The Center for Advanced Life Cycle Engineering (CALCE) is a world leader in systems reliability, accelerated testing, electronic parts selection, and supply-chain management. CALCE has over 120 faculty, staff, and students. Today, CALCE is funded by over 150 of the world’s leading companies at over $6M/year.

The Battery Group at CALCE performs fundamental and applied research on a variety of lithium-ion battery materials and form factors. This includes battery performance and safety testing, and the assessment of fundamental failure mechanisms that result in both long-term performance degradation (capacity fade / power fade) and catastrophic failures (cell venting / thermal runaway). Additionally, the team is developing state of charge (SOC) and state of health (SOH) prediction methods to control a battery during use.

Using both data-driven and physics-of-failure approaches, the CALCE Battery Group is developing models to predict performance degradation failure with consideration of the device’s life cycle operating and environmental conditions. Life prediction models are used to assess the reliability of lithium-ion batteries as they are implemented into various applications ranging from smart phones to automotive and space.

For questions related to CALCE’s battery research, please contact Michael Pecht, Director of CALCE, at pecht@calce.umd.edu.

NTSB Closes Boeing 787 Investigation: Questions Still Remain

The National Transportation Safety Board (NTSB) closed its investigation in November 2014 of the auxiliary power unit battery fire on the Japan Airlines Boeing 787 Dreamliner, which happened on January 7, 2013, in Boston, Mass. This battery fire incident, followed by another battery fire on January 16, 2013, led to the worldwide grounding of all Boeing 787 Dreamliners. NTSB concluded that the fire occurred due to an internal short-circuit in one of the cells and the propagation of heat to other cells. Other than suggesting improvements in the quality of the battery manufacturing process, the report emphasizes the need to develop standard testing procedures for detecting thermal runaway in a battery pack and determining the self-heating temperatures of cells. A robust battery management system capable of recording individual cell temperature and voltages and of providing thermal management that takes into account all the heat sources in a pack is an open problem to be solved.
Gas generation in lithium-ion batteries poses a safety challenge because of the threat of cell rupture, venting of electrolyte, and fire. Although gas generation can be largely avoided through proper battery management practices, including overcharge, overcurrent, and over temperature protection, inadvertent abuse could lead to the unsafe buildup of gas within the cell. If the internal pressure becomes too great, the cell’s safety vent will be activated. While this allows for the release of pressure, it is associated with the release of flammable electrolyte, toxic chemicals, oxygen, and hydrocarbon gases. Current methods of battery management cannot detect the onset of gas generation. Additionally, state of the art industry abuse standards do not properly quantify the risk of gas generation during battery design and qualification. Improvements in battery safety and reliability can be achieved through a better understanding of the gas generation mechanism.

The generation of gas in a battery can be attributed to a number of chemical reactions within the cell. Many of these reactions can occur concurrently to produce a large variety of gases, including oxygen, carbon dioxide, carbon monoxide, and methane. Two of the primary reasons for gas generation include overcharge and short circuiting. During overcharge, the cathode can become unstable as excess lithium is removed. This is of particular concern for the commonly used lithium cobalt oxide (LiCoO₂) cathode, which readily releases oxygen when more than half of its lithium is removed. Additionally, overcharge can lead to lithium metal dendrite formation in cells that do not have a proper anode-to-cathode loading ratio. Dendrites can cause internal short circuits that can lead to further gas generation reactions. As the temperature of the cell rises, the solid electrolyte interphase (SEI) layer can break down. Without a protective passivation layer, the electrodes react with the electrolyte and release gas as a byproduct. Further increases in temperature can lead to electrolyte decomposition and additional gas production.

Gas detection methods under development at CALCE relate the structural changes of the cell to the internal pressure as the battery is operated. This can be utilized in battery design and qualification to quantify the safety of a cell. Industry standards require abuse testing, including overcharge, thermal exposure, and external short circuit tests. Unfortunately, the standards tests only result in a pass/fail. As long as the cell does not vent or catch on fire, it receives a passing mark. This does not allow original equipment manufacturers (OEMs) to make adequate part procurement and vendor selection decisions based on safety.

