Industry Service Lab Accelerates the Development of Lithium-ion Batteries

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Eurofins EAG

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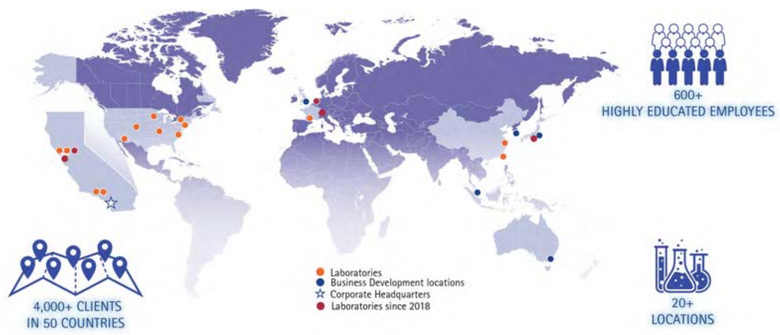


EAG Battery Lab

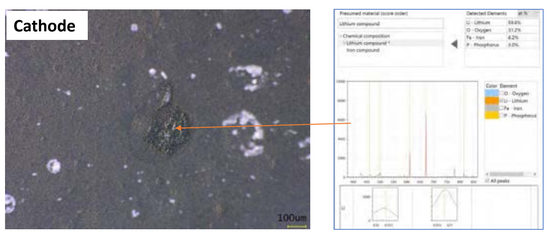
- A dedicated Battery Lab in **Milpitas, CA.**
- Total area ~2000 square feet with a dry room
- New services:
  - Cell level and pack level cycling test
  - Cell level cycling at different temperature (-40ºC up to 100ºC)
  - EIS measurement: 10μHz to 1MHz
  - Battery teardown inside Ar protected glove box
  - Coin cell fabrication
  - Defect, delamination of battery analysis by optical microscopy
  - Elemental analysis by Laser-Induced Breakdown Spectroscopy (LIBS)
  - Large cross-section and FIB/SEM tomography by Plasma FIB.
  - Air-free transfer mechanism from glove box to other materials characterization instruments.

	Advanced Microscopy	Bulk Material Analysis	Chemical Analysis	Failure Analysis	Gas Analysis	Materials Characterization	Reliability Testing	Surface Analysis
Raw Materials								
Impurity survey analysis (electrode raw materials)		•			•	•		
Compositional analysis (metal/lithium content of electrode raw material)	•	•	•			•		
Phase identification (electrode raw materials)		•	•			•		
Manufacturing Process								
Elemental composition (electrode, electrolyte, separator)	•					•		•
Elemental analysis, mapping and depth profiling (electrode, separator)	•		•			•		•
Chemical state and composition (electrode, separator)	•		•			•		•
SEI characterization (electrode, separator)	•					•		•
Particle size, particle coating analysis and particle depth profiling (electrode, separator)	•					•		•
Identification and quantification of anions and cations (electrode, electrolyte)			•			•		
Levels of atmospheric species (electrode, electrolyte)			•		•			
Organic composition (electrode, separator)						•		•
Characterization of volatile organic species (electrode, electrolyte)			•		•	•		
Impurity detection (electrode, electrolyte, separator)		•				•		
Organic compound degradation (electrode, electrolyte, separator)						•		•
Crystallinity phase (electrode, electrolyte)	•					•		
Thermal properties (electrode, electrolyte, separator)			•			•		
Application/Use								
Corrosion and contamination analysis	•			•		•		•
Delamination and void identification	•			•		•		
Battery Cycling							•	
Recycle								
Trace elemental analysis (recycled battery materials)		•			•			
Composition analysis (recycled battery materials)	•	•				•		

Optical Microscopy and Laser Induced-Breakdown Spectroscopy

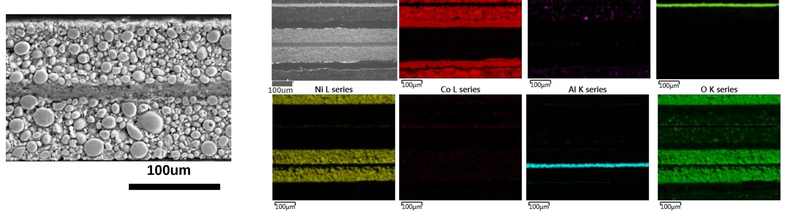
- Digital Camera documents the big defect like delamination shown below.

- LIBS could provide elemental analysis instantly under Optical Microscope. Shown below is a cathode materials of $LiFePO_4$. Light element like lithium, carbon, oxygen could be detected with um resolution.



Scanning Electron Microscopy and Energy-Dispersive Spectroscopy

- High resolution SEM/EDS can provide more detailed information of the battery materials morphologies and elemental maps.
- Right maps are the 2D elemental distribution of a commercial battery cathode by SEM/EDS.

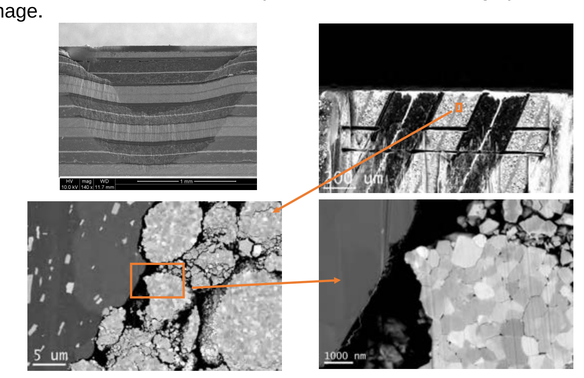


Ion Polishing and Plasma Focused Ion Beam

In order to study the active materials within the whole electrode, large cross sections are necessary. Now mm size cross section can be obtained within EAG battery lab by two methods:

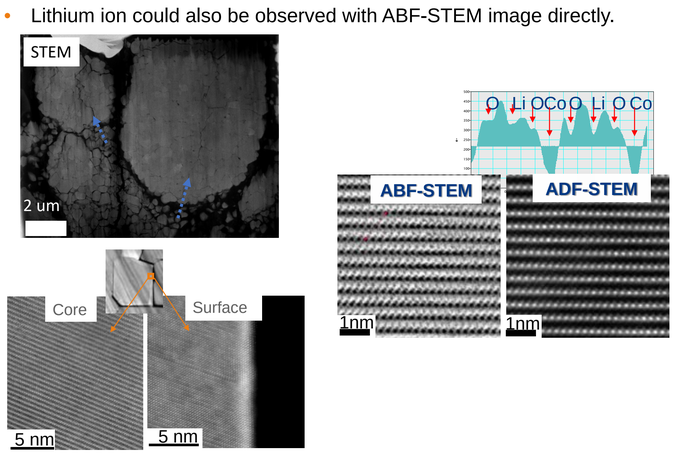
- Broad beam ion polishing
- Plasma FIB

Both methods can maintain battery electrode structure integrity without damage.



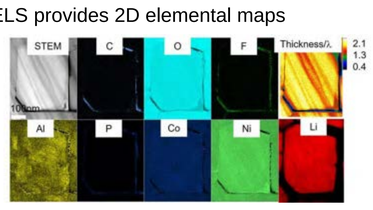
Transmission Electron Microscopy

- TEM has higher resolution than OM and SEM.
- Surface structure degradion could be investigated with atomic resolution AC-STEM.
- Lithium ion could also be observed with ABF-STEM image directly.

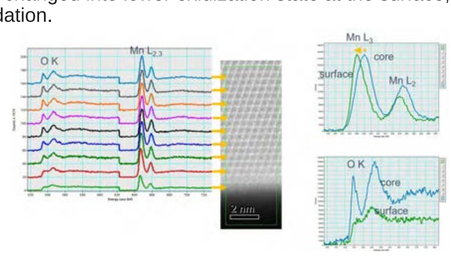


TEM and EDS/EELS

- STEM/EDS/EELS provides 2D elemental maps

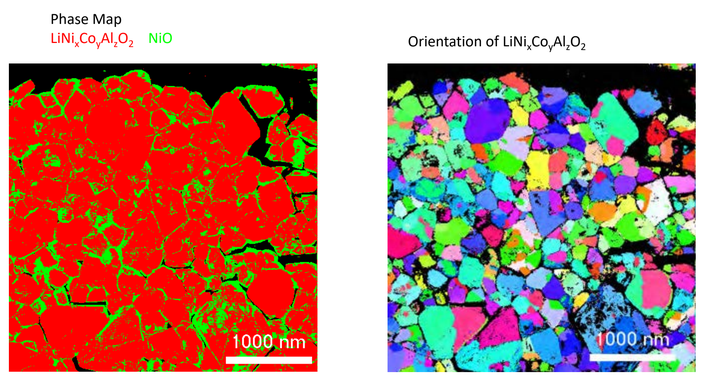


- EELS helps understanding the chemical state of transition metal. As shown below, Mn changed into lower oxidization state at the surface, indicating the degradation.



Precession Electron Diffraction

- TEM/PED provides phase distribution and grain orientation map at nm scale. As shown below, NiO was detected around cathode grains where near the edge or crack. Cathode grain has a homogeneous distribution based on their orientation maps.

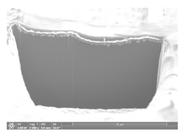


Cryo FIB and Cryo TEM/EELS

- RT FIB-creates significant artifact while Cryo FIB mitigates beam damage.

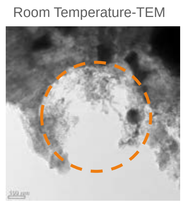
Room Temperature-FIB

Cryo-FIB

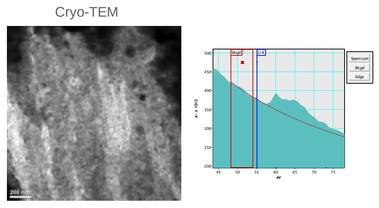


- RT TEM on Li-containing materials is challenging due to beam damage. While structure was preserved at cryo temperature which makes elemental analysis possible by EELS.

Room Temperature-TEM

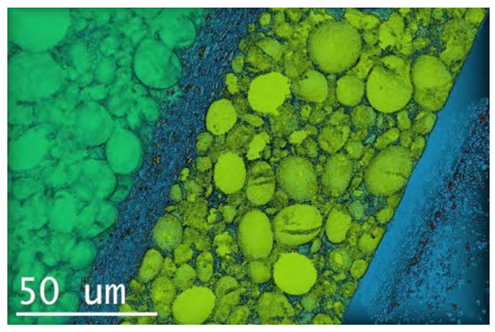


Cryo-TEM



FIB/SEM Tomography

- 3D Tomography based on FIB/SEM directly visualize the morphologies, pore structure, grain distribution. While Ga based FIB can only provide a small field of view, the new developed **PFIB** makes it possible to study materials with a larger FOV (shown below 150umx100umx100um data set).
- Elemental tomography is also possible with the aid of EDS while collecting FIB/SEM.



Atom Probe Tomography

- APT tomography reveals nm scale 3D structure and composition analysis includes light elements and trace elements (down to tens of ppm level) for cathodes like NCA, NCM, LFP and LCO as well as silicon-based anodes and oxide based solid state electrolytes. Shown below is a representative map for certain elements in the battery cathode.