Brochure

Thermo Fisher SCIENTIFIC

Analytical solutions for battery and energy storage technology

thermo scientific

Chemical, elemental, and structural analysis of batteries

The global lithium-ion battery market is expected to reach USD 93.1 billion by 2025. This growth is driven by the electrication of passenger vehicles, ESSs, and portable electronics that require high energy-density lithium-ion batteries. To improve battery performance, it is necessary to develop new materials and methodologies to understand the mechanisms by which performance deteriorates due to repeated charging and discharging. For the evaluation of batteries, materials, and components, an analytical method that can study the surface and condition at various scales is required.

We offer workflow solutions dedicated to battery materials that allow researchers and engineers to perform X-ray photoelectron spectroscopy (XPS/ESCA), electron microscopy (SEM, TEM, and FIB-SEM), spectroscopy (FTIR, Raman, and NIR), chromatography (IC, GC, TEA), mass spectrometry (GC-MS, HPLC, LC-MS, HR-MS, and ICP-MS), and nuclear magnetic resonance (NMR). We provide various solutions for battery and material parts analysis such as X-ray diffraction, X-ray fluorescence, flow measurement, viscosity measurement, extrusion, and torque flow measurement.

Using Raman, observation at the cell level is possible, and analysis down to the atomic scale is possible through transmission electron microscopy (TEM). Raman imaging can be used to observe the distribution of components and monitor how they change with charge and discharge cycles. Electron microscopy is used to study the 2D and 3D morphology of battery components at each stage of the battery life cycle. 3D visualization of cathode and anode, enabled by Thermo Scientific™ DualBeam™ FIB-SEMs and Thermo Scientific Avizo™ Software, allows quantitative characterization of the microstructure, including porosity, cracking, and tortuosity.

Spectroscopy, NMR, X-ray diffraction, and mass spectrometry are important techniques for studying structural and chemical changes and bond formation in battery electrodes. Redox reactions enable the analysis of electrode materials that change during the reaction, and they provide crystalline and amorphous information. Local differences in Raman spectral changes allow generation of state-of-charge (SOC) distribution maps showing composite electrodes using ex situ XPS for solid electrolyte interface (SEI) composition monitoring and in situ FTIR and Raman spectroscopy.

Rheology and viscosity measurement systems measure the dispersibility and coating ability of materials in electrode slurries. Torque rheometers provide information on the effect of additives on melt behavior, processability, and temperature or shear stability. Twin-screw extrusion helps advance the processing of battery slurries and facilitates solid-state batteries.

Thermo Fisher Scientific continues to innovate for companies forging the future of the energy era based on these leading-edge technologies. Whether your work takes you into the raw materials, components, quality control or failure analysis, our comprehensive portfolio of chromatography and mass spectrometry instruments, software and related tools and technologies can power your advancements, and enable a more sustainable future for us all. To help, we offer a wide range of in-depth solutions that can be used in the entire process, from solving complex analytical challenges to manufacturing mass production.

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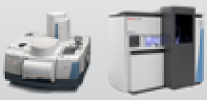
Technology solution for rechargeable battery workflow

The level of battery performance is measured by a combination of various factors, among which the quality of raw materials is essential and cannot be overlooked.

In addition to a multi-pronged approach to quality analysis, real-time data analysis and prediction, control systems for improving productivity at the battery cell stage and manufacturing process from the beginning to end, Thermo Fisher Scientific offers a wide range of excellent battery analysis solutions. From improving the safety and efficiency of batteries to the next generation of energy storage devices, meet the latest analysis solutions and technical services that are actively used in battery R&D.

Separator

Inorganics/ organics

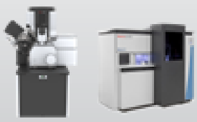


FTIR XPS

Compounding

Extrusion

Metal and impurity



EM XPS

Organics

FTIR Raman

EM XPS

Helios PFIB

FTIR

Raman

Electrolytes

Li salts

IC

Viscosity of electrolytes

Rheometer

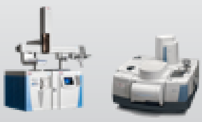
Structural integrity

FTIR

Common anions, organics acids

IC

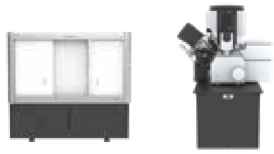
Gases



GC-MS FTIR

Cell

Cycle test



Micro CT EM

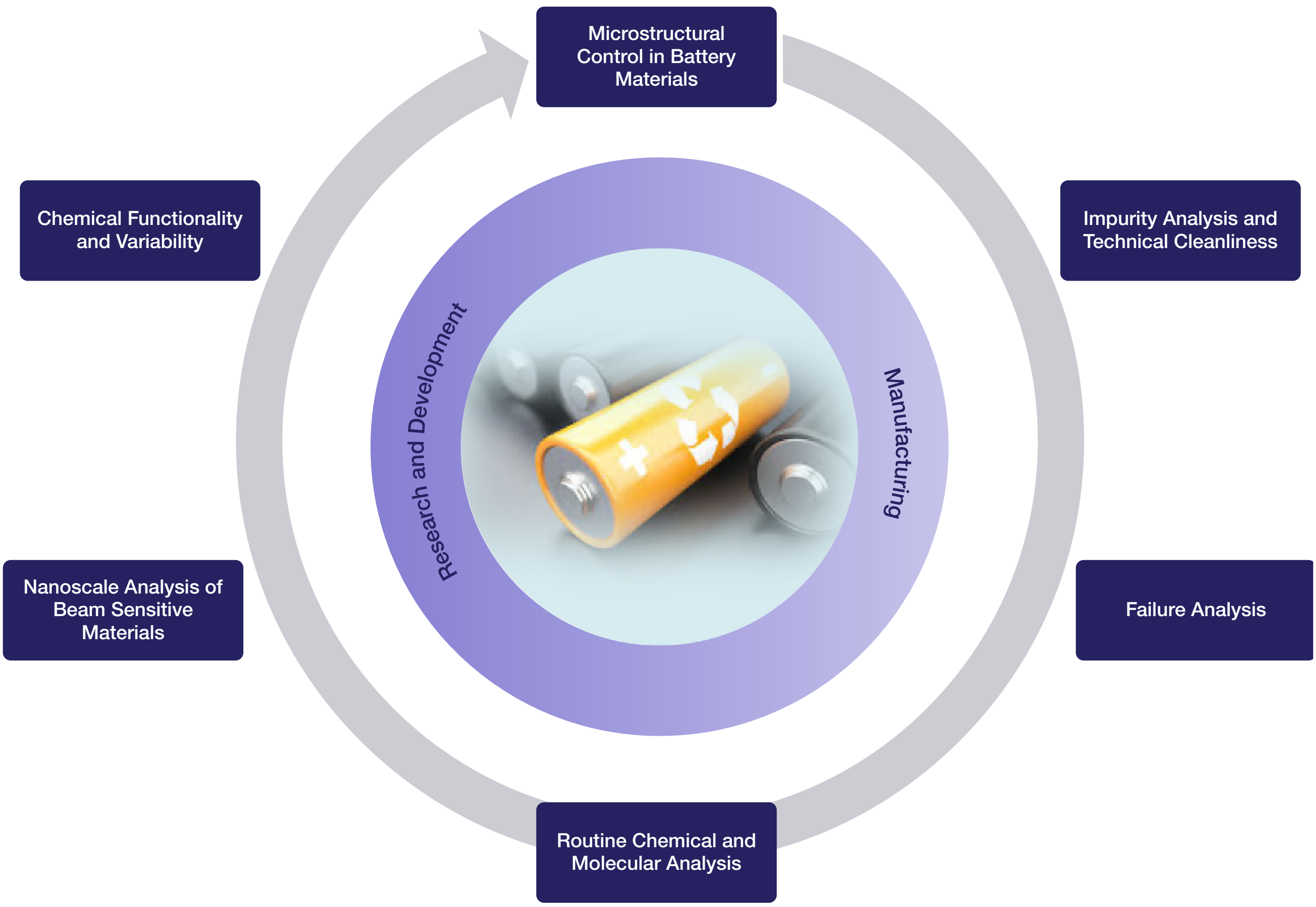
Cell

EM Raman

EM and surface analysis solutions

Imaging techniques such as SEM, DualBeam FIB-SEM, and TEM are mainly used to study battery materials and cells in 2D and 3D. Electron microscopy can provide analysis ranging from the mesoscale or macroscale to atomic scale.

