Revolutionizing Lead Batteries: CBI’s Key Findings

17 September 2024, ELBC, Milan, Italy

Dr. Begüm Bozkaya // Technical Manager // Consortium for Battery Innovation

CONSORTIUM FOR BATTERY INNOVATION

History of Technical Programs

ALABC from 1992 to 2018

1992-1996

Optimization of active material and grid alloys

Premature capacity loss mechanisms

Charging protocols

1997-1999

Battery management and charging algorithms

Improving cycle life for tubular gel and AGM batteries

2000-2002

Development of state-of-the-art separators for VRLA appl.

In-depth studies of residual elements

2003-2005

Optimization of NAM additives

Studies on the VRLA performance (electrolyte and plate manufac.)

2006

Development of Ultrabattery

42V demonstration projects

2007-2009

Impact of carbon on the negative plate performance

Different forms of carbon additives

2010-2012

Studies on carbon effect such as gassing

Verification and validation of different LABs for 42V appl.

2013-2015

Active material formulations for Start/Stop and duty cycles

Carbon enhanced VRLA bat.

2016-2018

Impact of additives on DCA and high-temp. durability

Operation of AGM batteries for frequency regulation and load following ESS

History of Technical Programs

CBI from 2019 onward

2019-2020

Enhanced DCA and high-temp. durability via carbon and expander

Charging algorithms to improve cycle life for ESS

2021-2022

Influence of barium sulfates on LABs for ESS appl.

Bipolar lead batteries for ESS appl.

Advanced characterization methods for lead cells

2023-2024

Opportunity fast charging for motive power appl.

In-operando characterization techniques during AUX charge regimes

2025-2026

New projects!

Impact of NAM and PAM additives for AUX appl.

Studies on mechanical properties of LABs for ESS appl.

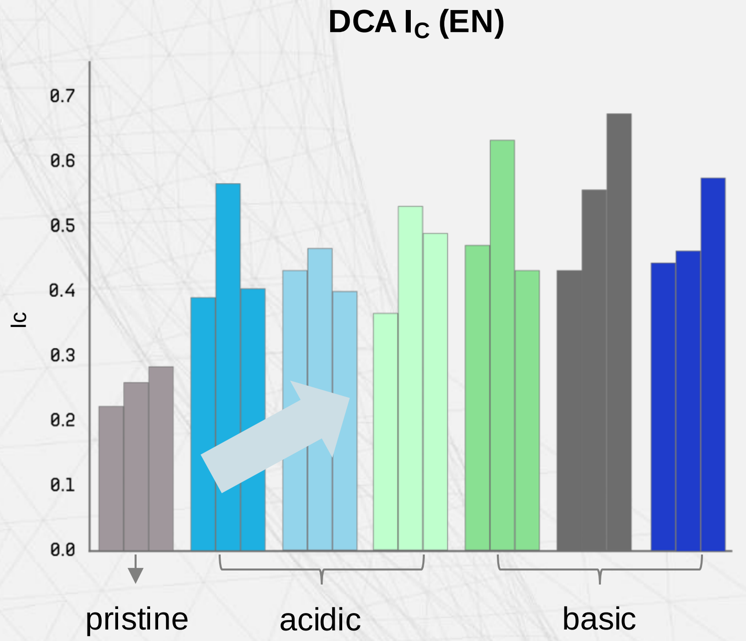
CBI issues Request for Proposals (RFP) based on KPIs stated in the Technical Roadmap!

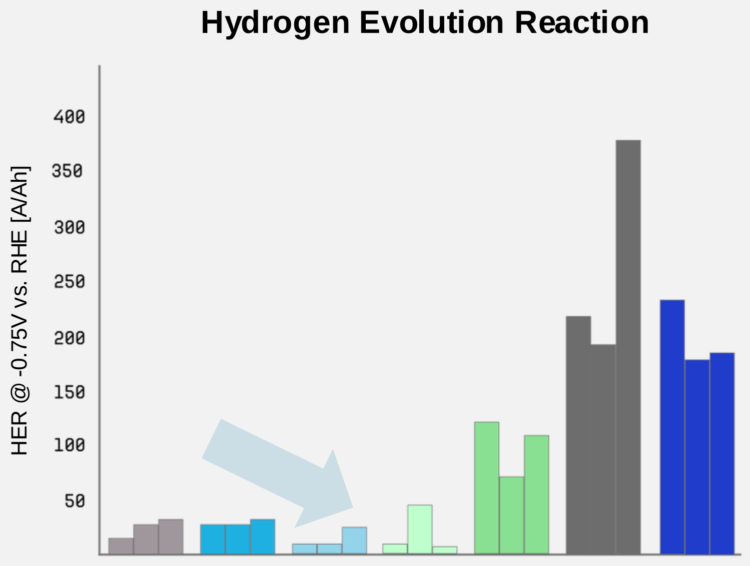
CBI Technical Program: Completed Projects 2023

