Conference Program

4th Annual International Conference

Battery Safety 2013

November 14-15, 2013 • San Diego, CA USA

Advancements in Systems Design, Integration & Testing for Safety & Reliabilty

Widely publicized safety incidents, hazardous events related and recalls of lithium-ion batteries have raised legitimate concerns regarding lithium-ion battery safety across various battery systems sizes and applications, from microelectronics and medical to automotive and aero space. Battery Safety 2013 is conveniently timed with our 9th annual Lithium Battery Power 2013 and our Next Generation Batteries conference and will address the concerns of battery safety and reliability by exploring a wide spectrum of related topics including the following:

- Application specific battery safety issues affecting battery performance
  - Microbatteries
  - Batteries for electronic devices
  - Automotive batteries
  - Battery systems for military applications
  - Batteries for aviation and aero space use
  - Large scale energy storage systems

- Major battery degradation and reliability factors
- Internal shorts, thermal runaway and stability, aging, catastrophic failure, etc.
- Intelligent battery management systems
- Abuse tolerance and advanced testing procedures and protocols
- Commercial cells evaluation and failure analysis
- Improving safety trough computational methods, modeling and simulation
- High throughput testing, automation and modeling for better safety
- Standardization and regulatory issues

Knowledge Foundation

Technology Commercialization Alliance

4th Annual International Conference

Battery Safety 2013

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Nothing can substitute the benefits derived from attending **Battery Safety 2013**. But if your schedule prevents you from attending, this invaluable resource is available to you. *Note: Documentation is included with conference fee for registered delegates and live and on demand webcasts are available for download.*

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Conference Agenda

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Thursday, November 14, 2013

8:00 *Registration, Exhibit Viewing/Poster Setup, Coffee and Pastries*

8:50 **Organizer's Welcome and Opening Remarks**

9:00 **The Right Path to Safety: Chemistry or System?**

Sam Jaffe, Senior Research Analyst, Navigant Research

Does a safe battery systems come from matching a safe chemistry for a particular application or from the safety engineering built into the integrated system? The answer is both, but this presentation will look at how different firms approach the safety issue (including A123, LG Chem and Tesla) and how their approaches have impacted costs and project success.

9:30 **Battery Level Safety and Safety Validation**

Larry J. Yount, President & CTO, LaunchPoint Energy and Power - LEAP LLC

The safety of a Li-ion battery involved both chemistry and systems issues, including BMS peformance. A Safety Analyis might begin with the BMS, but must be broadened to address all battery issues, including the potential for cell-level thermal runaway.

10:00 **Characteristics of Cells before a Thermal Runaway and How to Prevent it by a Better Battery Management System (tentative title)**

Michael Pecht, PhD, PE, Director, Center of Advanced Life Cycle Engineering (CALCE) Electronics Products and Systems, Professor of Applied Mathematics, University of Maryland

James Post, Executive Product Manager, Director, Battery Condition Test International Ltd, Hong Kong

Abstract is not available at time of publishing. Please visit www.KnowledgeFoundation.com for the latest Program updates.

10:30 *Networking Refreshment Break, Exhibit/Poster Viewing*

11:00 **SENSOR: Embedded Fiber-Optic Sensing Systems for Advanced Battery Management**

Peter Kiesel, PhD, Principal Scientist, and Ajay Raghavan, Electronics Materials and Devices Lab, Palo Alto Research Center (PARC), a Xerox Company*

Under the ARPA-E AMPED program for advanced battery management systems, PARC and LG Chem Power are developing SENSOR (Smart Embedded Network of Sensors with an Optical Readout), an optically based smart monitoring system prototype targeting batteries for electric vehicles (EVs). The system will use fiber optic sensors embedded inside Lithium-ion battery cells to measure parameters indicative of cell state in conjunction with PARC's low-cost, compact wavelength-shift detection technology and intelligent algorithms to enable effective real-time performance management and optimized battery design. This talk will give an overview of the project, the underlying enabling technologies, and then cover some promising initial experimental results from the project, including internal cell signal data and state estimation using fiber optic sensors embedded in Li-ion pouch cells over charge-discharge cycles. **W.Sommer, A.Lochbaum, T.Staudt, B.Saha, and S.Sahu*