Questions about CALCE’s gas generation research can be directed to Professor Michael Pecht (mpecht@calce.umd.edu) and Christopher Hendricks (chendri1@calce.umd.edu).

www.calce.umd.edu/batteries
Lithium-ion batteries are currently the most promising battery chemistry available in the market for aerospace applications due to their high energy/power density, lightness of weight and long lifetime compared to other battery chemistries. However, safety concerns exist due to the danger of lithium-ion batteries rupturing, igniting, or exploding under abuse conditions. There are several side reactions that can lead to battery degradation, such as lithium plating, copper deposition, and decomposition of electrolyte. The side reactions are closely related to the electrochemical states, such as overpotentials and concentrations.

The traditional equivalent circuit model in battery management systems only captures the input-output behavior of the battery, and cannot provide insights into physics of the battery. In contrast, the electrochemical model can be used to compute the potentials and concentrations inside the battery, thereby providing information on what is really happening inside the battery. The electrochemical model can also be used to optimize the performance of batteries and packs in the design phase. Virtual seeded fault simulation can be conducted to identify a state of health indicator using the electrochemical model by changing the health-related model parameters.

Detailed electrochemical models have been developed, including the key physics of Li-ion batteries, such as diffusion, migration, and reaction kinetics. These models are governed by coupled partial differential equations (PDEs). Thousands of states could be generated by conventional numerical solutions, such as finite difference and finite element. In order to implement these models in real-time battery management systems, simplification of the electrochemical model is needed. Some reduced order battery models have been developed, such as a single particle model (SPM), which has less than 10 states. However, in SPM, each electrode is modeled by a single spherical particle and the spatial variations of potentials are ignored. In addition, the electrolyte concentration is assumed to be a constant in time and space. Those assumptions are invalid for high current applications.

By analyzing the electrochemical model equations, it is found that the diffusion PDE in the solid particles consumes most of the computation. Therefore, the key part of model reduction is to simplify the PDEs in the solid phase. CALCE developed a model reduction method based on a rational Hermite interpolation. In this method, the $H_2$ norm error between the reduced order model (ROM) and the original model is minimized, and the first two moments of ROM and the original model are matched at the interpolation points in the frequency domain. A 10X reduction in computation time can be achieved without loss of accuracy.
Long-term Storage Effects on Capacity Fade of Lithium-ion Cells

CALCE is conducting a study to understand and quantify the effects of state of charge (SOC), storage temperature (ST), and time of storage (TOS) on irreversible capacity loss for LiCoO₂ cells. Storage tests were performed to examine how irreversible capacity loss evolves over time under four different storage temperatures (-40°C, -5°C, 25°C, and 50°C). Storage testing was conducted at three different states of charge (0%, 50%, and 100%) under the storage temperatures mentioned. For each combination of SOC and ST, four cells were tested under three different TOS conditions (2 weeks, 3 months, and 6 months). A multifactorial test matrix was developed to simulate the real-world conditions under which a cell can be stored. Storage tests can be applied to application-specific cells to acquire trends in data that exemplify the combination of SOC, ST, and TOS that reduces capacity loss and increases remaining useful performance. Calendar aging yielded larger amounts of irreversible capacity loss when storage conditions included high temperatures and large SOC values, although temperature was found to have a primary effect on capacity loss, whereas SOC had a secondary effect. The lowest amount of irreversible capacity is found at a specific combination of SOC and ST. Because storage environments vary in real-world situations and are difficult to control, investigation on the storage paths and the corresponding irreversible capacity loss is necessary. To determine the amount of irreversible capacity loss that a batch of cells will experience during varying path-dependent storage conditions, the development of a deterministic model that accounts for the degradation rate and quantifies the capacity loss for a given storage path is introduced.