The XPS provides critical chemistry information at the surface of the battery materials. In addition, Avizo Software can quantify important structural characteristics in battery samples, such as volume fraction, surface area, tortuosity, and particle size distribution at different conditions, e.g., charged state vs discharged state. We have designed battery workflow solutions to enable better research and development as well as improving material quality and yield in the manufacturing environment.



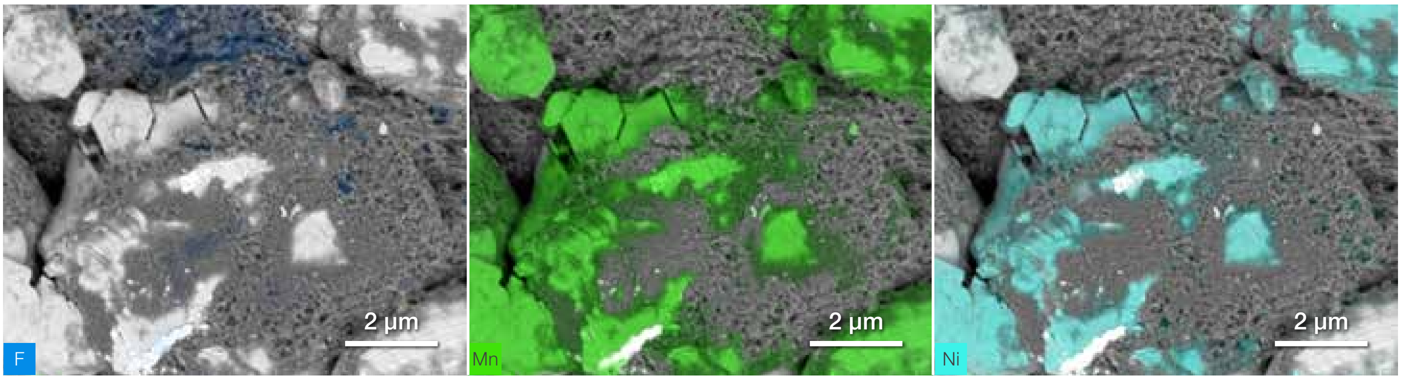
SEM

Scanning electron microscopy (SEM) is an imaging and analysis technique used for the characterization of materials' structure and chemistry at the microscale and nanoscale. Currently, it is widely used as an effective characterization tool among battery materials and cell manufacturers during materials R&D, quality control, and failure analysis. The materials applied to construct a battery are vastly different; for example, separator materials are electrically insulating and beam-sensitive, and Li-metal anode samples are electrically conductive and extremely air-sensitive. Scientists and engineers are facing a variety of challenges to accurately extract structure information on different battery samples.

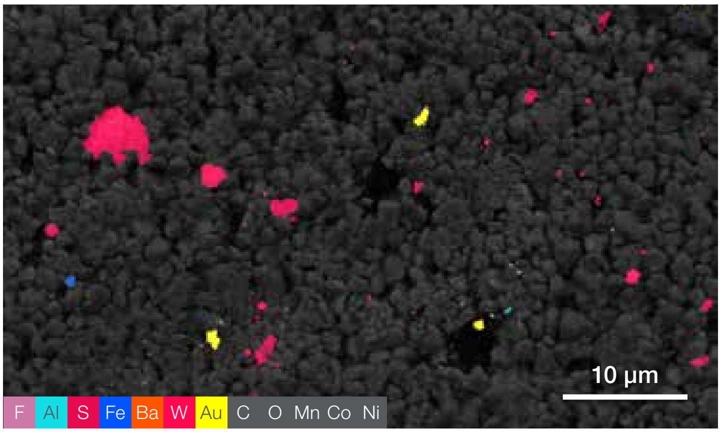
We offer advanced SEM imaging techniques that can meet a wide variety of needs in the battery industry, ranging from high-resolution imaging and *in situ* analysis to structural quantification and automated contamination analysis. Our instruments and software can help you solve your challenges in SEM imaging for battery characterization.

Features and applications:

- Live, quantitative, elemental mapping for fast elemental and structure analysis on battery materials
- Automated SEM/EDS workflow for impurity analysis for battery production QA/QC
- Inert gas sample protection solutions to observe sample without water or air contamination
- Advanced low-keV performance on beam-sensitive samples to enable accurate structural characterization without beam damage



Apreo SEM and ChemiSEM Technology analysis of a Li-ion battery cathode surface using real-time EDS.



Size class		A	B	C	D	E	F	G
Size range (µm)	Total	5 ≤ X <15	15 ≤ X < 25	25 ≤ X < 50	50 ≤ X < 100	100 ≤ X < 150	150 ≤ X < 200	200 ≤ X < 400
Iron	1		1					
Aluminium	443	256	167	19	1			
Other	272	123	115	32	2			
Salts	8	1	6	1				
NMC	99,286	37,745	43,173	17,398	960	8	1	1
Total counts	**100,010**	**38,125**	**43,462**	**17,450**	**963**	**8**	**1**	**1**