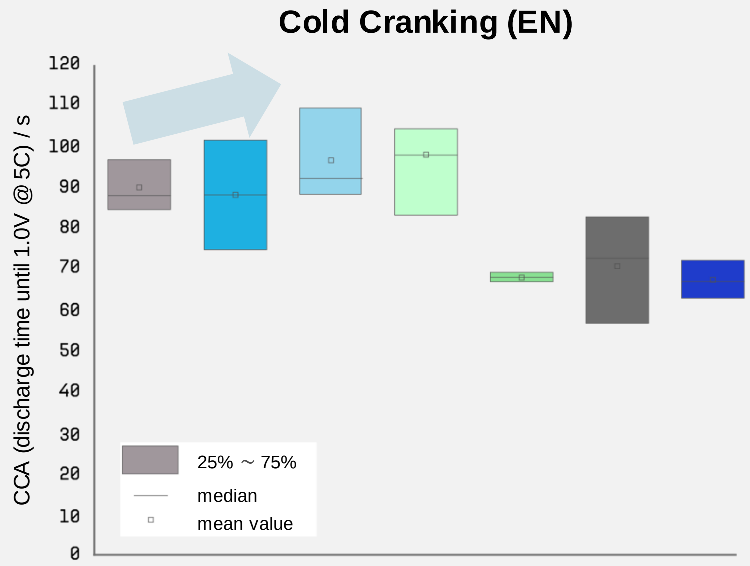
Partners	Project Title	Application	KPI
Gridtential Energy EAI	Bipolar Lead Batteries for ESS Applications	ESS	Service life, Energy density
INMA Exide Technologies	In-operando Neutron Scattering Analysis of the Charge/Discharge Processes inside the Battery Electrodes	ESS	Cycle Life
Fraunhofer ISC WUST	Investigations on the Effect of Carbon Surface Functional Groups on Electrochemical Behavior of Lead Carbon Electrodes	Automotive (Start/Stop, Micro-hybrid)	DCA, CCA, Water loss
TU Berlin Fraunhofer ISC Moll Batterien Ford	Best Practices of Cell Testing for EFB regarding DCA and High-Temperature Durability	Automotive (Start/Stop, Micro-hybrid)	High temp. durability, Water loss

Main Findings: Completed Projects 2023

Effect of Carbon Surface Functional Groups on the Electrochemical Behavior of Lead Carbon Electrodes





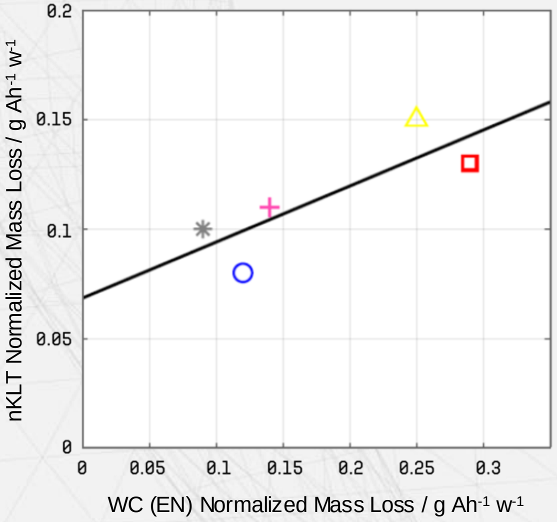


- Significant influence of carbon surface chemistry on the electrochemical performance
- Acidic carbons (e.g. oxidation) can reduce HER, while keeping DCA still high and increasing CCA

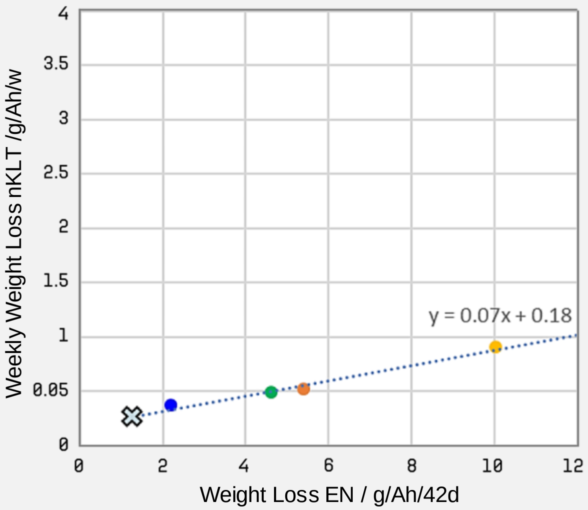
Main Findings: Completed Projects 2023

Best Practices of Cell Testing for EFB regarding DCA and High Temperature Durability