11:30 **Safety of Large Li-Ion Battery Systems**

Bart Mantels, Project Coordinator, VITO unit Energy Technology, Belgium

Until now, no systematic and comprehensive assessment of Li-Ion system safety exists for large grid-connected electric energy storage systems. This project developed and validated a framework for assessing the safety and reliability of large battery systems throughout the entire life cycle and at all levels of the system, building upon the generally accepted failure mode, effect analysis (FMEA) approach. This is a bottom-up analytical safety assessment that searches for potential failure modes, which is widely used in product development.

12:00 **The Advancements of Battery Management Systems**

Michael Worry, CEO, Nuvation; and

Jonathan P. Murray, Bloomy Energy Systems

We will discuss latest advancements in battery management systems (BMS), design considerations for implementing large scale hybrid and electric vehicles battery packs, proper test methods for validating and verifying BMS critical functionality throughout the product life-cycle. We will also address the issue of how a battery Hardware-in-the-Loop (HIL) system is used to simulate a range of battery cell conditions and state of health sensors for closed loop testing of a BMS alongside with its open software architecture for developing new control algorithms, and open simulation system for implementing new battery chemistries.

12:30 *Luncheon Sponsored by the Knowledge Foundation Membership Program*

2:00 **Presentation title to be confirmed**

Rachid Yazami PhD, Professor, School of Materials Science and Engineering, Nanyang Technological University, Singapore

Abstract is not available at time of publishing. Please visit www.KnowledgeFoundation.com for the latest Program updates.

2:30 **Electrochemical-Calorimetric Studies for The Determination of Heat Data of 40 Ah Lithium Ion Pouch Cells**

Carlos Ziebert, PhD, Researcher, Institute for Applied Materials & Applied Materials Physics, Karlsruhe Institute of Technology, Germany*

Commercial 40Ah NMC Li-Ion pouch cells were cycled under isoperibolic and adiabatic conditions at rates up to 1C in an accelerating rate calorimeter to investigate performance and thermal behavior. Heat capacities, and total generated heat were measured after calibration using Al alloy dummy cells and the latter was separated into reversible and irreversible parts by potentiometric and current interruption technique. All these data are needed for thermal modeling and management. **In collaboration with: E.Schuster, H.J.Seifert*

3:00 **An Introduction to the BMBF Project SafeBatt and the Implementation of Nail Penetration Tests for Commercial Type 18650 Lithium-Ion Cells**

Jan Haetge, PhD, Research Scientist, MEET - Battery Research Centre, University of Muenster, Germany

The presentation introduces the new beacon project SafeBatt that is funded by the German Federal Ministry of Education and Research (BMBF). The consortium consists of automotive manufacturers, supplying companies and academic institutions that cooperate to enhance the reliability and safety of lithium-ion batteries. The project focuses on improving the cell chemistry to increase the intrinsic safety of the battery and the implementation of sensors to monitor the safety relevant parameters inside the cell. Another topic is the optimization and standardizing of safety test procedures to validate safety concerns for state-of-the-art batteries and batteries with improved cell chemistry. MEET contributes with aging and safety tests of full cells and develops electrolytes with enhanced safety. Nail penetration tests in adiabatic conditions were performed in an accelerating rate calorimeter (ARC) to generate internal short circuits in commercial 18650 lithium-ion cells. We tested a selection of different cell chemistries with different states of charges (SoC). Through performing the measurements in adiabatic conditions, a detailed description of the temperature and pressure progress during the battery abuse is feasible. For future studies the ARC will be extended with further analytic instruments to perform online analytic measurements of the evolving gaseous products.