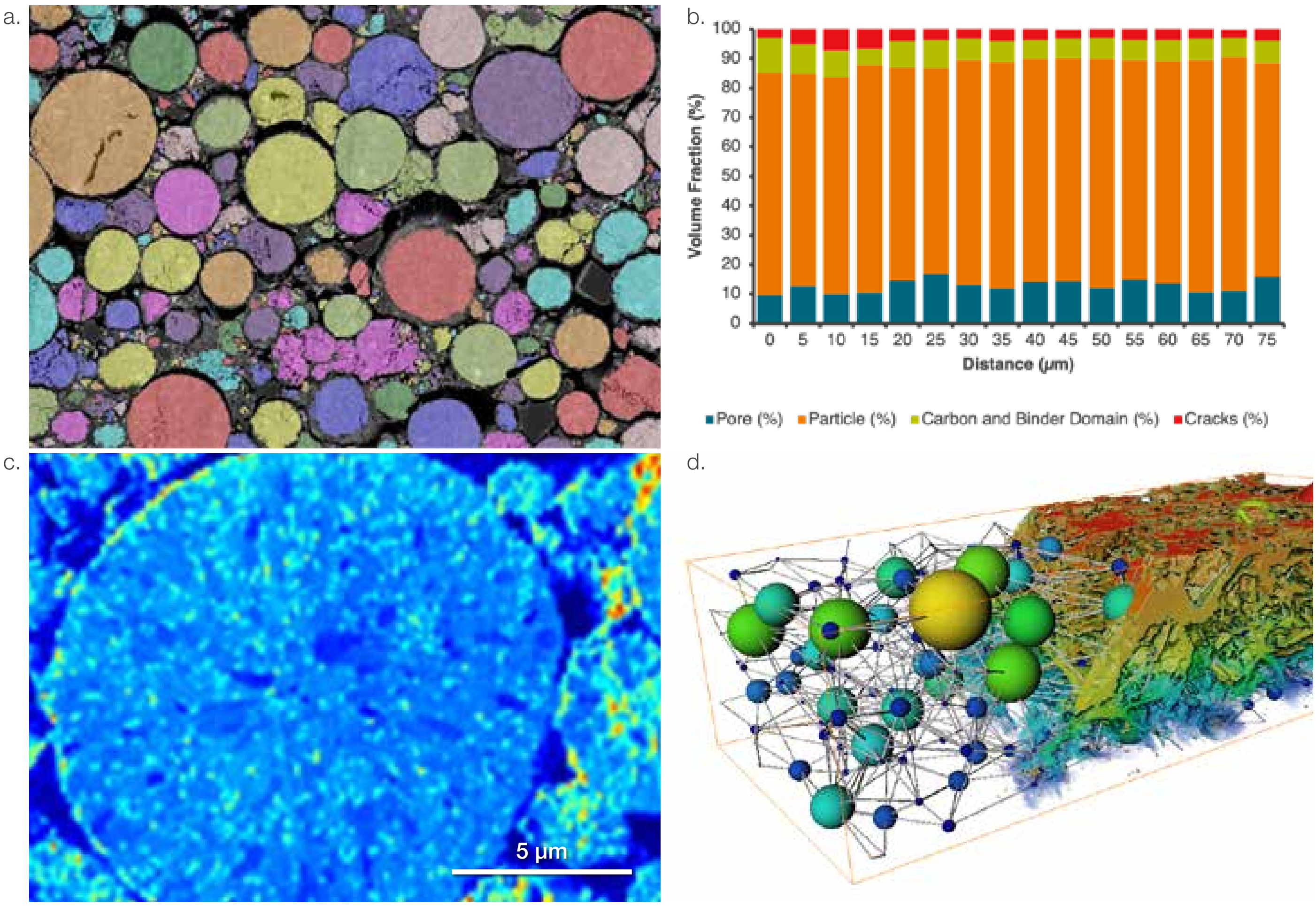
Identified particle contamination in NMC powders. Custom reports and classification table generated by Phenom ParticleX Battery Desktop SEM users.

DualBeam FIB-SEM

Long used across multi-disciplinary sciences including materials sciences, semiconductor, and biological applications, the DualBeam (focused ion beam scanning electron microscopy [FIB-SEM]), can perform both 2D and 3D imaging analysis to help you understand battery structure and performance correlations. In addition to SEM with electron column, the ion beam column provides the capability to mill into a surface to observe buried features so you can better understand properties below the sample surface. It has wide application in materials R&D and also failure analysis. We offer different DualBeam technologies to enable you to study a wide range of battery materials covering multiple length scales, from nanometer to millimeter.

Features and applications:

- Wide selection of FIB sources (Ga+, plasma ion, and laser) to cover wide range of applications for different battery materials (Li-ion, Li-metal, solid-state batteries) at multiple length scales
- 2D cross-section and 3D characterization with Avizo Software for structural quantification
- Thermo Scientific Auto Slice & View™ 4 Software and Thermo Scientific AutoTEM™ 5 Software provide automation for 3D data collection and TEM sample preparation to improve efficiency in battery R&D and production
- *In situ* detection of lithium distribution within the DualBeam via TOF-SIMS



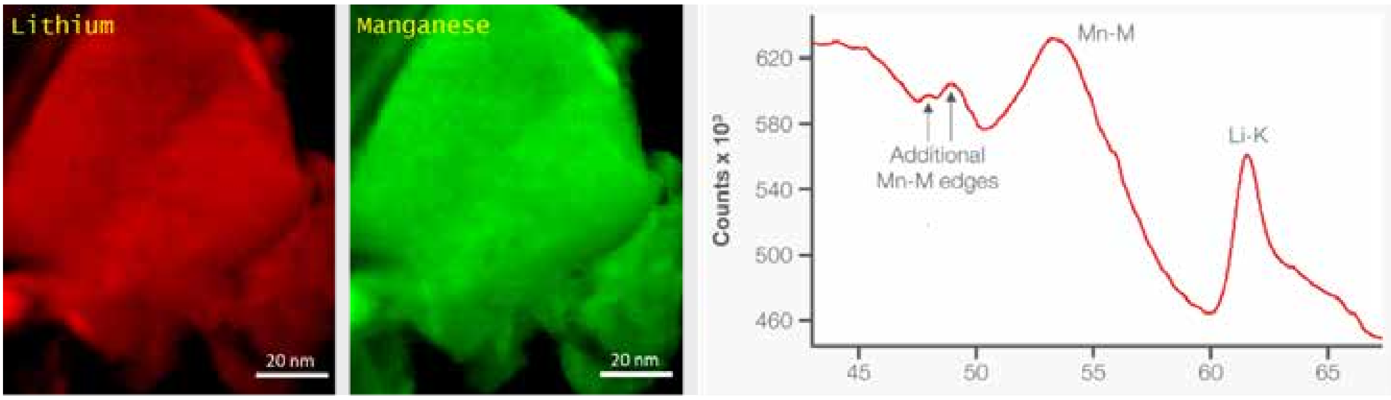
(a) and (b) NMC cathode cross-section prepared via Thermo Scientific Helios ™ 5 PFIB DualBeam and phase fraction analysis performed via Avizo2D Software; (c) TOF-SIMS analysis of the lithium distribution in NMC cathode; (d) 3D characterization of Li-ion battery graphite anode, data collected via Auto Slice & View 4 Software in Helios 5 Laser PFIB; structural quantification performed via Avizo Software.

TEM

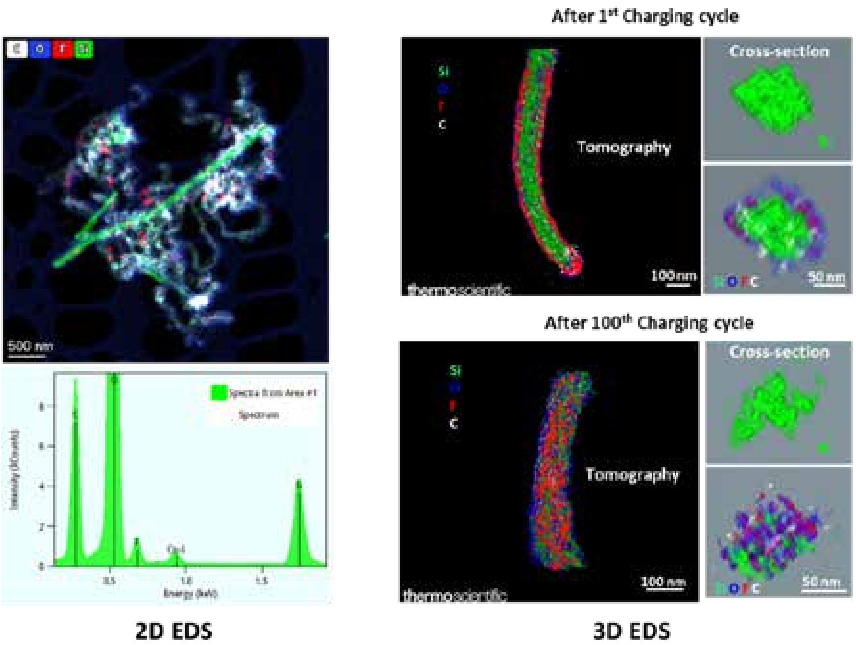
As scientists and researchers investigate materials at sub-nanometer or atomic levels, transmission electron microscopy (TEM) enables their material research on batteries, catalysis, metals, polymers, and novel materials to accelerate the development of next-generation technologies. Combining with holders designed for battery materials, TEM provides an unparalleled, high-resolution characterization solution for both air-sensitive and beam-sensitive battery materials to extract their structural and chemical information in their native electrochemical states. TEM diagnosis and analysis help unravel fundamental mechanisms (aging, failure mechanisms, etc.) at the sub-nanometer or atomic levels, resulting in the ability to understand in more detail the link between structure and performance, ultimately leading to advanced batteries with higher capacities.