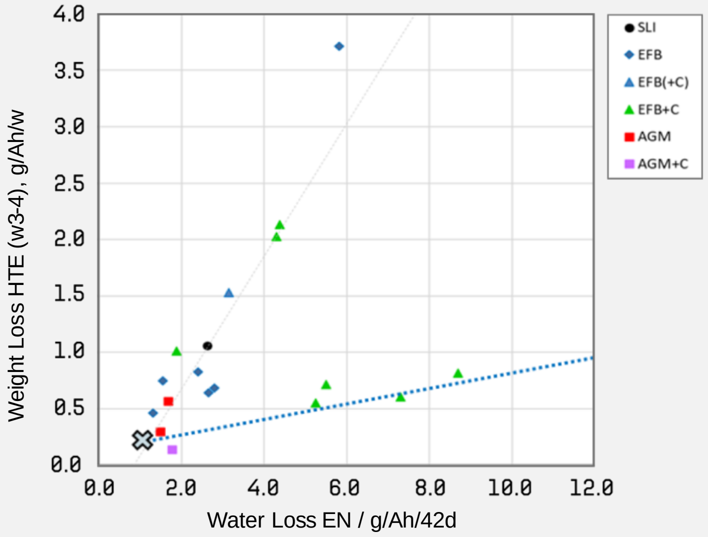
TU Berlin



Fraunhofer ISC



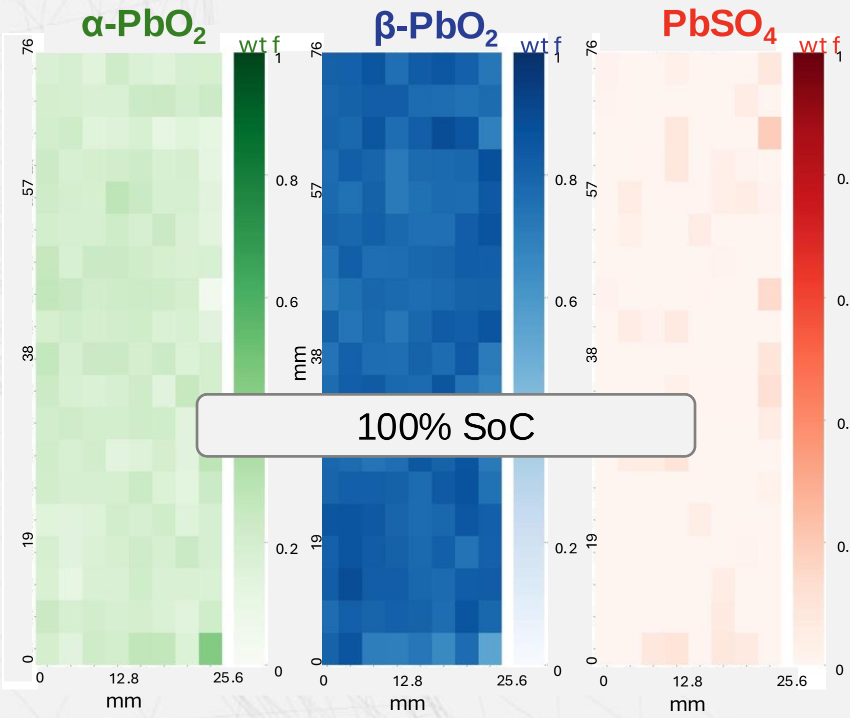
Research Data from Ford

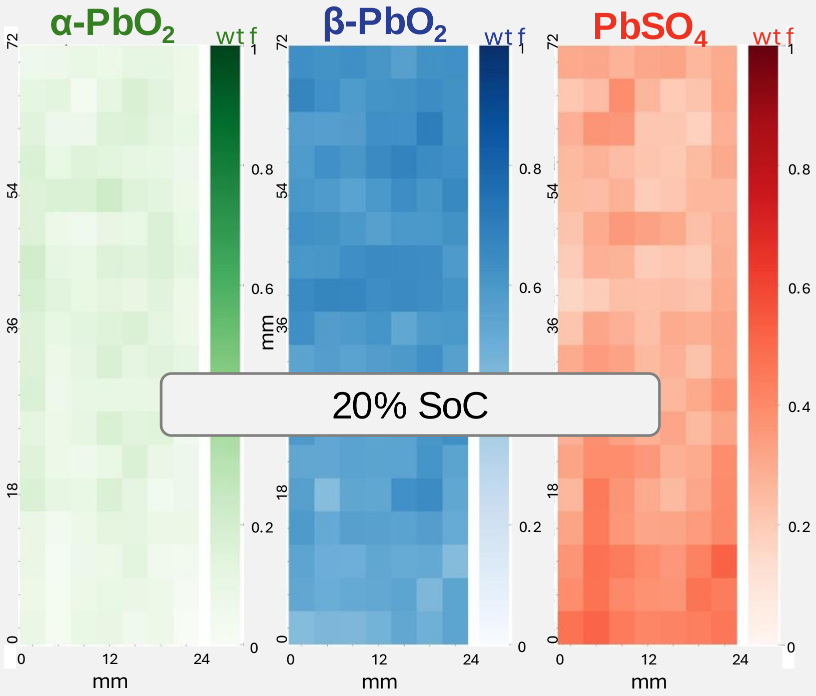


- Results from small test cells (2P1N, ISC) match with commercial-sized test cells (3P2N, TUB)
- Similar observation between 2V cells and EFB+C data from commercial batteries

Main Findings: Completed Projects 2023