Partial Cycling Effects on Capacity Fade of Lithium-ion Cells

Lithium-ion batteries are used in various forms in a variety of applications ranging from coin or pouch cells in portable electronics to large battery packs in automotive and grid applications. Battery cycling reduces the capacity of a battery irreversibly through a variety of physical and chemical degradation mechanisms. In most practical applications, batteries undergo charge-discharge cycling only for partial SOC ranges as opposed to the full 0%–100% range. Hence, it is important to study the effects of partial range cycling on battery life. Also, a battery can be derated to reduce the stresses on the active materials, thus extending the overall life of the battery and preventing premature faults. Partial cycling also does not provide information about the battery discharge capacity, which is an important metric for calculating battery State of Health (SOH). CALCE has been carrying out cycling tests on lithium-ion batteries with different cathode chemistries under various SOC charge-discharge ranges. CALCE is developing battery lifetime models under partial SOC range cycling. An optimal range of charge-discharge can be obtained from this model, which can be coupled with SOC estimation methods to achieve better health and life cycle management of batteries under real operating conditions.

Capacity and Remaining Useful Life Estimation of Lithium-ion Cells

Lithium-ion batteries are used in a wide variety of applications due to their high energy/power density. Prognostics and health management (PHM) can predict remaining useful performance (RUP) or remaining useful life (RUL) of batteries, which is useful to reduce the risks of battery failure and provide a comprehensive guide to battery maintenance. Lithium-ion batteries are the main power source of electric vehicles (EV) and hybrid electric vehicles (HEV); thus, lithium-ion batteries’ remaining capacity has a direct effect on EV driving mileage and road safety. CALCE is developing a new approach for battery prognostics based on a deterministic Bayesian approach. This approach provides probability distributions, considers system uncertainty, and mitigates the risk of failure. It is also able to update probabilities of future observations and obtain an appropriate predictive distribution while doing battery RUL prediction, due to its ability to combine coherently the results from previous experience and experiments.

More information on partial cycling and long-term storage effects can be obtained by contacting Prof. Michael Pecht (pecht@calce.umd.edu).

www.calce.umd.edu/batteries
CALCE Visits Army Research Laboratory (ARL) for Open Campus Initiative

CALCE researchers Dr. Michael Azarian, Christopher Hendricks, Saurabh Saxena, and Aristodemos Sotiris attended the Washington DC Regional Battery Excellence Center Inaugural Workshop at the Army Research Laboratory (ARL). The main objective of this workshop was to establish a Washington region Battery Center of Excellence with the collaboration of world-class research facilities and expertise in the area of energy storage systems available in the region. The proposed center will be led by ARL and co-led by the University of Maryland, College Park. It will be an integral part of ARL’s open campus initiative, which aims to provide open sharing of ARL’s world-class facilities and research opportunities to researchers from academia and industry.

Dr. Michael Azarian from CALCE presented the research performed by CALCE’s Battery Group in the areas of battery health management, reliability, failure analysis, and safety. Additional presentations were made by other academic institutions, government agencies, labs, and industry groups such as University of Maryland, College Park (UMCP), University of Maryland, Baltimore County (UMBC), University of Virginia, NIST, ARPA-E, Naval Research Laboratory (NRL), NASA Goddard Space Flight Center, and DuPont. An open discussion on the future research focus of the center followed. The need to address the reliability and safety of Li-ion batteries as well as future batteries with new material technologies, chemistries, and designs was emphasized for use in defense and other real-life applications.

CALCE Presents to the Naval Research Laboratory (NRL) and Army CERDEC Aberdeen Group

This past fall, CALCE researchers presented to the Naval Research Laboratory and Army CERDEC Aberdeen. The subject of the presentations was CALCE’s research on lithium-ion batteries.

Aristodemos Sotiris presented on long-term storage and the effects of state of charge and temperature on the irreversible capacity loss of lithium-ion batteries. Because many military applications require long storage times under potentially uncontrolled temperatures, models are needed that take into account the storage state of charge and temperature when predicting loss of capacity.

Christopher Hendricks presented on the detection of gas generation in lithium-ion batteries through structural measurements. The sensors currently employed in lithium-ion battery monitoring cannot capture the generation of gas, and quantifying gas generation can provide information about the safety of a battery during use.

Saurabh Saxena presented on the effect of partial charge and discharge cycling on capacity fade in lithium-ion batteries. In many practical applications, lithium-ion cells are not fully discharged, and there is evidence that partial cycling of batteries can reduce the rate of capacity fade.

