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Next Generation Batteries

April 30-May 1, 2013
Boston, MA USA

Application Driven Development of New Battery Chemistries & System Designs - *Lithium & Beyond*

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Next Generation Batteries

Conference Agenda

Tuesday, April 30, 2013

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

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

9:00 **Electrochemical Energy Storage Development at PNNL**

Wei Wang, PhD, Project Lead/Scientist; and Vincent Sprenkle, PhD, Chief Engineer - Electrochemical Energy Storage and Conversion, Pacific Northwest National Laboratory

The environmental concerns and constraints of the fossil fuels, combined with energy security concerns, have spurred increasing interest in higher efficiencies systems and renewable energy technologies. The transition from fossil based resources to renewable cannot be realized without effective energy storage technology. The DOE Office of Energy Storage Program at Pacific Northwest National Laboratory (PNNL) is focused on the development of cost effective energy storage technologies to meet future energy needs. Among the most promising storage technologies for the stationary applications are electrochemical storage technologies including redox flow batteries and Na-metal battery, and Na-ion technologies.

9:30 **Microfluidic Redox Battery**

Erik Kjeang, PhD, PEng, Assistant Professor, Mechatronic Systems Engineering, School of Engineering Science, Simon Fraser University, Canada

A rechargeable microfluidic redox battery is demonstrated that can operate without a membrane to separate the two half-cells. Developed as a low-cost power source for mass-produced wireless sensors and electronics, this transformative flow battery concept can be integrated on-chip and is compatible with low-cost materials and inexpensive micromachining and micro-fabrication methods. The layout, functionality, and performance of the proof-of-concept device will be discussed.

10:00 **Liquid Metal Batteries for Grid Scale Electricity Storage**

David Bradwell, CTO, Ambri, Inc.

Ambri is developing the liquid metal battery technology which was invented in the lab of Professor Donald Sadoway at MIT. Each cell consists of three self-separating liquid layers — two metals and a salt — that float on top of each other based on density differences and immiscibility. The system operates at elevated temperature maintained by self-heating during charging and discharging. The result is a storage system that is low-cost, easy to manufacture, long lifespan, reliable and safe.

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

11:00 **Bio-Battery: A Novel Micropower Source for Portable Electronics**

Sameer Singhal, Director, Biomedical & Energy Technologies, CFD Research Corp.

CFDRC is developing an enzyme catalyzed power source, Bio-Battery, which generates energy from readily-available fuels (sugars, alcohols, etc.). The Bio-Battery can power applications for both military and civilian needs. Additionally applications are seen in biomedical devices, where power generation from physiological fluids could lead to improved implantable medical devices. The technology's benefits include high energy density, safety, low-cost and renewable biocatalysts, and logistically-favorable fuels. A mature prototype has been demonstrated.

11:30 **Investigation of Graphite-Based Electrodes for Vanadium Flow Cell**

Vincenzo Antonucci, PhD, Head of Research, and Alessandra Di Blasi, CNR-Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano" (ITAE), Italy*

Several graphite-based electrodes are investigated for vanadium flow battery applications. These materials are characterized both as-received and after chemical or electrochemical treatments. The chemical treatment causes a cleaning of the electrode surface from adsorbed oxygen species or labile bonded functional groups in highly graphitic samples. Whereas, carbonaceous materials characterized by smaller graphitic domains or a higher degree of amorphous carbon show an increase of oxygen functional groups upon chemical and electrochemical pre-treatments. An increase of oxygen species content on the surface above 5 % causes a decrease of electrochemical performance determined by an increase of ohmic and charge transfer resistance. **In collaboration with: O.Di Blasi, N.Briguglio, A.S.Aricò, D.Sebastián, M.J.Lázaro, G.Monforte*

12:00 **Printed Thin Film Li-Ion Batteries**

Hélène Rouault, PhD, R&D Project Manager in Advanced Batteries, French Alternative Energies and Atomic Energy Commission (CEA), France;