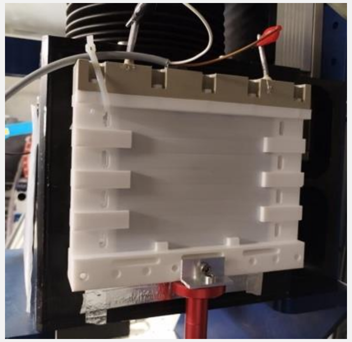
In-operando Neutron Scattering Analysis of the Charge/Discharge Processes inside the Battery Electrodes





1st cell setup

Upgraded cell setup

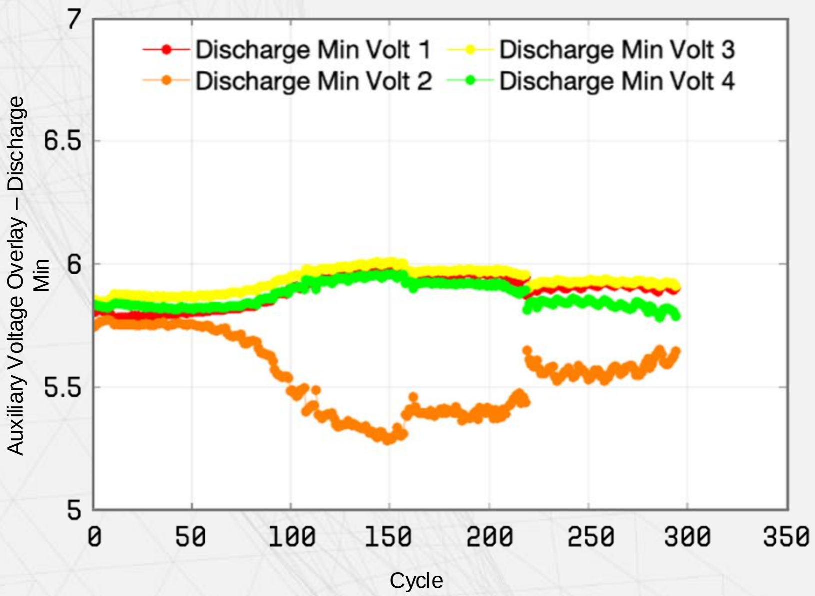


- Analysis of charge and discharge processes of commercial-sized electrodes by using in-situ neutron diffraction
- Determination of crystalline phases in PAM at different SoC → compositional map