3:30 *Networking Refreshment Break, Exhibit/Poster Viewing*

4:00 **An Easy Test Method to Differentiate Material System Safety Level**

Deng-Tswen Shieh, PhD, Researcher, Dept of Lithium Battery Reliability Design, Material & Chemical Research Laboratories, Industrial Technology Research Institute, Taiwan R.O.C.

For nail penetration test the signal of voltage and temperature are important safe index. Up to now temperature detection is only capable of measuring surface of the battery, what happened on the point of short is keen to be understood. The special design with thermocouple embedded inside the tip of nail can help us detect real temperature reliably and do quantitative analysis. With such method and device, we test lithium-ion battery cell by introducing different nail shape and material under different test conditions. This test method has the capability to quantify the safety of battery to several levels and therefore guide the material system design quantitatively, which can be a good screening method to differentiate the safety level of battery and material system design.

4:30 **Gaining Compliance to IEC 62133, 2nd Edition**

Rich Byczek, Global Technical Lead for Electric Vehicle and Energy Storage, Intertek

For manufacturers of products using rechargeable batteries, the recent release of the second edition of IEC 62133 has introduced a number of revisions affecting their equipment. The primary changes affect lithium-ion cells and lithium-ion batteries, as well as nickel cadmium and nickel metal hydride cells and batteries. During this presentation, Intertek expert Rich Byczek will walk you step-by-step on how to come into compliance with the second edition of IEC 62133.

5:00 **Exhibitor/Sponsor Showcase Presentations**

Friday, November 15, 2013

8:00 *Exhibit/Poster Viewing, Coffee and Pastries*

9:00 **Are Soft Short Tests Good Indicators of Internal Li-Ion Cell Defects?**

Judith Jeevarajan, PhD, Battery Group Lead for Safety and Advanced Technology, NASA Johnson Space Center

Several methods exist that can predict whether a li-ion cell has an internal defect. Some of those are self-discharge tests at end of charge voltages, soft short tests at the end of discharge voltages, etc. It is also not clear if these tests are a good reflection of contaminants or other types of defects inside the cell. This paper will address the topic of whether there is a good method to detect internal cell defects in li-ion cells.

9:30 **Development of an On-Demand Internal Short Circuit (NREL/NASA)**

Matthew Keyser, Senior Engineer, Vehicles and Fuels Research, National Renewable Energy Laboratory

NREL has developed a device to test one of the most challenging failure mechanisms of lithium-ion (Li-ion) batteries—a battery internal short circuit. Many members of the technical community believe that this type of failure is caused by a latent flaw that results in a short circuit between electrodes during use. As electric car manufacturers turn to Li-ion batteries for energy storage, solving these safety issues becomes significantly more urgent. Due to the dormant nature of this flaw, battery manufacturers have found it difficult to precisely identify and study. NREL's device introduces a latent flaw into a battery that may be activated to produce an internal short circuit. NREL uses the internal short circuit device to better understand the failure modes of Li-ion cells and to validate NREL's abuse models. The device can be placed anywhere within the battery and can be used with both spirally wound and flat-plate cells containing any of the common Li-ion electrochemical systems. Producing a true internal short, the device is small compared to other shorting tools being developed by industry and does not rely on mechanically deforming the battery to activate the short, as do most of the other test methodologies. With the internal short in place, the battery can be used and cycled within normal operating conditions without activating the internal short device. This allows the battery to be aged prior to activation. The internal short produced by NREL's device is consistent and is being developed as an analysis tool for battery manufacturers and other national laboratories as well as OEMs. This has broad-reaching applications as automakers bring electrified vehicles to market in larger numbers. NREL's presentation will outline the differences in the voltage and temperature response between the four different types of internal shorts within a battery. We will also present results showing the difference between a foil to foil internal short when a shutdown and non-shutdown separator are used in an 18650 $LiCoO_2$ cell.