Julio Abusleme, R&D Project Manager, Solvay S.A., Belgium

Multi-applicative smart tags, cards appear to be the next generation of devices, which could revolutionize the electronic commerce and smart communication, access, control in very large domain of applications (transport, ambient intelligence, industrial implant). Such products need embedded 2D power sources, offering the highest energy density. Basically made from inks, the lithium-ion technology is so really well adapted to be designed in such printed configuration. Consequently CEA and Solvay jointly have engaged a large program of development on innovative thin film and printable lithium-ion batteries, using monolithic structure printed from specific PVDF based inks, making them conformable and flexible.

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

2:00 **Advances toward Inorganic Li-Ion Cell Chemistries**

Kevin L. Gering, PhD, Technical Program Manager, Applied Battery Research, Idaho National Laboratory

Safety and longevity of lithium-ion batteries can benefit by an overall reduction of carbon within the cell chemistry. For example,

conventional organic carbonate solvents have low flash points and are not suitable for operation at 5V, while carbon anodes have been shown to trigger the fate of cathode stability under thermal runaway. INL is developing alternative cell materials for electrolytes and electrodes that are resilient at elevated temperatures, higher voltages, and offer distinct opportunities to custom-engineer attributes of battery performance and life.

2:30 **Discovery of a >250 mAh/g, Non-Layered Oxide Cathode Material for Lithium-Ion Batteries**

Steven Kaye, PhD, Chief Scientific Officer, Wildcat Discovery Technologies

Wildcat Discovery Technologies has developed a high throughput synthesis and screening platform for battery materials. Wildcat's system produces materials in bulk form, enabling evaluation of its properties in a standard cell configuration. This allows simultaneous optimization of all aspects of the cell, including the active materials, binders, separator, electrolyte and additives. Wildcat is using this high throughput system to develop new electrode and electrolyte materials for a variety of battery types (primary, secondary, aqueous, non-aqueous). In this talk, I will discuss our latest discovery, a non-layered oxide cathode with capacity >250 mAh/g, irreversible capacity <10%, and superior rate capability, cycle life, and energy stability to lithium-rich layered oxides in full cells.

3:00 **Tin Nanoneedles: A Cost Effective, Industry-Scalable Anode Technology for Lithium-ion Batteries**

M. Grant Norton, PhD, Professor, School of Mechanical and Materials Engineering, Washington State University

Tin is an attractive anode technology for next generation lithium-ion batteries because of its higher theoretical capacity than graphite. However, there is a large volume change during lithiation/delithiation cycling, which can degrade cell performance. To accommodate the volume change we synthesize the tin in the form of 1-D nanostructures using electroplating. Cell performance shows that these nanostructured tin anodes deliver capacities close to the theoretical value and have cycling stability exceeding most non-carbon-based anodes. Electroplating is a cost effective and industry scalable process to directly form tin nanostructures for lithium-ion battery anodes. Because of the mild synthesis conditions a wide range of substrates, including flexible and wearable materials, can be coated.

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

4:00 **New Binders for Lithium-Sulfur-Batteries**

Brigitta Pascucci, Institute of Technical Thermodynamics, German Aerospace Center (DLR), Germany*

PVDF, a common binder for sulfur-cathodes, requires toxic and/or low-volatile solvents. The drying conditions of such cathodes are either extreme, with loss of active material by sublimation or ambient, which enhance fabrication cost. Due to economically viable application processes, enhanced substrate adhesion, mechanical strength, chemical resistance, material and fabrication costs phenolic-, polyurethane-, epoxy- and silicon-based binders are studied, considering the binders electrochemical resistance first. **In collaboration with: Norbert Wagner, K.Andreas Friedrich*