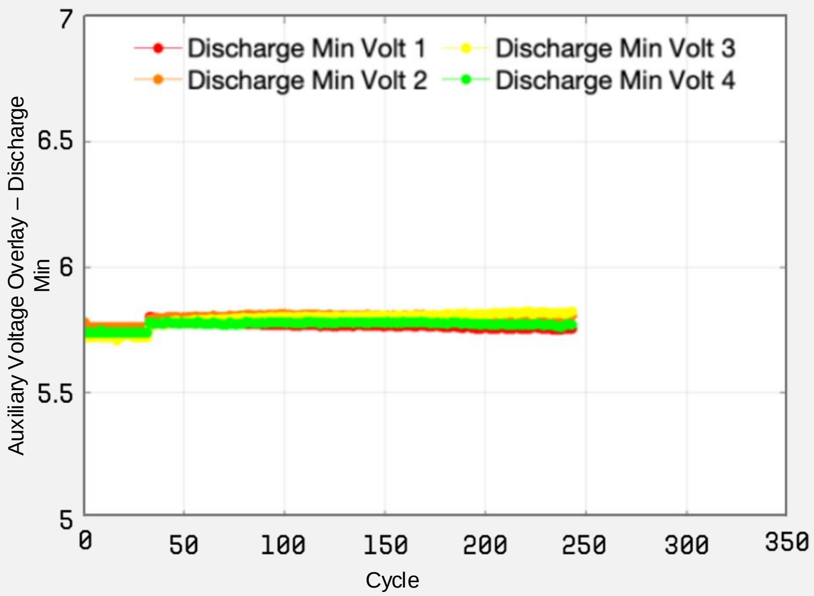
Main Findings: Completed Projects 2023

Bipolar Lead Batteries for ESS Applications

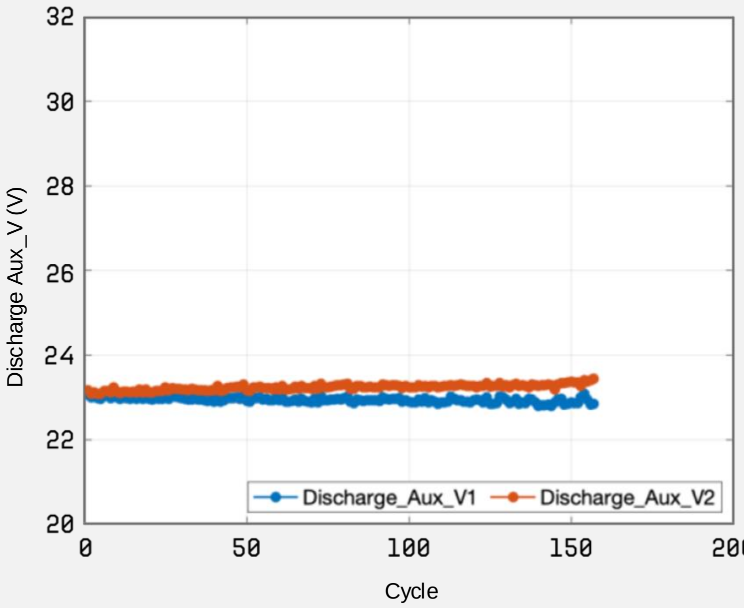
Individual monoblocs in 6V modules



Individual monoblocs in 6V modules



Two series strings of 24V modules



- Optimized methods for managing bipolar batteries for parallel strings including a comparison of different pack conformations
- Technoeconomic analysis of bipolar batteries (LCOS calculations based on photovoltaic time-shift service)

CBI Technical Program: Ongoing Projects

Partners	Project Title	Application	KPI
C&D Trojan EAI	Opportunity Fast Charging and Improved Energy Throughput for Motive Power Applications	Motive Power	Charge time, Energy throughput
UNT Ecobat East Penn	In Situ Imaging and Phase Analysis of Live Cell Lead Battery Materials from Auxiliary Battery Cycling Testing Regimes	Automotive (Auxiliary)	Charge efficiency
Hammond Group East Penn Eclipse Energy	Examination of the Effects of Surfactant Coatings & Particle Size of Barium Sulfate on the Structure Changes and Overall Performance of NAM in ESS Applications	ESS	Cycle Life
Villanova University	Proof of Concept Testing and Magnetic Field Monitoring in Cycled Lead-Acid Cells	ESS	Cycle Life

Ongoing Projects: Motive Power

Opportunity Fast Charging and Improved Energy Throughput for Motive Power Applications

Scope:

- Development of opportunity and fast-charging methodology (target: 1h or less charging time from 30% to 80% SoC)

