Group Discounts are Available! Special rates are available for multiple attendees from the same organization. For more information on group discounts contact Joseph Verange at jverange@cambridgeenertech.com. com or 781-247-6263.

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| BEST VALUE PRICING | | |
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| *(Includes Access to **Three** Tutorials and **Two** Conferences OR **One** Training Seminar and **Two** Conferences)* | **Commercial** | **Academic, Government** |
| Late Registration Rate After February 22 | $2599 | $1699 |

| SEMINAR ONLY PRICING | | |
|---|---|---|
| *(Includes Main Seminar Conferences Only, Does Not Include Access to Tutorials or Training Seminar)* | **Commercial** | **Academic, Government** |
| Late Registration Rate After February 22 | $1899 | $1299 |

| TUTORIAL ONLY PRICING | | |
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| *(Includes Tutorials Only, Excludes Conferences and Training Seminar)* | **Commercial** | **Academic, Government** |
| One Tutorial | $379 | $279 |
| Two Tutorials | $649 | $479 |
| Three Tutorials | $899 | $649 |
| Four Tutorials | $1099 | $799 |

| TRAINING SEMINAR ONLY PRICING | | |
|---|---|---|
| *(Includes Training Seminar Only, Excludes Conferences and Tutorials)* | **Commercial** | **Academic, Government** |
| One Training Seminar | $899 | $649 |

| STUDENT FELLOW* | |
|---|---|
| Student Fellow Pricing | $299 |

**Full-time graduate students including Masters, PhD candidates and post-docs are eligible for the student poster rate. A poster is required. Includes access to Main Seminar only, does not include Tutorials.*

| **Tutorials & Training Seminar** Monday & Wednesday |
|---|
| **TUT1:** Battery Safety and Abuse Tolerance Validation |
| **TUT2:** Materials Selection and Design for Batteries with High Energy Density, Ultralong Cycle Life and Excellent Safety |
| **TUT3:** Technoeconomic Analysis of Battery Material Development and Manufacture |
| **TUT4:** 21st Century Battery Raw Materials |
| **TUT5:** Li-ion Cell Design and Manufacturing: Processes, Equipment and Quality Control |
| **TUT6:** Advances in Solid State Batteries |
| **TUT7:** Value of LIB Secondary Use & Recycle |
| **TUT8:** Aligning Intellectual Property Strategies with R&D and Commercial Goals – Part 1 of 2 |
| **TUT9:** The Rechargeable Battery Market: Value Chain and Main Trends 2018 - 2028 |
| **TUT10:** Improving the Energy Density of Batteries with Silicon-Based Anodes |
| **TUT11:** Lithium Battery Transport Regulations: New Developments Impacting the Storage and Packaging of Lithium Batteries and a New Lithium Battery Hazard-Based Classification System for Shipping |
| ~~**TUT12:** Aligning Intellectual Property Strategies with R&D and Commercial Goals – Part 2 of 2~~ |
| **TUT13:** Advanced Battery Design and Selection Criteria for Medical Device Applications: From Implants to Surgical Tools |
| **TS1:** Lithium-Ion Battery Cell and Pack Technology |

| **Main Seminar Conferences** Tuesday-Wednesday | **Main Seminar Conferences** Wednesday-Thursday |
|---|---|
| **C1A:** Next-Generation Battery Research | **C1B:** Lithium-Ion Development & Commercialization |
| **C2A:** High Performance Battery Manufacturing | **C1B:** Lithium-Ion Development & Commercialization |
| **C3A:** Battery Power for Automotive Applications | **C3B:** Battery Power for Consumer Electronics<br>**C2B:** Alternative Applications in Energy Storage |
| **C4A:** Battery Safety | **C4B:** Battery Management Systems |

How to Register: **InternationalBatterySeminar.com**
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