Wei He presented on order reduction for a battery electrochemical model in order to enable a real-time solution of the equations describing the physics behind a working battery. Real-time use of electrochemical models can improve control strategies and provide further information about lithium-ion battery failure; however, order-reduction is necessary to actually solve the complex electrochemical models.

Jing Tian presented on advanced condition-based maintenance (CBM+) techniques for aircraft feature extraction, anomaly detection, trend analysis, and prediction. A software toolbox of these techniques was also delivered.

Anto Peter discussed how the failure modes in electrical double layer capacitors (EDLCs) can be identified by using step stress testing. The fundamental physical and chemical processes leading to the degradation of EDLCs’ performance were also discussed. Data from step stress tests can also be used to develop life tests, which in turn can be used to design life models for EDLCs.
New Battery Equipment–Medex Supply–FRZ-CT40-2

CALCE’s battery team has recently installed new battery storage equipment from MedexSupply. MedexSupply has one of the largest catalogs of medical, surgical and diagnostic supplies available online. Refrigerators and freezers can be found in their extensive online collection of products from globally recognized and trusted brands.

The FRZ-CT40-2 model has a capacity of 1.7 cubic feet and can reach temperatures as low as -40 °C with an accuracy of ±1°C. Other features include control in both Celsius and Fahrenheit with a simultaneous readout of set point and chamber temperature. The two FRZ-CT40-2 model freezers are being used for an experimental study conducted by CALCE on lithium-ion battery storage for the determination of irreversible capacity loss given the environments in which the battery cells are stored.

For a demonstration of the test equipment performance or for information about purchasing test equipment from Medex Supply, please contact Bhanu Sood at bpsood@calce.umd.edu.

CALCE and PC Test Begin Joint Research

The use of batteries in extreme environments, such as those experienced in military, aerospace, and drilling applications, requires that batteries be qualified under a variety of external stresses to verify that they can maintain safe and effective operation. In the field, mechanical stresses can be brought on by changes in atmospheric pressure or by compressive loading.

The tests outlined in industry standards, such as the IEEE 1725 Standard, are based solely on a pass or fail criteria where the battery is considered to have passed if there is no evidence of leakage, venting, explosion, and fire. This approach does not allow a user to properly assess the safety of a lithium-ion battery. CALCE and PC Test of Columbia, Md., are jointly investigating the effects of low external pressure and compressive loading on the performance, degradation, and risk factors of lithium-ion batteries. This collaborative work seeks to provide quantitative analysis of batteries under low hydrostatic pressure and compressive uniaxial loads. In particular, these tests will help to evaluate the functional differences between external uniaxial mechanical loads versus hydrostatic pressure loads.
Dr. Michael Azarian presented at the Battery Safety Conference on November 14, 2014, held at the Capital Hilton in Washington, D.C., and participated in a safety-focused panel discussion along with leaders in the lithium-ion battery community. CALCE’s presentation was well received and sparked significant discussion about the role of prognostics and health management (PHM) in improving lithium-ion battery safety. The presentation highlighted research taking place at CALCE related to all aspects of battery management and control, including performance and life cycle testing, degradation mechanisms and modeling, and prognostics and anomaly detection.

The panel discussion demonstrated the desire in industry and academia to improve battery safety using a multi-faceted approach. Improvements to battery monitoring and control were emphasized as one possible way to prevent further catastrophic failures. This aligns well with CALCE’s research in the development of new techniques to detect precursors to catastrophic failure and the implementation of advanced battery models to maximize the use of the battery while preventing the occurrence of dangerous side reactions.

Professor Michael Pecht gave the keynote address at the International Forum on Reliability Engineering Applied Power Battery on October 31, 2014, at Ming Chi University of Technology (MCUT) in New Taipei City, Taiwan. Professor Pecht’s topic was “Advances in Lithium-Ion Battery Reliability and Safety.”