4:30 **Nanofiber/Microfiber Lithium Ion Battery Separators**

Brian Morin, PhD, President and COO, Dreamweaver International

Current stretched porous film battery separators for lithium ion batteries are thin, strong, and provide a good barrier between electrodes, at the cost of having very high internal resistance and low ionic flow. In this work, linear nanofibers and microfibers are combined in wet laid nonwoven processes to give separators that are strong and thin, but have higher porosity (60%) and much higher ionic flow. Batteries made with these separators are able to give similar performance at much higher electrode coat weights, reducing the surface area of both current collectors and separator and also the volume of electrolyte needed. Total mass reduction can be as high as 20% (1.3 kg/kWh), with raw material cost savings of over 25% ($55/kWh). Volume savings are 0.5 liters/kWh. Batteries made with similar construction show much higher charge and discharge rate capability. Temperature stability is also improved, from a current stability temperature of about 110°C up to 175°C. Applications include all power source applications that require high energy density, high power, high temperature stability, including cell phones, laptop and tablet computers, power tools, and electric and hybrid vehicles.

5:00 **Boehmite-Based Nanocomposite Separators**

David Avison, Director, Core Technology Group, Madico

The separator is a critical component in liquid electrolyte batteries; its role will become increasingly more important for the current generation of high energy- and/or power- density lithium-ion batteries being developed for automotive and other high performance applications. To address the demanding safety, performance, and economic requirements of these applications, a novel class of boehmite-based nano-composites has been developed and is being scaled to commercial production. The chemistry, thermal, electrochemical, morphological, and economic attributes of these materials will be reviewed.

5:30 **Exhibitor/Sponsor Showcase Presentations**

Wednesday, May 1, 2013

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

8:45 **Prospecting for a Counterpart of Moore's Law for Rechargeable Lithium Batteries**

K.M. Abraham, PhD, Northeastern University Center for Renewable Energy Technology, Northeastern University

Advances in microelectronics guided by Moore's Law have enabled the proliferation of portable consumer products such as laptop computers, tablets, cell phones, digital cameras, personal digital assistants, electric vehicles, and a variety of power tools. The last two decades have also seen impressive advances in rechargeable battery technologies although it is generally recognized that their progress lagged behind that of microelectronics. The natural question is whether we can formulate a counterpart of Moore's

Law for guiding the rapid progress of rechargeable battery technologies. In this talk I will provide a brief overview of rechargeable batteries, with an emphasis on recent advances in materials and engineering of practical batteries, particularly lithium-ion batteries and those beyond today's Li-ions,. The energy densities of Li-ion batteries have increased from about 200 Wh/liter in the middle nineteen nineties to more than 600 Wh/liter today. The prospect for creating a counterpart of Moore's Law for rechargeable batteries depends on gaining a clear understanding of the factors governing the energy, power and rechargeability of practical batteries. Modest advances in energy density and significant advances in power density can be made through battery engineering. On the other hand, significant advances in energy density and cycle life rest with discovering new electrode materials and optimally engineering them. A benchmark law may be formulated to guide advances in power density whereas the discovery of new materials capable of ultrahigh energy density practical batteries may just hinge on serendipity in research guided by electrochemical principles.

9:15 **High Specific Energy Lithium Cells for Aerospace Applications**

Florence Fusalba, PhD, Batteries Program Manager, Laboratory for Innovation in New Energy Technologies and Nanomaterials (LITEN), French Atomic Energy Commission (CEA), France

Among various parameters, high specific energy is the most important criteria for aerospace applications. A breakthrough is expected in this domain to be able to prepare batteries with the key driver for application of at least 250Wh/kg BoL at cell level. Exploring a number of possibilities in the quest for more environmentally friendly aircrafts or to sustain satellite requirements, operating with high reliability & efficiency, under specific environment including large temperature range, the major challenge remains demonstrating sufficient cycle life for such high energy cells.