Features and applications:

- Fast, precise, quantitative, high-resolution characterization of microstructure, composition, and chemical state in battery materials
- X-CFEG provides better, faster STEM and analytics, as well as much better energy resolution
- Thermo Scientific Velox™ Software for fast, easy multi-mode data acquisition and analysis
- High-performance EDS under cryo condition for SEI characterization



EELS spectrum images of Li battery materials. The Mn-M edge fine structure and Li-K edge in the Li battery are distinguished with an energy resolution of <0.28 eV. Results were collected on a Thermo Scientific Talos™ F200 (S)TEM with X-CFEG, Panther STEM, and Gatan Continuum 1066 at 200 kV. Sample courtesy Dr. Chongmin Wang, PNNL.



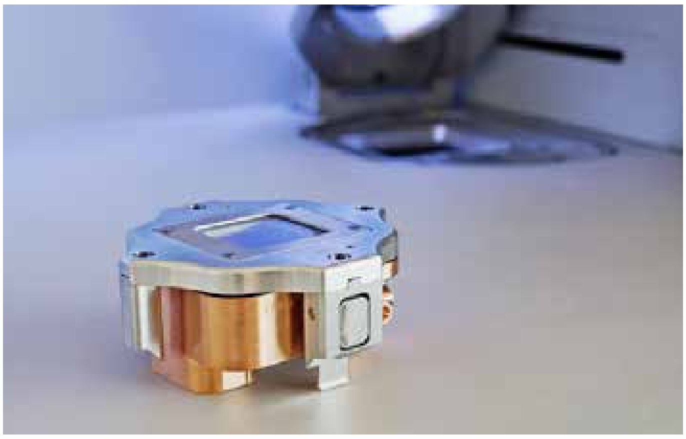
2D and 3D elemental distribution of the SEI in nanosized Si electrode wires after different battery cycles. Acquired on a Talos TEM with Thermo Scientific Super-X™ EDS Detector under cryogenic conditions to preserve structural and chemical information. Sample courtesy Dr. Chongmin Wang, PNNL.

XPS

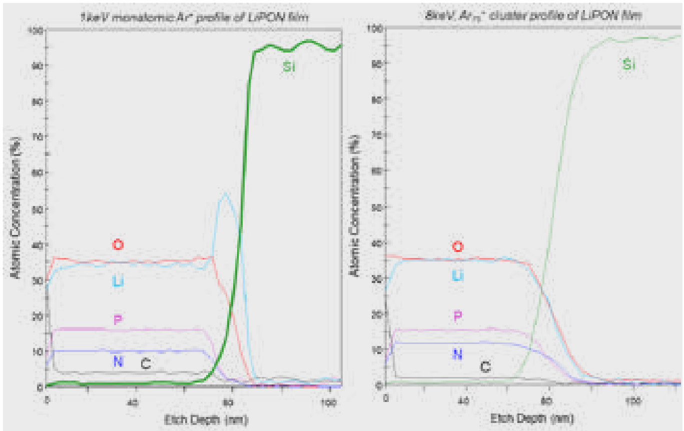
X-ray photoelectron spectroscopy (XPS), also known as electron spectroscopy for chemical analysis (ESCA), is a technique for analyzing the surface chemistry of a material. XPS can measure the elemental composition, empirical formula, chemical state, and electronic state of the elements within a material. It is widely used for analyzing battery samples to understand the surface chemistry of battery materials; for example, understanding the formation process of the solid electrolyte interface.

Features and applications:

- Effective detection of lithium in the battery materials, such as SEI characterization
- Transferal of samples from a glove box to the instrument without air exposure via vacuum transfer module
- Ar cluster-ion depth profiling permits analysis of electrodes and separators without affecting chemistry
- Sample heating, cooling, and electrical biasing possible *in situ* for various battery materials and system evaluation within XPS



Vacuum transfer module for sample protection.



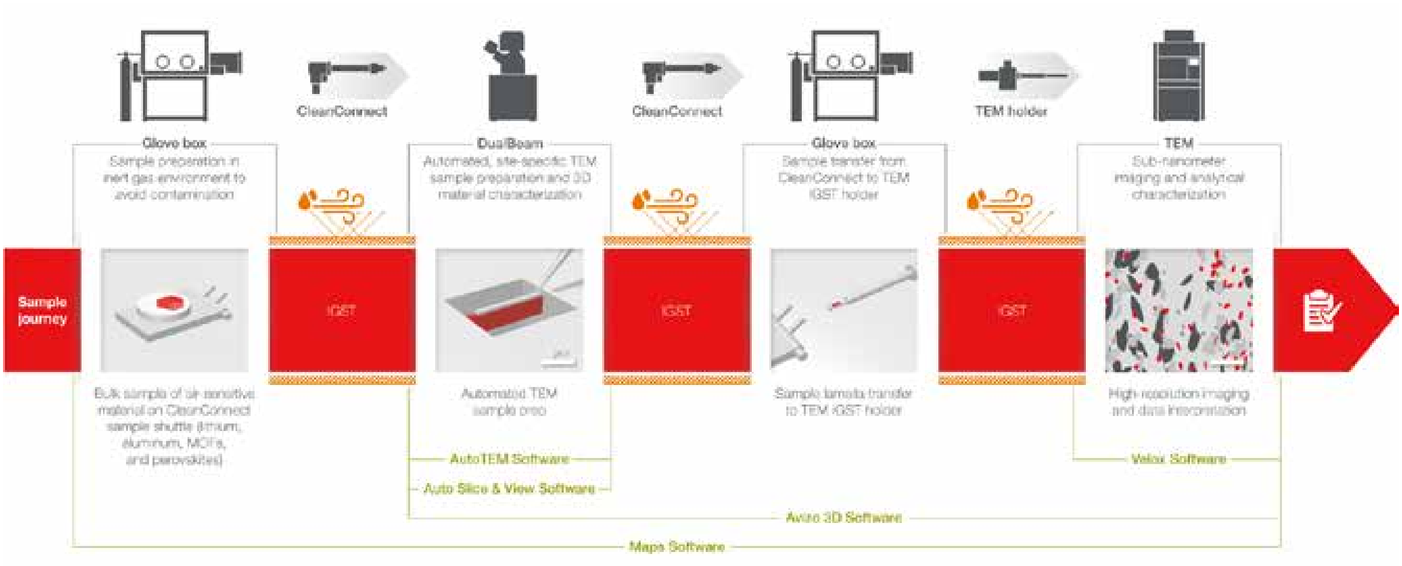
Depth profiling analysis of the LiPON solid electrolyte to understand the stoichiometry of the film as a function of depth. The 1 keV monatomic profile induces Li “pile-up” at the interface as defects while cluster profile induces Li “pile-up” at interface.