In 2012, MCUT established the Battery Research Center of Green Energy, a state-of-the-art, $2.7M research facility focusing on research and development of future green energy technologies.
Researchers from Harbin Institute of Technology China Visit CALCE

From left to right: Daisy Zheng (visiting scholar), Saurabh Saxena (CALCE), Christopher Hendricks (CALCE), Wei He (CALCE), Prof. Yu Peng (HIT), Prof. Michael Pecht, Prof. Datong Liu (HIT), and Aris Sotiris (CALCE).

Prof. Peng Yu and Prof. Datong Liu from the Harbin Institute of Technology (HIT) visited CALCE and met with Prof. Pecht and the Battery Group to discuss collaboration on prognostics and health management of batteries. HIT, located about 1000 miles northeast of Beijing, is a member of the prestigious C9 League, an association of the top nine Chinese universities, and consistently ranks among the best engineering schools in China.

Prof. Yu Peng is a Full Professor with the Department of Automatic Test and Control, School of Electrical Engineering and Automation, HIT, where he is also the Vice Dean of the School of Electrical Engineering and Automation. His current research interests include automatic test technologies, virtual instruments, system health management, and reconfigurable computing.

Prof. Datong Liu is currently an Associate Professor with the Department of Automatic Test and Control, School of Electrical Engineering and Automation, HIT. His current research interests include automatic test, machine learning and data mining for test data processing of complex systems, data-driven prognostics and health management, lithium-ion battery prognostics, and system health management for aerospace.

www.calce.umd.edu/batteries
Researchers from Beijing Jiaotong University Visit CALCE to Discuss Battery Systems for China’s High Speed Trains

From left to right: Prof. Jiang Jiuchun, Prof. Michael Pecht, and Prof. Zhang Weige.

Prof. Jiang Jiuchun and Prof. Zhang Weige visited CALCE and discussed options with Prof. Pecht for collaboration between Beijing Jiaotong University and CALCE on the reliability of battery packs in high speed trains, including the reliability of interconnections between cells, PCB boards, and insulation. Other possible areas of cooperation include big data analysis of electric car fleets.

Prof. Jiang Jiuchun is the Dean of the School of Electrical Engineering at Beijing Jiaotong University and also the Director of the National Active Distribution Network Technology Research Center (NANTEC). His research mainly focuses on electric vehicle (EV) charging stations, battery management systems, and microgrids. In 2011, over half of EVs in China were developed by Prof. Jiang’s group. His group also designed the charging stations for the Beijing Olympic Games, Shanghai EXPO, Guangzhou Asia Games, and 16 cities in the “Ten City Thousand EV” project.

Prof. Weige Zhang is Associate Professor at Beijing Jiaotong University (BJTU). He is the Director of the Center for Renewable Energy at BJTU. He has more than 10 years of experience on the development of battery management systems and charging technologies. He has designed many charging stations in China and has participated in many national standards for electric vehicles.
Dr. Pierre Dersin, Renowned PHM Researcher, Visits CALCE

On January 30, 2015, Dr. Pierre Dersin from Alstom Transportation, France, visited CALCE. He gave a presentation on “Predicting electronics devices’ variable failure intensity.” It was clear that CALCE’s development of physics-of-failure for electronics, as well as research on PHM, has been making international waves.

Born in Belgium, Dr. Dersin obtained his PhD in Electrical Engineering in 1980 from the Massachusetts Institute of Technology (MIT). He worked on the reliability of large electric power networks as part of the Large Scale System Effectiveness Analysis Program sponsored by the US Department of Energy, MIT, and Systems Control Inc. He later joined Fabricon, where he was involved with fault diagnostic systems for factory automation.

Since 1990, Dr. Dersin has been with Alstom Transport, where he has occupied several positions mainly involved with RAMS (Reliability, Availability, Maintainability, and Safety) and maintenance. Since 2007, he has been RAM Director of Alstom Transport’s Information Solutions and leader of Alstom Transport’s Reliability & Availability Core Competence Network. Since April 2014, Dr. Dersin has been co-director of the joint Alstom-Inria Research Laboratory for digital technologies applied to mobility and energy.