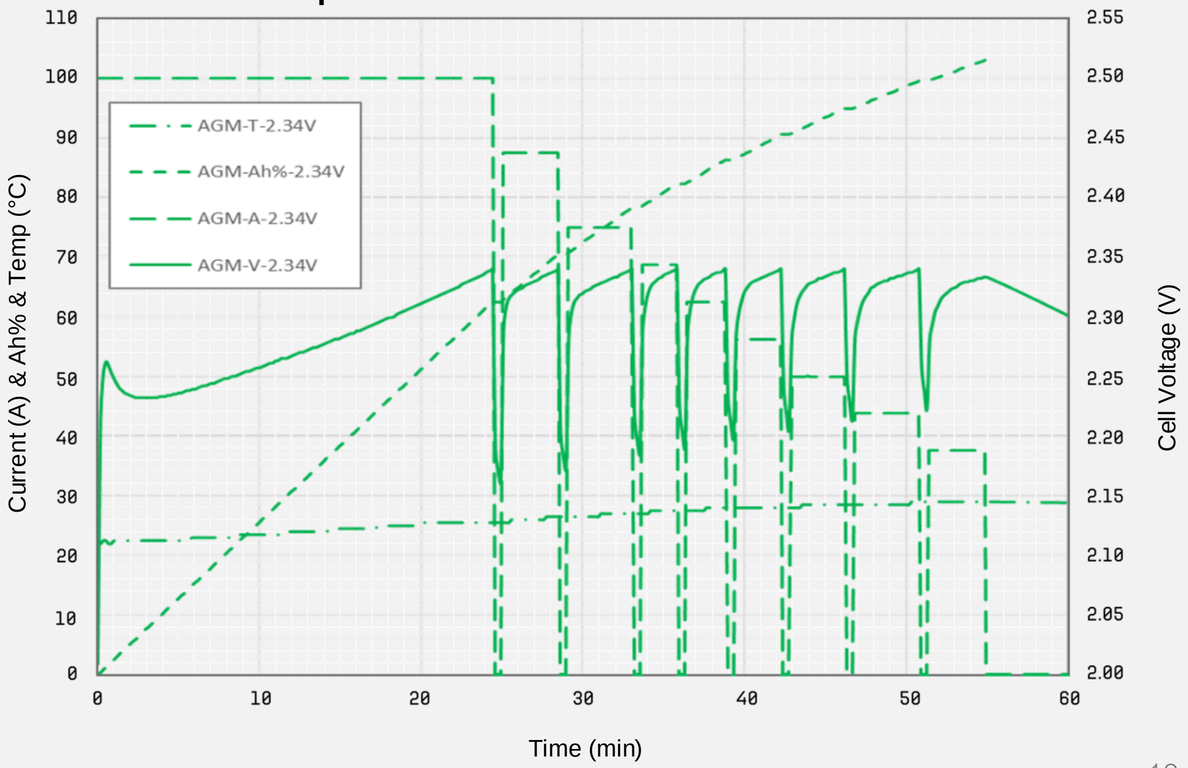
Experimental:

- IEC 60254-1 Endurance Cycle Life Test
- Opportunity charging: new Multi-Step Tapering Current Charging (MTCC)

Overview:

- Probe the MTCC methodology parameters (e.g. rest time) on 2V cells
- Confirmation of an effective method at the 2V cell level on 8V batteries, including tear down analysis
- MTCC testing on 48V string and further cycling tests

MTCC profile of 2V AGM – from 30% to 80% SoC



Ongoing Projects: Automotive

In Situ Imaging and Phase Analysis of Live Cell Lead Battery Materials from Auxiliary Battery Cycling Testing Regimes

Scope:

- In-situ characterization of Pb electrodes to identify performance-defining heterogeneities that develop during representative tests for AUX batteries

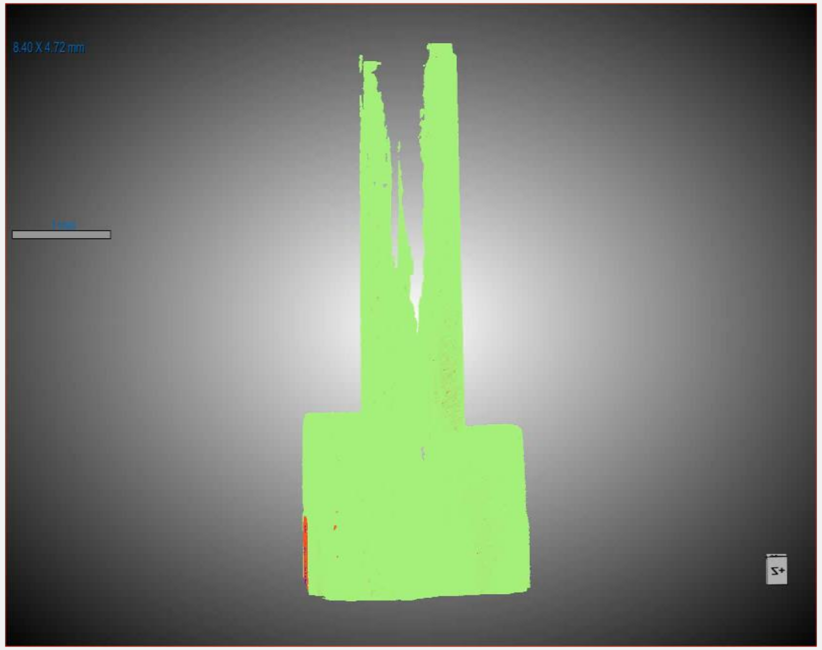
Experimental:

- Microscopy, tomography and diffractometry techniques such as XRM coupled with micro-CT and synchrotron-XRD

Overview:

- Characterization of 2V mini-cell using XRM with micro-CT
  - Generate 3D bulk images for high-resolution investigation of surface and interior
  - Determine heterogeneous phases occurring during cycling, like porosity and cracks
- In-situ SR-XRD on live Pb foils during cyclic voltammetry to observe amorphous and crystalline phases

2V mini-cell – Pb phases from XRM, CT



Ongoing Projects: ESS

Examination of the Effects of Surfactant Coatings & Particle Size of Barium Sulfate on the Structure Changes and Overall Performance of NAM in ESS Applications

Scope:

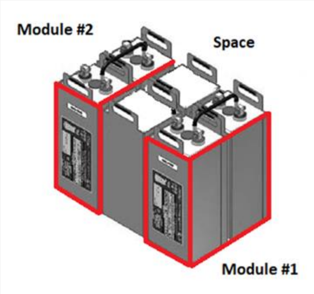
- Reveal influence of particle size and surface/surfactant treatment of $BaSO_4$ on its ability to function as nucleation agent in lead batteries

Experimental:

- Five different commercially available $BaSO_4$ materials having different size categories with or without surface coating
- IEC 61247-1 Cycle Life Test

Overview:

- Investigation of $BaSO_4$ materials on the negative electrode properties
- Electrical testing of 2V cells according to IEC cycle life test to choose best performing $BaSO_4$ materials
- Confirmation of 2V cells with full-scale battery testing



Characteristic	Best Performance	2nd Best
Highest % Pb	PB-08	EWO
Lowest % PbSO4	EWO	PB-08
Highest final Surface Area	HU-N	HD-80
Largest Pore Area	HU-N	HD-80
Largest Pore Volume	HU-N	HD-80
Largest Pore Size	HU-D	PB-08
Smallest Estimated Particle Size	HU-N	HU-D
Highest EoD Voltage	HU-N	F-102
Highest % of Initial Capacity	HU-N	HU-D

Ongoing Projects: ESS

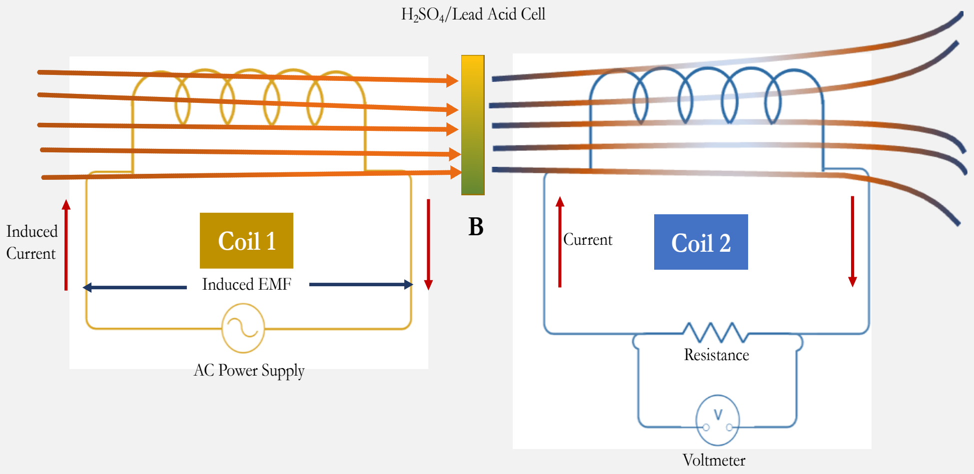
Proof of Concept Testing and Magnetic Field Monitoring in Cycled Lead-Acid Cells

Scope:

- Demonstrate changes in the magnetic field strength of the H^+ ions during charge and discharge of cells for the estimation of SoC & SoH

