3rd Annual International Conference

Battery Safety 2012

Conference Program

December 6-7, 2012 • Las Vegas, NV USA

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

Widely publicized safety incidents and recalls of lithium-ion batteries have raised legitimate concerns regarding lithium-ion battery safety. Battery Safety 2012 is conveniently timed with Lithium Battery Power 2012 and will address these concerns by exploring the following topics:

- Application specific battery safety issues affecting battery performance
- Major battery degradation and reliability factors
- Battery management systems
- Commercial cells evaluation and failure analysis
- Advances in testing techniques and protocols
- High throughput testing, automation and modeling for better safety
- Standardization & Regulatory issues

Conveniently timed with

8th Annual
Lithium Battery Power 2012

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3rd Annual International Conference

Battery Safety 2012

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Conveniently timed with another special event

8th Annual International Conference

Lithium Battery Power

December 4-5, 2012
Las Vegas, NV USA

Thursday, December 6, 2012

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

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

9:00 **Safety Improvements of Lithium Ion Battery Electrodes that Incorporate Carbon Nanotubes**

Brian J. Landi, PhD, Assistant Professor, Chemical & Biomedical Engineering, Rochester Institute of Technology

The safety of traditional cathode and anode composites has been improved using single wall carbon nanotubes (SWCNTs) as a conductive additive replacement. A 30-40% reduction in exothermic reaction energy has been measured by differential scanning calorimetry (DSC) for overcharge conditions. Such analysis is extended to high capacity Ge and Si-SWCNT electrodes where proper reduction in the surface area along with the high thermal conductivity of SWCNTs results in similar benefit.

9:30 **Thermal Decomposition Pathway of Delithiated Cathodes**

Zonghai Chen, Chemist, Electrochemical Energy Storage Group, Chemical Sciences & Engineering Division, Argonne National Laboratory

Thermal decomposition of delithiated cathodes has drawn major attention due to its contribution to the thermal runaway of lithium-ion batteries. In situ high energy X-ray diffraction was deployed to investigate the mechanism of thermal decomposition of delithiated cathodes. The impact of materials composition as well as electrolytes will be discussed in this talk.

10:00 **Cells' and Battery Safety in High-End Applications**

Malgorzata (Maggie) Gulbinska, PhD, Lead Materials Scientist, Yardney Technical Products

Yardney's batteries are used in multitude of air, land, sea, and space applications and must meet very stringent performance requirements. Pushing the boundaries of performance of batteries requires concerted efforts dedicated to understanding and implementing battery safety. The safety-related work at Yardney starts at the fundamental understanding level and extends to cell design improvements as well as the cell pack and battery level developments. This presentation summarizes the current safety-related advancements at Yardney. **In collaboration with: F.Puglia, G.Moore, S.Cohen, and S.Santee*

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

11:00 **Considerations of High Energy Safety and Abuse Testing**

David G. Miller, Manager, Test and Evaluation Branch, Energy, Power and Energy Division, Naval Surface Warfare Center (NSWC) Crane

The paper will discuss pre-test, test, and post-test safety considerations associated with high energy battery safety and abuse tests. The assessment of post-test batteries and the safing of the test site will also be discussed. Several video examples of worst case events will be shown.

11:30 **How Entropymetry Helps with Battery Safety Assessment?**

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

Pursuing our decade-long research effort on thermodynamics studies of lithium ion cells, we have followed changes in the entropy and enthalpy profiles of full coin cells in the process of thermal ageing, long cycle ageing and high voltage (over-)charging. We also developed a new differential thermodynamics method that enables a highly accurate assessment of the cells' state of health (SOH) and state of safety (SOS). We developed the equipment for thermodynamics measurements of battery cells (BA-1000, KVI PTE LTD, Singapore). BA-1000 machine automatically scans the cell at different states of charge and collect thermodynamics data by applying a small, yet highly accurate, temperature change to the cells, which affects its open-circuit voltage (OCV). We will present entropy and OCV profiles of a lithium ion battery based on graphite anode and $LiCoO_2$ cathode. Data refers to onsets of crystal structure changes in the anode and the cathode, respectively. We've used these onsets as "markers" to follow changes in the battery SOH and SOS. The differential entropy profiles during high voltage (HV) ageing, as well as anode and cathode peaks evolution will also be discussed. In this presentation, we will discuss how thermodynamics data converts into SOH and SOS assessment.