Seamless inert gas sample transfer workflow for battery characterization

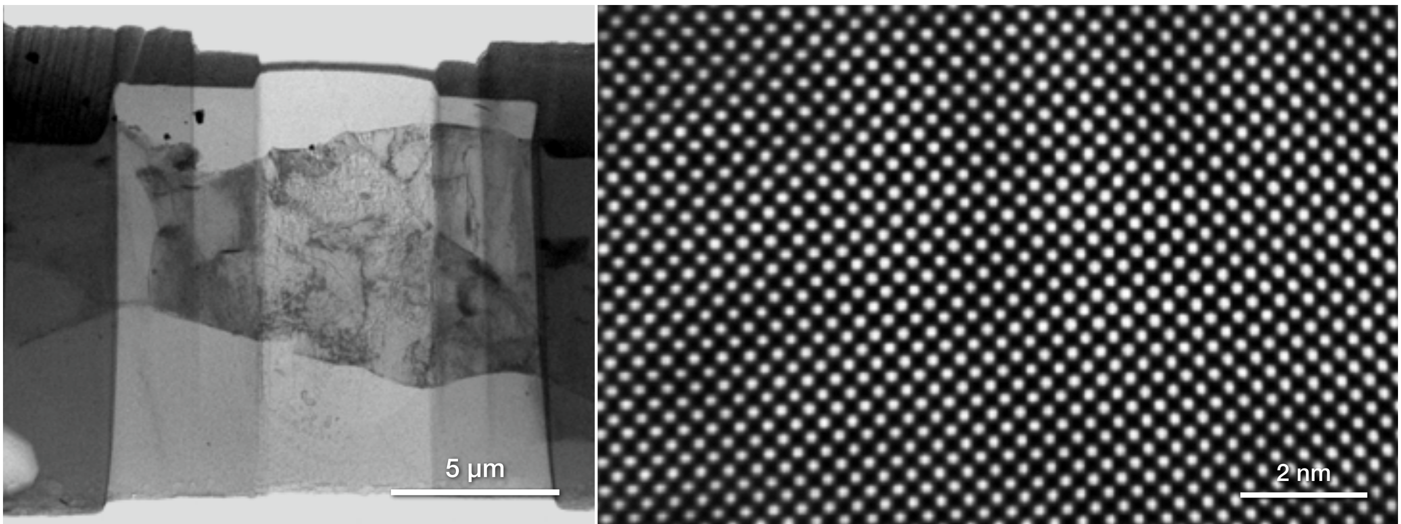
Most of the battery materials such as li-metal, solid state electrolyte, lithium salt, and cycled electrode are air-sensitive. Optimum sample preparation and sample transfer between various instruments without compromising sample integrity is crucial for such battery material analysis. The Thermo Scientific IGST (inert gas sample transfer) Workflow uses tools like the Thermo Scientific CleanConnect™ Sample Transfer System to allow you to focus on your battery research rather than worry about contaminating the sample.

Features and applications:

- Sample integrity is preserved, resulting in high-end material characterization in its native state
- Ergonomic and modular design of the CleanConnect System
- In-house design of the CleanConnect System enables seamless connectivity and automatic integration with a variety of SEMs and DualBeams
- Compatibility with cryo-stage allows sample integrity while milling against high temperatures



IGST Workflow using Thermo Scientific scanning electron microscopes.



TEM lamella image of lithium (left), high-resolution TEM image of lithium (right).

Electron microscopes and XPS products

SEM products:

Phenom Pharos
Desktop SEM

Phenom XL G2
Desktop SEM

Phenom P-Series
Desktop SEM

Phenom ParticleX-Series
Desktop SEM

Axia
ChemiSEM

Prisma E
SEM

Quattro
ESEM

Apreo 2
SEM

Verios 5
SEM

DualBeam products:

Scios 2

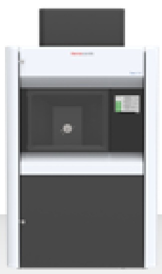
Helios 5
DualBeam

Helios 5 PFIB

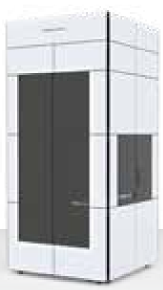
Helios Hydra
PFIB

Helios 5 Laser
PFIB

TEM products:



Talos

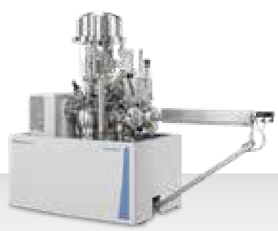


Spectra

XPS products:

K-Alpha

Nexsa G2



ESCALAB Qxi

Spectroscopy solutions

Spectroscopy solutions (FTIR, Raman, XRF, and XRD) are fundamental techniques commonly used for structural and chemical analysis as well as defect analysis for battery electrodes. Such technology allows for the analysis of electrode materials as they change during redox reactions and provide information on crystalline and amorphous phases.

Changes in Raman spectra can be used to create state-of-charge (SOC) distribution maps showing composite electrodes. When monitoring the solid electrolyte interface (SEI) formation, the composition is commonly studied by ex situ XPS and FTIR and Raman spectroscopy to monitor SEI.

Cathode	Anode	Binder	Electrolyte/ Separator	Cell / Module / Pack
• Normal/defective difference analysis of NCM raw material • Check the difference in NCM electrode ratio (111,622,811) • LCO electrode cross-section mapping (difference analysis before/ after charging and discharging) • Check LFP electrode peak	• Comparison of artificial/natural graphite • Analysis of differences by raw material (D/G ratio) • Silicon-based anode material charging and discharging before/after change and distribution	• Cathode electrode PVDF distribution • Anode material electrode-CMC, SBR • LFP cathode material PVDF distribution	**Electrolyte** • Electrolyte before and after cycling change • Distribution according to impregnation time • Solvation **Separator** • PE deterioration change • Anode/Cathode/ Separator interfacial analysis	• Tab failure cause analysis (a specific chemical coating or not) • Surface stain analysis • Foreign body analysis • Causes of appearance dents: difference in binder content • Electrode surface sunspot difference

ARL™ PERFORM'X WDXRF Spectrometer

XRF

X-ray fluorescence analysis (XRF) analyzes samples (powders, solids, liquids) for elemental or oxide composition (Be[4] to Am[95], up to ppm to % levels) and provides qualitative and quantitative insight.

Features and applications:

- Elemental analysis of raw materials (Si anode material, Ni-Co-Mn, Cu/Al foil, electrolyte)
- Sample surface mapping and analysis of small spots down to 0.5 mm
- Simple sample preparation and non-destructive analysis of more than 80 elements
- Unique ability to quantitatively analyze all types of samples without standard samples (UniQuant)
- Quantification of metal impurities in graphite anode materials
- Phase analysis of cathode materials by combination with XRD data (NMC, NCA, LCO, LMO, LMNO, LFP)

ARL™ EQUINOX 100 XRD

XRD

X-ray diffraction (XRD) is produced by a cathode ray tube with respect to the angle of diffraction according to Bragg's law. It is obtained by measuring the intensity of the generated primary X-ray beam. Non-destructive XRD analysis is used to characterize and identify different chemicals, phases, and structures within a sample.

Features and applications

- Non-destructive analysis
- Phase identification and structure determination in anode and cathode
- Thin-film analysis of coated surfaces
- Thickness determination

DXR3xi Raman Imaging Microscope

Raman spectroscopy/microscopy/ Raman imaging

Raman spectroscopy provides a structural fingerprint that can be used to identify molecules and monitor their changes in a sample. The use of Raman microspectroscopy allows you to monitor subtle structural changes across a given area, providing chemical-spatial information. A diffraction-limited spot size and high-precision stage movements allow you to interrogate your sample with chemical mapping, giving insight to the system. Raman spectroscopy is a well-established method used to study the degree of association for electrolyte ions in solutions as well as polymeric materials. Battery performance has a direct correlation to the binding of these ions and is important to understand for battery research.