Alstom is one of the largest railroad companies in the world and has pioneered the application of health monitoring, diagnostics, and prognostics to railway switches and crossings, because these assets are an important contributor to the maintenance cost of railway infrastructure and the impact of their failure on traffic is substantial. In his presentation at CALCE, Dr. Dersin highlighted the importance of understanding the failure rate of electronic components in the railroad industry, mentioning multiple possibilities for collaboration between CALCE and Alstom.

Dr. Bhaskar Saha (PARC) Visits CALCE

Dr. Bhaskar Saha from Palo Alto Research Center’s (PARC) intelligent automation team delivered guest lectures for a graduate course on Prognostics and Health Management offered by CALCE. He presented his work on lithium-ion battery prognostics during the lectures. Prior to joining PARC, Dr. Saha worked as a research scientist at the Prognostics Center of Excellence at NASA’s Ames Research Center. His seminal work in the area of battery prognostics using Bayesian inference techniques has influenced many other researchers in their pursuit of improved remaining useful performance estimates.

Dr. Saha met with the CALCE Battery Group on October 24, 2014, and discussed his current research projects on lithium-ion batteries and how they complement the ongoing research at CALCE. Considering the computational complexity of first-principles-based battery models, implementation of data-driven techniques for battery states and remaining useful life (RUL) estimations for a real-time battery management system is an active area of research. CALCE researchers have been working aggressively in this area.
Prof. Christopher Rahn (Penn State) Visits CALCE

Prof. Christopher Rahn from Pennsylvania State University visited CALCE on October 24, 2014. He is currently a Professor of Mechanical Engineering, Co-director of the Battery & Energy Storage Technology (BEST) Center, and Director of the Mechatronics Research Laboratory at Penn State. His research interests in regards to lithium-ion batteries lie in the area of first-principles-based reduced-order battery modeling, State of Charge (SOC) and State of Health (SOH) estimation techniques for individual cell and battery packs, and aging mechanisms. CALCE’s Battery Group presented their research work to Prof. Rahn and discussed his current research work and future collaborative opportunities between CALCE and BEST.

Dr. Abbas Tourani (Coventry University) Visits CALCE

Dr. Abbas Tourani presented his work on thermal management of lithium-ion cells for electric vehicle applications at CALCE on December 15, 2014. Dr. Tourani’s work involves modeling the thermal distributions across the surface of the lithium-ion cell with the use of coupled 1D and 2D models. Dr. Tourani is an Assistant Lecturer in the Department of Mechanical Engineering at Coventry University (UK). Ongoing research suggests that temperature is one of the main degradation factors, and corresponding degradation mechanisms should be accurately modeled. CALCE’s research on thermal management is necessary in order to accurately model the degradation trends experienced by lithium-ion batteries due to extreme temperatures. In high energy/high power applications, proper thermal management of batteries is also necessary for safety.

James Post (Battery Condition Test) Visits CALCE

James Post of Battery Condition Test Ltd. met with researchers at CALCE on December 15, 2014, to discuss ongoing CALCE studies on lithium-ion batteries and their implementation for the improved battery management system (BMS) design for electric bicycles (E-bikes). As E-bikes become more popular around the world, improved battery management systems are needed to maintain safety, reduce warranty costs, and enable reuse and recycling of degraded batteries. Mr. Post had earlier visited CALCE in April 2014 and expressed his interest in CALCE’s research in lithium-ion battery state estimation, degradation and life-cycle modeling, and safety and reliability assessment. Researchers from CALCE presented their work on battery storage and partial state of charge (SOC) cycling. Results from the partial SOC study can be really useful in deciding the optimal range of charge–discharge for batteries during cycling for extending the life of the battery. Also the BMS should be able to take into account the capacity fade of the battery when not in use for a long period of time.