12:00 **Study of Polarization Effect and Thermal Stability in Aged Lithium-Ion Battery**

Alvin Wu, Research Engineer / Corporate Research, Underwriters Laboratories Taiwan Co., Ltd., Underwriters Laboratories

Research into the safety performance of lithium-ion cells has increased tremendously in recent years. Field failures, though rare, may suggest that some failure mechanisms are dependent upon the state of the cell over a period of time, as such rechargeable sources of energy experience many charging and discharging cycles. UL has hence proposed a project to investigate the safety performance in aged lithium-ion cells. After a series of study, the polarization effect and the shift in the thermal properties in aged cells are found to be the major causes to safety concerns.

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

2:00 **Effective Approach toward Safe Li-Ion Battery**

Sheng S. Zhang, PhD, Research Chemist, Sensors and Electron Devices Directorate, U.S. Army Research Laboratory

Fire and explosion of Li-ion battery (LIB) have been reported from cell phone, laptop computer to electric vehicle. All these incidents are related to the rapid release of huge chemical energy stored in LIB in an extreme manner, which is initiated by heat. Many laboratory tests, such as nail penetration, crashing, overcharging, and shorting, have shown that in most cases the heat is self-generated in the form of I2R by the internal or external electric circuit shorting. The heat melts down separator, resulting in direct chemical reactions of the charged cathode (a strong oxidizing agent) and anode (a strong reducing agent) materials. In this presentation, we discuss the causes of fire and explosion in LIB, review the current efforts to the safety of LIB, and propose a more effective and feasible approach for the better safety of LIB.

2:30 **Internal Shorts in Li-Ion Cells – What Does it Take to Cause One that is Catastrophic**

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

A simulated internal short test method has been in work at NASA with UL collaboration for the past two years. The test protocols used to simulate internal shorts in 18650 Li cobaltate cells are currently being validated on li-ion spinel and prismatic-metal-can cell designs. Cell CT scans and destructive physical analysis (DPA) were used to understand the results and repeatability and reproducibility of the test method. Data obtained from the analysis is indicative of the fact that the heat evolved during the internal short should be extremely localized and should compromise more than one layer of separator for it to become a catastrophic hazard. Results of the DPA and data on the new cell designs will be presented in support of this observation.

3:00 **Stability and Safety of Cathode Materials (with Possible Al Doping) for Li-Ion Batteries: Thermodynamic and Electrochemical Studies**

Hans J. Seifert, PhD, Professor, Research Associate, Institute for Applied Materials - Applied Materials Physics (IAM-AWP), Karlsruhe Institute of Technology, Germany

Electrochemical reactions and phase transformations occurring in the active materials such as $LiMO_2$ (M = Ni, Co and/or Mn) and LiM_2O_4 compounds with possible small addition of Al were studied using adiabatic and isothermal battery calorimeters. The thermal behaviour and the heat output were investigated during charging-discharging in and self-assembled coin and commercial 18650 cylindrical cells. Current interruption technique was used to measure the irreversible heat while the reversible heat was determined by potentiometric measurements at different depths of discharge (DOD). The performance of these cells under different operating conditions (temperature, C-rate) was evaluated. **In collaboration with: Petronela Gotcu-Freis, Carlos Ziebert*

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

4:00 **Experimental Study of an Air-Cooled Thermal Management System for High Capacity Lithium-Titanate Batteries**

Ajay Prasad, PhD, Professor, Dept of Mechanical Engineering, University of Delaware

Lithium-titanate batteries have become an attractive option for battery electric vehicles and hybrid electric vehicles. In order to maintain safe operating temperatures, these batteries must be actively cooled during operation. Liquid-cooled systems typically employed for this purpose are inefficient due to the parasitic power consumed by the on-board chiller unit and the coolant pump. A more efficient option would be to circulate ambient air through the battery bank and directly reject the heat to the ambient. We designed and fabricated such an air-cooled thermal management system employing metal-foam based heat exchanger plates for sufficient heat removal capacity. Experiments were conducted with Altairnano's 50 Ah cells over a range of charge-discharge cycle currents at two air flow rates. It was found that an airflow of 1100 ml/s per cell restricts the temperature rise of the coolant air to less than 10°C over ambient even for 200 A charge-discharge cycles. Furthermore, it was shown that the power required to drive the air through the heat exchanger was less than a conventional liquid-cooled thermal management system. The results indicate that air-cooled systems can be an effective and efficient method for the thermal management of automotive battery packs.