Raman spectroscopy analysis provides insight into the polymer matrix and how additives can affect its crystallinity, which has an impact on performance. Understanding the degree of crystallinity can be used to improve the mechanical and electrochemical properties of synthetic polymer electrolytes.

Features and applications:

- Raw material analysis (graphite, metal oxide, lithium compounds)
- Visualization of chemical composition distribution on the sample surface
- Profile of chemical change during battery cycling
- Suitability for allotrope studies of carbon and transition metals

Nicolet™ iS50 FTIR Spectrometer with Nicolet RaptIR™ FTIR Microscope

FTIR

Fourier transform infrared spectroscopy (FTIR) is another analytical method that provides molecular information about a sample. Its information is complementary in nature to Raman.

During research on battery materials, FTIR can be used to identify lithium species and provide highly precise information about samples' chemical bonding, functional groups, and the changes they undergo during chemical reactions. This allows FTIR to be a powerful technique for both reaction monitoring and finished product quality assurance.

FTIR often takes advantage of comprehensive libraries of IR spectra. These libraries can be commercially available or can be created by the user so that both common materials and company-specific proprietary products can be studied. FTIR can be used for a wide variety of battery analysis, including Li-S, Li-O2, Na-ion, Mg, and various others. Thermo Fisher Scientific boasts an extensive network of experts and is able to support your vibrational spectroscopy needs for your battery research.

Features and applications:

- Raw material analysis (graphite, metal oxide, lithium compounds)
- TGA-IR—Thermal decomposition of SEI layer, separator, and positive and negative analysis after charging/discharging
- Various real-time analyses of electrolytes (*in situ*/operando analysis)

FTIR Gas Analysis

- Evolved gas analysis during thermal runaway of the battery
- Evaluation of gases collected after degassing or automated gas analysis
- Smoke toxicity analysis as part of the battery safety test
- Ambient air monitoring or fence line monitoring in a battery manufacturing facility

FTNIR

Fourier transform near infrared spectroscopy probes combination bands and overtones of fundamental vibrations. As it is less prone to detector saturation, less sample preparation is involved. FTNIR is a bulk sample measurement technique.

Features and applications:

- Accurate moisture determination in solvents, electrolytes, and lithium compounds.
- Residual moisture analysis of finished anode and cathode films

Chromatography and elemental mass spectrometry solutions

To control the quality of raw materials and products in the initial, intermediate, and production stages of the lithium-ion battery industry, positive and negative electrode materials, electrolytes, separators, and instrumental methods for testing other raw materials are required.

Analysis of major elements such as Li, Co, and Mn in raw material management, and also the content of impurities that seriously affect the material quality and performance of battery products, must be strictly managed.

ICP-MS/OES equipment is required for this analysis, and ICP-OES is required for QA/QC of battery parts production. These instruments provide sensitivity, robustness, and reproducibility. In addition, ICP-MS is useful for R&D laboratories that require lower detection limits and greater analytical flexibility.

In the intermediate stage of the lithium-ion battery manufacturing process, comprehensive physicochemical analysis of each part of the battery is conducted to investigate and enhance product performance and safety.

Accurate quantification and structural analysis of unknown compounds is possible with IC and IC/HRMS.

GC-MS is used to analyze the electrolyte composition of batteries, and Thermo Scientific Orbitrap™ Technology can analyze electrolyte derivatives for R&D and academic research.

iCAP Pro Series ICP-OES

ICP-OES

After ionizing the sample by spraying it on Ar plasma, qualitative and quantitative analyses can be performed with an inductively coupled plasma optical emission spectrometer by measuring the intensity of light emitted when transitioning to a state.

Features and applications:

- Robust analysis and quantification
- Fast detection of major and trace elements in the ternary cathode material
- Excellent precision and accuracy quantifying major elements, such as nickel, cobalt, manganese, and lithium
- Well-suited for detecting and quantifying elements in lithium salts and alloys

iCAP RQ ICP-MS

ICP-MS

After converting inorganic elements in the sample into monovalent cations in a high-temperature Ar plasma environment, the sample passes through a quadrupole mass filter to separate it into the intrinsic mass of the element. Qualitative and quantitative analysis instruments are used to measure the detection intensity of ions (count/sec).

Features and applications:

- Detects and quantifies the extent of chemical degradation caused by changes in trace elemental composition
- Helps identify metal-based degradation species and explain degradation pathways

ICS-6000 HPIC and Orbitrap™ Exploris™ Series IC-MS

IC/IC-MS

The Thermo Scientific Dionex™ ICS-6000 HPIC System is a highly configurable IC (Ion Chromatography) that can also be operated as a capillary IC. It maximizes performance and is still very easy to use. Double high-pressure channels separate faster without compromising resolution; one channel is optimized for capillary flow, and the other is 4 mm standard or 2 mm microbore (you can optimize the mod).

The Thermo Scientific Orbitrap Exploris™ 120 IC-MS (Mass Spectrometer) features quadrupole and Orbitrap to provide excellent scan speed and durability.

Resolution: 120,000 possible implementations.

Features and applications:

- Identifies non-volatile electrolyte degradation products
- Identifies and quantifies metal-based degradation species (when coupled with ICP-MS)
- Performs 2D-IC analyses, which is important when performing trace analysis in the presence of high concentrations of interfering matrix ions
- Runs simultaneous analyses with single- or dual-channel configuration

ISQ™ 7610 Single Quadrupole GC-MS

GC-MS

The Thermo Scientific ISQ™ 7610 Single Quadrupole GC-MS System can reach low detection limits and obtain rich information with accurate detection of mass-fragments and molecular ions. By identifying and quantifying compounds formed during electrolyte aging, GC-MS systems can provide new insight into Li-ion battery degradation.

Features and applications:

- Qualitative and quantitative composition of Li-battery electrolyte
- Reliability and accuracy for composition analysis and quality control
- Simplified operation, automated workflows, and extended dynamic range for consistent results
- Thermo Scientific NeverVent™ Technology, extended-life detector, and intelligent software eliminate unnecessary downtime

Orbitrap™ Exploris™ GC 240

GC-MS

The Thermo Scientific Orbitrap Exploris™ GC 240 system is powered by Orbitrap technology. It provides the resolution, mass accuracy, and sensitivity you need to analyze unknown substances and get the most reliable and comprehensive data for detection, identification, and quantitation.

Features and applications:

- Fluorophosphate or organic fluorine produced by aging of the electrolyte
- Identification of additives to reduce electrolyte aging by analyzing phosphate, etc.
- Qualitative and quantitative analysis of volatile unknown mixtures or impurities in electrolytes
- Qualitative and quantitative analysis of unknown compounds in battery-generated gases

Thermo Scientific™ Vanquish™ Core HPLC systems

Liquid Chromatography

Whether you are analyzing electrolyte solvents or working to achieve the next breakthrough in battery recycling, our liquid chromatography solutions offer a complete workflow solution that can improve your productivity and deliver a maximum return on your investment.