9:45 **Development of a PVA/TiO2 Polymer/Gel Membrane for the Zinc/Air Battery**

Jean-Francois Drillet, Research Scientist, DECHEMA Research Institute, Germany

TiO_2 modified PVA membranes were synthesized and tested in a primary cell with a zinc paste and a MnO_2 air electrode. First measurements in a button cell show an enhancement of the cell capacity of about 6-10% compared to that of commercial cells equipped with a separator. At 10 mA discharge current, a capacity of 660 mAh g-1 zinc has been measured. By using a membrane with a thickness of about 70-150 µm, an increase of about 25mV in cell voltage was observed at 20 mA. The excellent performances were attributed to the high ionic conductivity of the polymer/gel membrane and to an optimal electrolyte management at the membrane-electrode interface.

10:15 **High Energy Flexible Thin Solid State Li-ion Batteries: Nanostructured Electrodes and Electrolyte Materials**

Elena Shembel, PhD, CEO and President, Enerize Corporation

Thin film flexible solid state Li-ion batteries based on proprietary inorganic solid electrolyte, high energy nanostructured binder-free Si-graphite anode, and binder-free spinel based cathode. Synergetic effect of technology and equipment for thin film deposition reduces costs, increases productivity of the battery fabrication, and provides reliability and high performance of batteries. Solid inorganic electrolyte enables to use batteries from minus 10°C and up to plus 250°C. Areas of applications with high benefits include oil & gas drilling, hot environment, vehicle running uphill, deep mining, aerospace. Enerize has 3 US patents and 3 US patent applications in the area of thin film solid state batteries.

10:45 *Networking Refreshment Break, Exhibit/Poster Viewing*

11:15 **The Power Demand Gap**

Mouli Ramani, Vice President, Lilliputian Systems, Inc.

With devices using more power than ever, especially smartphones, lithium ion batteries just cannot keep up with the power demand. Lilliputian Systems has developed a solid oxide fuel cell designed to solve this "demand gap" and charge any device that subscribes to the USB standard. The charger can provide up to two weeks of power for smartphones, GPS, cameras and many other consumer electronics devices on a single power cartridge.

11:45 **ZEBRA Battery system for range extender architecture in a Fuel Cell Hybrid Vehicle**

Vincenzo Antonucci, PhD, Head of Research; and Laura Andaloro, CNR-Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano" (ITAE), Italy*

The range extender architecture represent an advantageous choice, both from a technical and economic point of view, for the hybridization of stationary and transport systems that use fuel cell and batteries systems. With reference to this configuration the CNR TAE Institute is involved in a national project regarding the development of a hybrid electric city bus based on a range extender architecture. Six ZEBRA batteries (Zero Emission Battery Research Activities) recharge a reduced size (rated power 5 kW) of PEM fuel cell system (low investment cost) obtaining the increase of 30% of the range with respect the pure electric version of the vehicle. Present work intends to relate the configuration of batteries and fuel cell system realized for the city bus project. **In collaboration with: F.Sergi, G.Napoli, N.Randazzo*

12:15 **Novel 3D-Microbatteries: Modeling and Design**

Dmitri L. Danilov, PhD, Researcher, Department of Chemical Engineering and Chemistry, Eindhoven University of Technology, The Netherlands

All-solid-state micro-batteries (MB) are in the focus of modern battery research. The new concept of 3D integrated MB is based on the etching of deep 3D-structures into a Si substrate, increasing the effective surface area. New possibilities exist to increase the energy density by applying novel Li-storage materials. Mathematical modeling provides insight into the functioning of all-solid state Li-ion batteries. In particular charge/discharge profiles of 3D-MB with prospective Si anode are calculated, energy and power limitations of complete device as

function of design parameters are studied. 3D integration reduces the current density and improves electrode and electrolyte kinetics. It leads to considerable gain in battery performance.