10:00 Li-Ion Battery Safety Test for High Power Applications

JaeSik Chung, PhD, CTO, PCTest Engineering Laboratory

The adoption rate of LiB in high power applications has getting increased but the test information for its cell abuse and safety test was not reported much yet compare to that of small portable electronics. Besides, the operating conditions and usage environment of the high power application, especially power tool application, are much harsher than that of small portable electronics so that the test items and conditions for the high power application should be considered more carefully to simulate adequately the cell abuse conditions in connection with the devices. In this presentation, we will report the cell abuse safety testing (simulation in electrical, mechanical and thermal and thermal behaviors) for the high power application cells and compare the results between cell capacities and will discuss about those implications.

10:30 *Networking Refreshment Break, Exhibit/Poster Viewing*

11:00 Leclanché Highly Safe Titanate Lithium-Ion Batteries

Deghenghi Gianluca, Buqa Hilmi, Blanc Pierre, Leclanché SA, Switzerland

Advanced titanate-based cell technology entails the very high safety of Leclanché batteries; cells pass successfully the most severe safety tests, with impressively low level of reaction in response to abusive conditions. Moreover, Leclanché unique separator technology ensures unparalleled thermal stability of cell, adding extra safety in case of overheating or short-circuit. Innovative, unprecedented Leclanché water-based production process, applied to all electrodes, minimizes environmental impact of cell manufacturing, while improving performances.

11:30 Enhanced Battery Safety through *In-Situ* Coatings

Christopher M. Lang, PhD, Group Lead – Energy Technologies, Physical Sciences Inc.

Safe, high performance cells are required to power next generation technologies. However, increasing energy densities of batteries tighten the required tolerances and the potential for catastrophic system failure. Physical Sciences Inc. has developed *in-situ* coatings that maintain the required high performance levels, while improving the abuse tolerance of cells. This presentation will discuss the results of these development efforts and highlight the performance benefits these technologies offer.

12:00 An Experimental Study on Heat Evolution inside a Lithium-Ion Battery Cell by Embedded Fiber Bragg Gratings

Gwo-Shyang Hwang, PhD, Scientist, Department of Mechanical Engineering, National Taiwan University, Taiwan R.O.C.*

The performance and safety of Li-ion batteries have close relationships with the thermal environment inside and outside battery cells. It is well-known that poor thermal management will result in fast degradation of Li-ion batteries and even a hazardous condition such as thermal run-away. Hence, a vast amount of research has been devoted to studying the thermal behavior of Li-ion cells and its relation with the electrochemical and chemical processes during charge and discharge. However, due to the lack of direct measurements of temperature inside the Li-ion cells, it was normally resorted to numerical simulations based on thermal-electrochemical models in the past research. Although the simulation results appear to have good agreements with experimental data excluding interior temperature of battery cells, it is difficult to verify the accuracy of the simulated thermal behavior inside battery cells. In this research, the Fiber Bragg Grating (FBG) sensor is adopted as an embedded temperature sensor for a Li-ion battery cell by exploiting its merits: it is chemically inert; it can withstand high temperature (up to 250 °C for non-decay reflection spectra), and it can be connected in series (multiplexing). Besides the average temperatures, temperature gradients along a fiber grating can be derived from its measurements in real-time. Based on the measured average temperatures and temperature gradients inside a Li-ion cell, insights of the thermal behavior of a Li-ion battery can be obtained. **In collaboration with: K-H.Chang, K.Li, C-C.Ma, D-W.Huang*

12:30 *Lunch on Your Own*

2:00 Realistic Multivariate Modeling of Lithium Batteries Using a Proportional Hazards Methodology

George M. Lloyd, PhD, Staff Scientist, ACTA Inc., andP. P. Mukherjee, PhD, Prof, Energy and Transport Sciences Laboratory, Texas A&M University

We overview the methodology underlying a proportional hazards model (PHM) that establishes a framework ideally suited for performing reliability estimates for lithiubased batteries. We establish the notion of covariate trajectories, which can include both intrinsic battery factors (morphology, etc.) and extrinsic factors (environmental histories, in particular). The methodology allows prediction of battery reliability among a discrete set of non-stationary stochastic environments or along an arbitrary stochastic covariate trajectory. Such scenarios are typical for batteries, which are typically used for portable and mobile applications such as electric vehicles. The framework yields the expected value of prognostic statements, sample realizations, and a non-parametric estimate of the corresponding distributions in order to infer extreme event probabilities. Implementation of the model itself is well within the capabilities of current embedded processing architectures commonly found on battery-powered systems.