4:30 **Self-Discharge Mechanism Reduces Consequences of Internal Shorts**

Andrew J. Manning, President and CTO, Lithium Battery Engineering, LLC

Internal shorts are considered the most dangerous safety problem and are insidious in lithium ion cells. Such shorts can generate enough heat to initiate exothermic reactions, resulting in venting and fire. Freya Energy has developed a new separator which responds to localized over-heating of cells. The separator discharges the cell when it reaches 100°C through a controlled 'self-discharge' and has been shown to be effective in discharging cells with shorts, before exothermic reactions commence.

5:00 *Exhibitors and Sponsors Showcase Presentations and Concluding Discussion*

5:45 *End of Day One*

Friday, December 7, 2012

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

9:00 **Battery Management at the System Level: Safety, Performance and Reliability**

Larry J. Yount, President & CTO, LaunchPoint Energy and Power - LEAP LLC, and Mark Gunderson, Manager Systems Engineering, Johnson Controls, Inc.

- The advent of electronic controls in the vehicle has brought on an increasing need or relevance to safety
- Drive by wire, break by wire, cruise controls have been leading functions for safety in the vehicle
- Electric propulsion has exposed the automotive industry to new areas of safety hazard – new large energy source, high voltage
- More rigorous regulations and standards are being brought to bear into the automotive space due to the advance battery electric propulsion – i.e. ISO26262
- Historically, critically safety systems have implied rigorous design methods and redundant systems driving significant cost.
- Automotive has be a high volume cost conscious industry
- JCI is making a strong effort to provide state-of-the-art safety systems at the battery system level
- JCI has addressed battery system safety through our material, cell, electronic controls, and system level components.
- With varying conditions and failure modes within an electric propulsion system, there are always some hazards that can only be sufficiently mitigated through BMS intervention
- JCI has developed a battery that optimizes system safety taking maximum advantage of capabilities provided through BMS electronics and software control.
- Key Messages:
  - Developed fully ISO26262 ASIL D capable fail-safe controls system without significant electronic redundance
  - System level top-down safety concept development approach optimizes battery system cost while meeting safety regulations
  - Adopted best in class safety analysis approaches in safety development
  - JCI has focused to develop system safety with cell safety as an integral element of the total solution

9:30 **Using Distributed Intelligence to Achieve Cost Efficient Functional Safety**

Karl Vestin, Director of Research & Development, Lithium Balance A/S, Danmark

As the industry around large scale lithium ion batteries matures, the requirements for functional safety increases. With incidents involving electric vehicles in recent memory even more emphasis is put on the application of structured methods to ensure safe battery operation. But functional safety comes at a price. Costs for development and production skyrockets as multiple redundancies and fail-safes are added to the designs. This presentation addresses the concept of functional safety from an architectural standpoint. Building the safety architecture in new and innovative ways reduces the costs of the safety features without compromising safety or functionality.

10:00 **Safety Analysis Design of Lithium-ion Battery EV Pack through Computer Simulation**

Christian E. Shaffer, PhD, COO, EC Power LLC

Battery pack designers currently test battery packs for EVs, HEVs, and PHEVs by building prototypes and seeing how well and safely they work under dangerous safety conditions. EC Power engineers, working in conjunction with the Penn State ECEC, have developed revolutionary tools for the simulation of battery packs under extreme safety conditions. The fully-coupled electrochemical and thermal model will be used to give fundamental insight into pack-level safety events. Accurate computer simulation of packs under such conditions, such as the examples shown, can significantly reduce the number of expensive packs that OEMs will need to physically test, leading to potentially substantial cost savings, while simultaneously minimizing workers' exposure to potentially dangerous test conditions.