12:45 *Lunch on Your Own*

2:00 **New Frontiers in Power, Safety, and Life**

Mujeeb Ijaz, CTO, A123 Systems LLC

In January of 2013, A123 Systems, Inc was acquired by Wanxiang America, following bankruptcy filing the prior November. All A123 assets were included, with the exception of business associated with government programs. A123 Systems is now privately owned, and has been renamed A123 Systems LLC. A132 business is focused on four market segments: transportation, grid, lead acid replacement, and high performance solutions for unique, niche market opportunities. The A123 R&D team has become an independent business unit, and has developed an impressive technology portfolio, including world class High Power cells, VDA HEV technology, state of the art High Energy cells, and cells with incorporated Redox Shuttles. We are looking to expand collaborative relationships and technical programs in ways that leverage our strengths and will add value to others. This presentation shares technology capabilities and portfolio highlights.

2:30 **On The Road of Harmonizing Batteries Safety Standards**

Chritian Michot, INERIS, France; and Laurie B. Florence, Principal Engineer - Large Format Batteries, Fuel Cells & Capacitors, Underwriters Laboratories LLC

In order to promote the introduction of EVs into the international market, the EU, USA and Japan agreed in November 2011 to cooperate on development of EV safety global technical regulations. For that reason, in September 2012, UL LLC and INERIS initiated a cooperative agreement with the goal to focus on ways to reduce inconsistencies between Li-ion EV battery safety standards. A comprehensive review of mechanical, electrical and environmental tests is provided with recommendations for harmonization of test conditions and for mutual recognition of test results are identified. **In collaboration with: Underwriters Laboratories*

3:00 **Characterization of Automotive Li-Ion Cells in Relation to Their Material Properties Based on the Test Standards**

Grietus Mulder, Researcher, VITO Unit Energy Technology, Belgium*

The presentation that VITO proposes has two components that depend on each other: the methods to characterize automotive (Li-ion) battery cells; test results with a translation to material properties and shape. Six test standards exist for automotive cells and battery systems. These standards have been defined to ensure that battery systems can cope with specific tasks like powering an electric vehicle or a power assisted hybrid electric vehicle. However, to compare cells with each other, the test methodologies in the standards have to be harmonized and be executed at clear C-rates. An enhanced test methodology has been constructed, consisting of 5 tests. Then 13 cells with 5 species each have been tested covering a wide range of materials, shapes and capacities. The test results can be related to material and shape with help of graphs. The test results can also be related to physical relations. Depicting physical relationships behind cell properties can reveal effects that are invisible from the absolute value of the property. Clear relations to cell (cathode) chemistry can be found for voltage shape, voltage range, and energy density. The influence of cell shape and chemistry can be discerned in the test results on temperature, efficiency, resistance and charge behavior. However, the knowhow of the manufacturer appears often to be more deciding. **In collaboration with: Bart Mantels, VITO; Noshin Omar, VUB*

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

4:00 **A Data Based Analysis of Overcharge Abuse of Lithium Ion Cells**

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

TÜV SÜD, a global third party provider of product testing and certification services, has performed SAE, USABC and other abuse tests on hundreds of large format lithium ion cells to gauge the robustness of cells. This presentation covers the overcharge behavior of over 160 cells of different formats, chemistries, capacities, test environments and test parameters. All of the data is from tests performed by TÜV SÜD since 2010. The data has been organized to show how this population of cells has responded in terms of Hazard Severity Level (HSL) and maximum temperature in relation to capacity, charge rate, physical constraint and other factors.

4:30 **Grid Connection Challenges for Next Generation Batteries**

Brent Harris, PEng, Vice President, Chief Technology Officer, Sustainable Energy Technologies Ltd., Canada

Advances in battery technology combined with the accelerating deployment of solar PV and other renewable energy systems on electricity systems around the world. This presentation will outline the unique technical and regulatory challenges that must be addressed by grid connect power electronics developed for these applications.

5:00 **Exhibitors and Sponsors Showcase Presentations / Selected Oral Poster Highlights**

5:30 *Concluding Remarks, End of Conference*

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