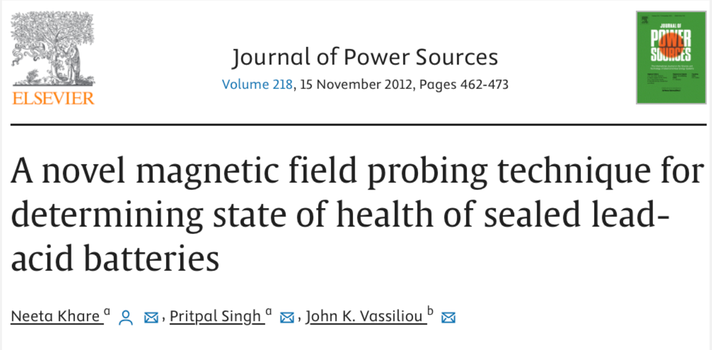
Experimental:

- Magnetic field probing involves placing a cell between 2 coils
    - AC voltage is applied to Coil 1 and the output voltage is measured across Coil 2
    - Linkage between electrolyte concentration and changes in the magnetic flux
- Coupled coil setup including different electrolyte concentrations and 2V cells



Overview:

- Coupled coil measurements to determine optimal AC input frequency delivering maximum magnetic field response
- Testing optimized experimental setup with 2V cells
- Testing magnetoresistive sensors for monitoring the magnetic field changes for modelling of the magnetic behavior of lead batteries


ELSEVIER

Journal of Power Sources
Volume 218, 15 November 2012, Pages 462-473

A novel magnetic field probing technique for determining state of health of sealed lead-acid batteries

Neeta Khare [a], Pritpal Singh [a], John K. Vassiliou [b]

CBI Technical Program: New Editions

Partners	Project Title	Application	KPI
Fraunhofer ISC Moll Batterien E. Karden	Testing Charge Recovery for Auxiliary Lead Batteries on Laboratory Scale	Automotive (Auxiliary)	Charge recovery, PPC, DCA
Hammond Group BAS East Penn	Examination of the Effects of Novel Metal Silicates on Improved Pulse Power and Charge Acceptance Capabilities of Lead Acid Batteries for BEV Auxiliary Applications	Automotive (Auxiliary)	Charge recovery, PPC, CCA
BDS University of Texas	Integrating Cycling Performance, Materials Science, and In Situ Electrical Analysis to Elucidate Structure/Function Relationships Defining Electrode Integrity in FLD, VRLA and TUB Batteries	ESS	Cycle Life
Jinkeli Power Technology	Research on Positive Electrode Additives for ESS Applications	ESS	Cycle Life
Villanova Uni. East Penn	Characterization and Modelling of Mechanical Properties of Lead Batteries for ESS Applications	ESS	Cycle Life

Under discussion

New Editions: Automotive

Fraunhofer ISC, Moll Batterien, E. Karden

Scope:

- Reveal impact of carbon additives on charge recovery and pulse power characterization for 2V cells and commercial sized batteries

Overview:

- Proof of concept study to reveal effects of cell layout on charge recovery and PPC
- Effect of DCA additives and formulations (DoE study) on charge recovery and PPC for 2V cells
- Electrical tests of 12V SLI and EFB+C containing best performing NAM additives

Hammond Group, Bulgarian Academy of Science, East Penn

Scope:

- Reveal influence of various doped monosilicate materials as additives to PAM on the electrochemical performance of lead batteries related to AUX applications

Overview:

- Characterization of the lead monosilicate additives
- Analysis of positive plates containing 7 LMS additives
- Electrical testing of 2V cells inc. charge recovery, charge acceptance and PPC
- Testing of 12V batteries with best-performing additives

New Editions: ESS

This project is under discussion!

Black Diamond Structures, Uni. of Texas

Scope:

- Analysis of various lead batteries (VRLA, TUB, bipolar) to correlate mechanical properties of electrodes to their cycle life for ESS appl.

Overview:

- Testing the performance of LABs via IEC 61427 and PNNL-22010
- Analysis of mechanical properties of electrodes by various methods
- Tear-down analysis of electrodes

Jinkeli Power Technology Co.

Scope:

- Reveal the impact of various PAM additives on different shallow cycle regimes related to ESS appl.

Overview:

- Preparation and characterization of several PAM additives
- Electrical testing of 2V cells according to IEC 61427-1
- Tear down analysis of electrodes after battery failure

Villanova University, East Penn

Scope:

- Modelling the mechanical changes in lead electrodes with respect to ESS cycle life

Overview:

- Measuring mechanical properties of fresh and cycled electrodes
- In-situ characterization of electrode material degradation as a function of cycling
- Modelling electrode degradation

THANK YOU!

Dr. Begüm Bozkaya // Technical Manager // Consortium for Battery Innovation

CONSORTIUM FOR BATTERY INNOVATION

TECHNOLOGY FOR TOMORROW

International Lead Association

CONSORTIUM FOR BATTERY INNOVATION