Naval Surface Warfare Center Researchers Visit CALCE

Visitors from the Naval Surface Warfare Center (NSWC) visited CALCE and discussed potential collaborative work. The NSWC is spread out over eight centers across the United States where technical operations, personnel, technology, and other services and products all are aimed at meeting the warfighters’ needs. In addition, NSWC is responsible for research, development, test, and evaluation, as well as support in regards to maintenance and in-service engineering. NSWC and CALCE have similar goals in terms of battery prognostics and battery safety and reliability assessment, and future collaborative work could improve research output.

www.calce.umd.edu/batteries
Visiting Scholar Huang Tubante

Mr. Huang Tubante is an M.S. student at City University of Hong Kong, where his major is multimedia information technology. His internship started in June 2014 and ended in September of the same year. His research at CALCE was focused on lithium-ion battery cycle life characterization and finding an optimized SOC range for cycling to yield the lowest irreversible capacity loss. Tubante’s internship included lithium-ion battery testing, test design, experimental operation, and data processing and analysis.

Visiting Scholar Daisy Zheng

Ms. Daisy Zheng is a Ph.D. candidate in the National Active Distribution Network Technology Research Center (NANTEC), School of Electrical Engineering, Beijing Jiaotong University, China. Her major is the application of new energy, especially the application of lithium-ion batteries. She has performed work on battery measurement techniques, battery management systems (BMS), and has published several papers in the last three years. As a visiting scholar to CALCE, she majors in Prognostics and Health Management (PHM) and Big Data Analysis. Her research at CALCE focuses on SOH (state of health) and RUL (remaining useful life) prognostics of lithium-ion batteries based on electrochemical modelling and data mining.

Visiting Scholar Dr. Laura Yinjiao Xing

Dr. Laura Yinjiao Xing received a Ph.D. in Systems Engineering and Engineering Management (2014) at City University of Hong Kong, and a M.S. in Mechanical and Electrical Engineering (2010) and a B.E. in Mechanical Engineering (2007) at Nanjing University of Aeronautics and Astronautics, China. Before joining CALCE in 2015, she worked as a research engineer in 2012 Laboratories at Huawei Technologies Co. Ltd. (2014), China, as a research assistant at City University of Hong Kong (2014), and as a trainee in the Operation Management Leadership Program at GE Aviation, China (2010). Her research focuses on system monitoring, statistical modelling, and data analysis for the purpose of improvement of system reliability and operational performance. Application areas of her research mainly include battery management (electric vehicles, telecommunications devices, and UPS, etc.) and degradation-related products or systems.
Expanding CALCE Battery Database

CALCE is collecting data on lithium-ion cells for long-term storage tests and long-term cycling tests. Data acquisition involves the use of various testing methods that belong to beginning of life performance testing, during operational-life testing, and end-of-life performance testing. Some of the data collected includes impedance, discharge capacity, dimensions, weight, temperature, and strain. This collection of data can be used for comparative analysis throughout the experimental process so that degradation trends can be found and parameter relationships can be created and subsequently assessed.

Lab Services Projects

CALCE assisted a leading home appliance manufacturer to determine causes of Li-ion coin cell failure. The reported problem involved an increased rate of self discharge of the batteries and subsequent failure of the appliance. The analysis process included contact resistance measurement, X-rays inspection, visual inspection, and disassembly. Charge-discharge simulations were employed to determine the discharge capacity of the cells for comparison to manufacturer specifications as well as to quantify the irreversible capacity loss. Disassembly of the good and bad cells was conducted to assess the internal design of cells as well as to perform Energy Dispersive Spectroscopy (EDS) and Scanning Electron Microscopy (SEM) for comparing the active material composition and particle shapes and sizes in good and bad cells.

CALCE also assisted in assessing the failure of batteries in wearable electronics. The effort behind this project involved in-depth physical, electrical, and electro-chemical analysis of the batteries. Users of the wearable electronics reported elevated temperatures that led to subsequent failure of the battery cells. The specific problem that was addressed was in regards to a foreign agent penetrating the casing of the cell, causing a short circuit and thus causing the battery to catastrophically fail. Analysis of batteries from failed units was conducted with the application of a variety of qualification and performance tests that included X-rays analysis, charge-discharge cycling, and dis-assembly of the cell coupled with EDS and SEM for an in-depth look at the particle level. Results indicated that one or more sharp objects had created a cavity in the cell casing, which in turn penetrated through the active layers and caused an internal short circuit.