Features and applications:

- Versatile, robust multiple wavelength detection
- Industry-leading flow and gradient precision
- SmartInject technology for unsurpassed precision with sample dosage and retention time
- Innovative air stream cooling for maximum sample integrity in both the sampler and the charger module
- Full suite of method transfer tools makes adoption easy

Battery slurry processing

Process 11 Parallel Twin-Screw Extruder

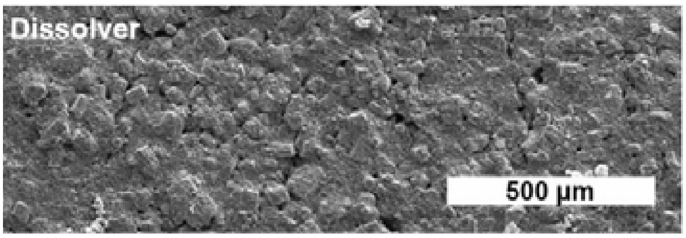
- Compact twin-screw extruder
- Suitable for containment

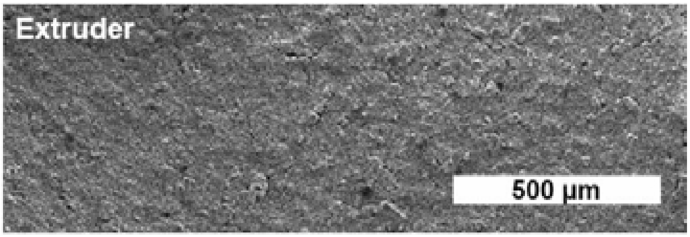
Extrusion

Extruders, i.e., parallel twin-screw extruders, present a continuous mixing technology for battery pastes with no batch-to-batch variations, minimal material losses, smaller footprints, and lower labor assignments than the use of planetary mixers. The high shear forces in the twin-screw extruder also provide stronger dispersive mixing while allowing for reduction of organic solvents in the pastes at the same time. Thermo Scientific twin-screw extruders offer battery paste compounding in lab- and pilot-scale for battery research and development with:

- Low material requirement down to 50 g
- Flexible screw design
- Split barrels for quick cleaning
- Containment solutions

Easy scalability of the extrusion process to production scale renders the development of novel formulations on lab-scale extruders highly relevant for industrial applications.





Left: Cathode slurry mixed using a dissolver. Right: Cathode slurry mixed using a twin-screw extruder.

Rheological analysis of Li-ion battery slurries

HAAKE MARS iQ Rotational Rheometer

- Rotational rheometer
- Ball-or air-bearing system

Rheometry

Knowledge of the flow characteristics of electrode pastes is essential to predict:

- Behavior in the electrode coating process
- Energy consumption when stirring or pumping pastes
- Dispersion stability during storage
- Parameters for a precise quality monitoring

While low-viscosity pastes are beneficial for the coating process where high shear applies, a high viscosity at low shear rates bestows the pastes with greater resistance against phase separation. Thermo Scientific HAAKE rotational rheometers measure viscosity functions of battery pastes over a broad range of shear rates. Also, viscoelastic behavior and structural changes in the pastes can be characterized with high resolution to tailor new battery paste formulation and secure constant quality.

In-line process solution

In lithium-ion battery manufacturing, web gauging measurement and control systems play an important role in improving product quality, uniformity, traceability, and safety.

The Thermo Scientific LInspector Measurement and Control System is our new solution developed with over 70 years of measurement experience. The system is specially designed to solve the need for accurate electrode coating amount measurement, multilayer separator thickness measurement, and electrode calendering thickness. The sensor's accuracy, reporting capabilities, and innovations combined in a Thermo Scientific system, enable a single-source, end-to-end solution. This enables manufacturers to improve the safety, consistency, and efficiency of lithium-ion batteries to be able to provide high-quality, reliable products.

Electrode coating

Thermo Scientific 21PlusHD Measurement and Control System

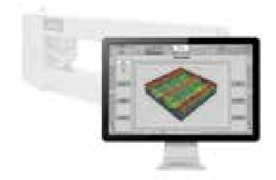
- Flexible and reliable measurement LInspector System
- 2x greater coverage and more reliable fault detection
- Intelligent multi-frame control system
- High precision and functional resolution
- Beta and X-ray options

Electrode calendaring

Thermo Scientific LInspector Laser System

- Fast scan for profile shape control
- Ultra-precision laser measurement
- Stripe and patch filing algorithm
- Various electrode materials, surface roughness, and reflectivity

Separator film



21PlusHD Measurement and Control System

- Quick feedback and automatic extrusion die control
- Cast and stretch sheet profiles and dual frame system for measurement
- Provides measurements regardless of membrane composition (beta)

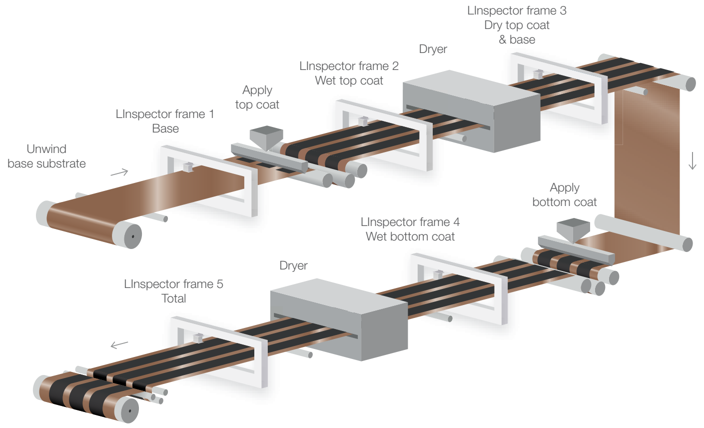
Process intelligence and predictive service

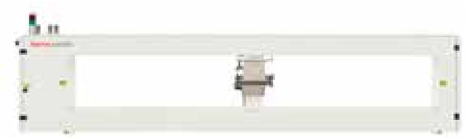
- Key information at a glance
- Simplify operator decision-making
- Real-time feedback for process control
- 24/7 remote device health and forecasting with service diagnostics

End-to-end coating process monitored and controlled at every step

Improving battery manufacturing quality

- Intelligent multi-frame control system
- Higher measuring range
- Highest precision and functional resolution





LInspector

Beta and X-ray sensor

Thickness gauge

The LInspector Measurement and Control System provides sensors, measurement, reporting, and remote instrumentation. This is done by combining innovations such as condition monitoring capabilities for manufacturers.

We help you improve the quality, speed, and efficiency of your battery production process. As a result, more defects are detected, waste is reduced, and product durability is improved.

For the electrode coating line, beta and X-ray sensor technology can be combined with anode coating and cathode coating on all instruments via Thermo Scientific SICAL (Substrate Independent Calibration) Algorithm.

A more accurate coating amount, whether the plate is copper or aluminum, can be calibrated directly, and measurement is possible.

Beta and X-ray sensor technologies can be used to measure membrane thickness. This option is an ideal choice for laser-based sensor calendaring lines.

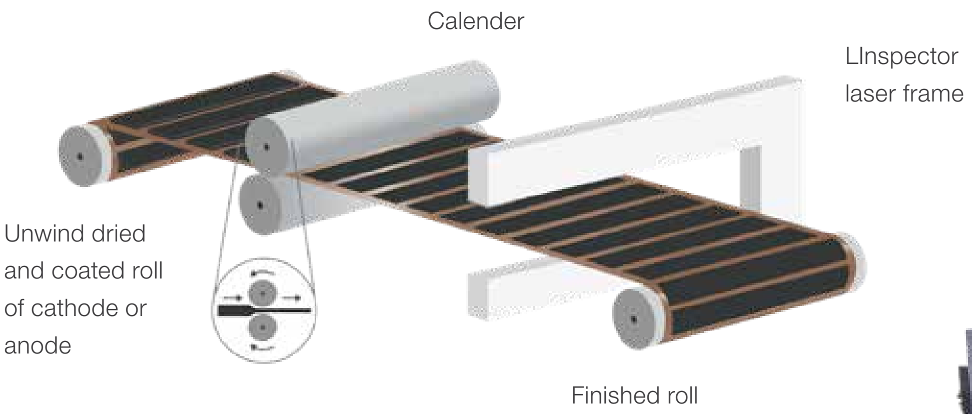
Features and applications:

- Separator
- Anode and cathode coatings
- Positive and negative calendering

Calendering line measurement

Providing dimensional conformity.