2:30 Safer Batteries Through Predictive Simulation

John A. Turner, PhD, Group Leader, Computational Engineering & Energy Sciences Group, Oak Ridge National Laboratory

Modern battery packs store a significant amount of electrochemical energy that can pose a safety risk uncontrollably released. A comprehensive computational model for the battery configurations would enable us to expand the parameter space of adverse conditions and accident scenarios beyond what can be tested experimentally. We describe the development of computational models for simulating mechanical, electrochemical, and thermal responses of the prismatic and cylindrical battery cells under both normal and abnormal conditions. The models are based on finite element method (FEM) formulations of the partial differential equations describing the above physical phenomena. Algorithmic, implementation and computational details are described, and model calibration and comparison of the simulations with the ongoing battery safety experiments will be presented.

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3:00 *Networking Refreshment Break, Exhibit/Poster Viewing*

3:30 **Monitoring Off Gas from Lithium Ion Batteries**

Davion Hill, PhD, Principal Engineer, Det Norske Veritas

DNV is presently testing an off gas sensor for implementation in monitoring and control of lithium ion batteries. The sensor has been shown to provide early warning to a thermal event. This work is funded by the ARPA-e AMPED program.

4:00 **New Metallic Contaminant Detection System Based on Faraday's Law of Electromagnetic Induction**

Saburo Tanaka, PhD, Prof, National University Corporation, Toyohashi University of Technology, Japan

For manufacturers producing Li-ion batteries or its materials, problems with metallic contaminants are critical issues. When contamination occurs, the manufacturer of the product suffers a great loss from recalling the tainted product. The lower detection limit for practical X-ray imaging is on the order of 1 mm. A detection system using a SQUID is a powerful tool for sensitive inspections. We previously proposed a direct detection system using multi-channel SQUIDs. In that system, an object with a contaminant is magnetized by a permanent magnet, and then a SQUID detects the remnant field of the contaminant. Because the detection width is defined by the size of the SQUID, eight-channel SQUIDs are required to inspect a specimen with a width of 65 mm, for example. This procedure is costly, and as a result, the system has not been widely used in the field. To circumvent this problem, we propose an indirect high-Tc SQUID magnetic metallic contaminant detector combined with a coil and magnet. The principle of the system is based on Faraday's law of electromagnetic induction. The detection section consists of permanent magnets and copper-wound pickup coils. The signal is magnetically transferred to a SQUID magnetometer. The differential pickup coil successfully measures an iron test piece with a size of 40 µm when the test piece was moved with a speed of 100 m/min. The advantage of this indirect detection method is that the detection width is wider than the previous SQUID direct detection method. The detector is able to detect a 50-µm iron test piece within a range of 20 mm with an SNR greater than 5. Since two coils are differentially connected in series, a detection width of 40 mm (2 - 20 mm) per channel is realized and two SQUIDs are sufficient for an inspection width of 65 mm. This is a great advantage compared to the direct detection system, which requires eight-channel SQUIDs to inspect an object with a width of 65 mm. This detection method is effective for the inspection of non-metallic materials such as the plastic film separator of a Li-ion battery. If the criterion of the detection size is moderated and 100 um, the SQUID sensor can be replaced by a low cost flux gate magnetic sensor. In the case, the cost of the system is dramatically reduced. In my talk, the evaluation results of the indirect contaminant detection system using a flux gate magnetic sensor will be also discussed.

4:30 **Selected Oral Poster Highlights**

5:00 *Concluding Remarks, End of Conference*

4th Annual International Conference

Battery Safety 2013

Registration Information

November 14-15, 2013 • San Diego, CA USA

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