Guest Lecturers for Course ENME737: Prognostics and Health Management

Professor Michael Pecht taught a course on PHM during Fall 2014, which included various discussions on data driven techniques for the health management and prognostics of systems. Guest lecturers from academia and industry presented their ongoing research to students and discussed real-world issues regarding diagnosis and prognosis of systems.

- Professor George Vachtsevanos from Georgia Tech University presented on fault tolerant control, which included fault migration, fault accommodation, and reconfigurable control with the objective to design high confidence and reliable dynamic systems.
- Dr. Bhaskar Saha from Palo Alto Research Center (PARC) presented on the uncertainty management of failure prognostics with an objective to understand the reliability of the system in question.
- Professor Michael Todd, Vice Chair of the Department of Structural Engineering at the University of California, San Diego presented on verification and validation in structural health monitoring and damage prognosis.
- Dr. Charles Farrar from the Los Alamos National Laboratory presented on structural health monitoring, specifically the historical development, the current status, and present research needs.
- Professor Peter Sandborn at the University of Maryland presented on availability contracting and design availability as well as cost and return on investment (ROI) analysis for prognostics and health management.

www.calce.umd.edu/batteries
Recent CALCE Battery Publications

The following are selected CALCE publications on lithium-ion batteries. For more information please see CALCE battery website: http://www.calce.umd.edu/batteries/articles.htm


Are You Interested in Getting a PhD at the University of Maryland in Li-ion Battery or Super-Capacitor Technologies?

The University of Maryland, College Park has established an impressive track record of battery and super-capacitor research. The objectives are to make an impact in energy storage by developing methods and tools to prevent failures, enhance safety, and make better use of the available energy. The demand for people with this expertise is now widespread in all sectors of industry, from consumer electronics to automotive and aerospace.

At the University of Maryland, research has focused on a wide range of important topics in battery life cycle use and management. Estimating the internal electrochemical state of the battery is required to implement effective control and monitoring algorithms. This includes developing data-driven and physics-based state of charge models for mission planning and state of health models to assess the degradation of the battery as it is used. Researchers at Maryland have also developed fault detection methodologies to detect precursors of and mitigate catastrophic failure. This requires identifying the root cause of battery failure and assessing the reliability and safety of batteries and battery packs as a function of their usage environment and stresses applied during the life cycle. Super-capacitor studies have helped to reveal the key failure modes and mechanisms in response to thermal and electrical stresses. This research is multidisciplinary, drawing from the fields of electrochemistry, reliability, mechanics, electronics, controls, and machine learning. CALCE laboratories are well equipped with latest tools and equipment for analysis and have collaboration with national and international research centers giving qualified students access to facilities and experts around the globe. You can find more information on battery research at CALCE at http://www.calce.umd.edu/batteries/index.html.

Financial support is available through research assistantships for those interested in obtaining a Ph.D. at the University of Maryland in Li-ion battery technologies. If you have obtained a M.S. with a focus on batteries, with knowledge of electrochemical devices and experience in testing and model development, please apply. Preference will be given to students with a MS degree in science and engineering with evidence of related skills such as:

- Electrochemistry and secondary battery fabrication
- Prognostics and Health Management (PHM) algorithm development
- Battery test equipment experience (brands such as Arbin, Cadex, Maccor)
- Electrochemical testing (e.g., cyclic voltammetry, GITT, PITT, Impedance Spectroscopy)
- Failure analysis (e.g., non-destructive analysis, cell disassembly, materials characterization)
- Multiphysics model development (e.g., COMSOL, FEA)
- Programming experience (e.g., Matlab, Python, R)

For additional information, please contact Professor Michael Pecht at pecht@calce.umd.edu with a resume that provides information on relevant skills and prior experience. Information about applying to the Mechanical Engineering PhD program at University of Maryland can be found at http://www.enme.umd.edu/grad/admissions.

Join The CALCE PHM Consortium

To become a member and support the CALCE battery and PHM team, please email Prof. Michael Pecht (pecht@calce.umd.edu) and we will provide you with the membership agreement.

www.calce.umd.edu/batteries