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

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11:00 Integrity of Safety Testing for Li-Ion Batteries

Brian M. Barnett, PhD, Vice President, TIAX LLC

Safety of lithium-ion batteries is a critical topic that has not received adequate attention in the past, in no small part because data regarding actual safety failures have been severely restricted. Nevertheless, the battery community has defined and, in some cases, standardized a number of tests intended to assess safety of lithium-ion cells and batteries. TIAX has investigated Li-ion battery safety for several years and has direct experience investigating Li-ion safety incidents, working closely with major Li-ion battery manufacturers. These investigations, along with fundamental studies undertaken by TIAX to understand the mechanism of safety failures, simulations designed to shed light on the factors that determine thermal runaway, and experiments triggering safety failures in the lab have elucidated critical issues pertaining to how safety events take place and the relevance of safety testing. These insights will be discussed and a new framework by which to consider Li-ion battery safety, as well as its safety testing, will be proposed.

11:30 Mechanisms of Catastrophic Battery Failure

Nicholas Williard, Researcher, Center for Advanced Life Cycle Engineering - CALCE, University of Maryland

Battery failure can be generalized into two broad categories, slow progressive degradation and immediate catastrophic failure. To date, most theoretical work has been performed on the former with little work focusing on how to model, predict, or mitigate the onset of catastrophic failure. This presentation will explain the root cause mechanisms that lead to catastrophic failure and will offer solutions on how to better predict and handle this problem.

12:00 Metallic Contaminant Detection System for Li Ion Battery Sheet

Saburo Tanaka, PhD, Professor, Presidential Adviser, Toyohashi University of Technology, National University Corporation

A sensitive detection system using 8ch superconducting magnetic sensor for metallic contaminant in a lithium ion battery anode or separator was developed. Finding ultra-small metallic foreign matters is a big issue for a manufacturer, which produces commercial products such as a lithium ion battery since metallic contaminant has a risk of internal short. Outer dimension of metallic particles less than 100 micron cannot be detected by a conventional X-ray imaging. Therefore a high sensitive detection system for small foreign matters is required. We have developed an eight channel high-Tc SQUID roll to roll system for inspection of a lithium ion battery anode or separator with width of 60-70 mm. A special microscope type cryostat was developed and eight SQUID gradiometers were mounted on it with separation of 9.0 mm. As a result, small iron particles of less than 50 micron on the real lithium ion battery anode with width of 60 mm were successfully detected. This is the practical system for the detection of the contaminants in a lithium ion battery anode sheet or separator.

12:30 *Lunch on Your Own*

2:00 2013 - New Rules for Shipping Lithium Batteries

James E. Powell, President, Transportation Development Group

In 2013, stricter Air shipping regulations take effect for small lithium batteries. These rules include classifying some previously excepted shipments as "Hazardous Materials"□ (requiring a diamond hazard label and documentation) if packaged in certain configurations. In some cases the new limit for excepted small batteries will drop from 100 Wh to 3.7 Wh or from 2 grams to 0.3 grams, a 97% reduction. Anyone who uses air transport in the supply chain must understand these and other changes.

2:30 An Approach to Robust, No Surprises Design Verification Testing

Erik J. Spek, PEng, Chief Engineer, TÜV SÜD Canada

This paper will discuss the normal approach to Design Verification (DV) testing for the launch of a battery for an electric vehicle and considerations that can help avoid costly surprises and delays. DV testing is usually treated as a program cost item and a schedule entry and planning is typically limited to arranging for prototypes and resources. Battery DV plans require additional planning to account for new risks, system interactions and dependencies. Some of these are staged tests to demonstrate risk management, engineering discipline and predictable outcomes. Examples of how this can accomplished will be presented.

3:00 Required Testing for Safety of Lithium Ion Batteries

Swati Umbrajkar, PhD, Manager, Chemical Process Evaluation Group, Chilworth Technology, a DEKRA Company

We will overview the conditions that can cause thermal runaway chain reactions in lithium ion batteries--leading to leaks, smoke, gas release, fire and explosion. We will discuss the new IEC 62133 standard, which went into effect May 1, 2012, that specifies requirements and tests for the safe operation, shipping and export of these batteries.

3:30 Selected Oral Poster Highlights & Concluding Discussion

4:00 *Concluding Remarks & End of Conference*

3rd Annual International Conference

Battery Safety 2012

Registration Information

December 6-7, 2012 • Las Vegas, NV USA

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