- Fast scan for profile shape control
- Accurate laser measurement
- Stripe and patch filing algorithms
- Various electrodes with rough surfaces and reflectance
- Suitable for material measurement



Electrode sheet thickness

Laser Scanner

Chemical reagents for battery technology

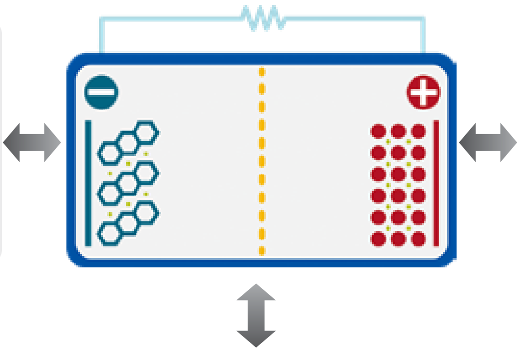
A battery consists of four elements: anode, cathode, electrolyte, and separator. We provide high-quality metals, metal oxides, solvents, and reagents, as well as raw materials.

Research and production

We supply all materials needed for positive/negative active materials and precursors for battery research and manufacturing.

Anode

- Carbon black
- Graphite powder
- Silicon Oxide
- Lithium foil



Cathode

- NCM(811, 955…)
- LCO
- ZnO
- Sulfur Pieces

Electrolyte

- $LiPF_6$
- $LiBF_4$
- LiTFSi
- Li2S
- P2S5
- LiCl

Other materials

- Foil(Al,Cu,Ni,Li)
- Binder(PVDF,SBR,NBR)
- Conductive additive
- Al tap / Ni tap / Lead tap
- Al pouch
- Separator
- Solvents

Key products for all-solid-state electrolyte research

We supply various raw materials other than Li2S required for all-solid battery electrolyte and electrolyte synthesis.

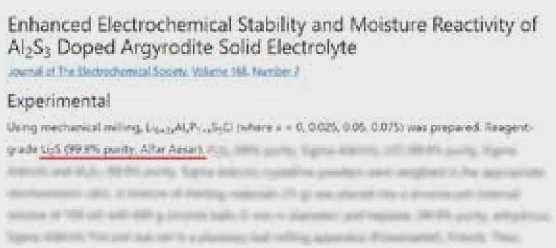
Li2S CoA

Ca	<33	Al	<18
Ba	<1	K	<11
Mg	<18	Na	<144
Si	<39	Sr	<1
Lithium sulfide	99.9%		

Values given in ppm unless otherwise noted

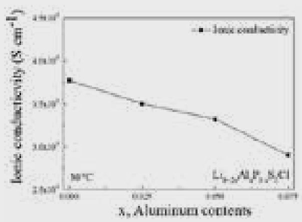
- Lithium Sulfide : 99.9%
- Product number : 012839
- G to KG size is available

References

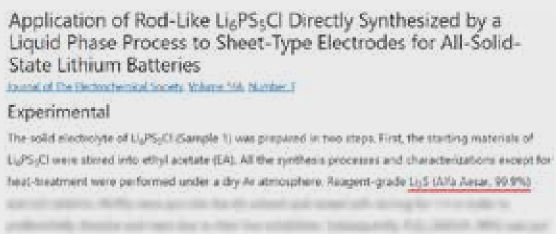

Enhanced Electrochemical Stability and Moisture Reactivity of Al_2S_3 Doped Argyrodite Solid Electrolyte

Experimental

Using mechanical milling, $Li_{6+2x}Al_xP_{1-x}S_5Cl$ (where x = 0, 0.025, 0.05, 0.075) was prepared. Reagent-grade Li_2S (99.9% purity, Alfar Aesar)

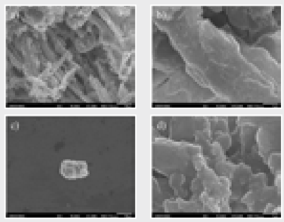


The ionic conductivity of Li6+2xAlxP1−xS5Cl (where x = 0, 0.025, 0.05, 0.075).


Application of Rod-Like Li_6PS_5Cl Directly Synthesized by a Liquid Phase Process to Sheet-Type Electrodes for All-Solid-State Lithium Batteries

Experimental

The solid electrolyte of Li_6PS_5Cl (Sample 1) was prepared in two steps. First, the starting materials of Li_6PS_5Cl were stirred into ethyl acetate (EA). All the synthesis processes and characterizations except for heat-treatment were performed under a dry Ar atmosphere. Reagent-grade Li_2S (Alfa Aesar, 99.9%)


Morphologies of Li6PS5Cl solid electrolytes prepared by:
a), b) the liquid phase process and
c), d) mechanical milling.

Chemical reagents and materials for battery technology

Whether you are engaging in research for the next cation alternative with inorganics and ligands or finding new organic molecules to tap into their resonance abilities for ion transfer, or post-reaction analysis on samples, we have a complete line of solutions for your battery research workflow.

Our lab-to-line workflow:

Formulation materials for anode and cathode research

Our line of Thermo Scientific inorganic products provides high-quality salts, complexes, and conjugated molecules such as fullerene. We also have an extensive range of pure metals such as lithium and copper foil, magnesium turnings, and more.

Formulation materials for electrolyte research

Our range of Thermo Scientific fine, organic chemical products offers a wide selection of carbonyl, aromatic, heterocyclic, and conjugated reagents that allow you to leverage their resonance abilities. We also provide high-quality formulation inorganic salts like lithium hexafluorophosphate and lithium perchlorate. These product lines are also available in our AcroSeal Packaging, ensuring that your reagents are protected against air and moisture for a longer shelf-life.

Production and bulk capabilities

Whether you're ready to take your research into production or require chemicals in bulk volume as a laboratory need, our custom and bulk team will be here to help scale it up. Choose from a range of customizations from CoA requirements, pack-sizes, mixed blends, and more.

Analytical solvents for chromatography

No matter the type of chromatography instrument you are using or the sensitivity requirements of your analytical needs, our Fisher Chemical solvents provide a range of purities and grades to ensure you are getting the desired outputs. Pick from a range of HPLC, LC/MS, Optima®, or UHPLC-MS grades.

Solvents for trace elemental analysis (TEA)

Our Thermo Scientific range of Specpure™ standards offers a comprehensive line of spectrochemical analytical standard solutions.

For trace elemental analysis such as AAS, ICP, or ICP-MS, we take pride in our range of Fisher Chemical acids that are available at ppb or ppt levels, depending on the grade used.

About Thermo Scientific AcroSeal Packaging:

Chemical reactions often involve the use of air- and moisture-sensitive solvents, pyrophoric and hazardous reagents. Our AcroSeal Packaging is an industry-leading packaging solution for safe handling of these types of materials that are used in drug discovery, agrochemical research, flavors and fragrances, diagnostics, NMR analysis, and other applications.

The AcroSeal cap

Our brands

thermo scientific

Our Thermo Scientific chemicals portfolio is built on a foundation of our legacy brands, including Acros Organics, Alfa Aesar, and Maybridge brands. Our portfolio includes over 80,000 chemicals and biochemical reagents, such as ultra-pure organics, heterocyclic building blocks, solvents, coupling reagents, screening libraries for drug discovery, organometallics, ligands, metal catalysts, precious metal compounds, and performance materials for electronics and nanotechnology.

fisher chemical

A comprehensive portfolio of solvents and reagents for laboratories engaged in research, development, and analysis at any level.

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thermo scientific

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