bestmag

07–10 October 2024

The international quarterly for the battery technology industry

The Battery Show North America

Huntingdon Place, Detroit, MI

Event preview in association with

informa markets

Welcome to the the Battery Show

Now entering its 14th year, North America's largest advanced battery event will take over Huntington Place in Downtown Detroit this October. The Battery Show brings together engineers, business leaders, top-industry companies, and innovative thinkers to discover ground-breaking products and create powerful solutions for the future. More than 19,000 attendees are expected to take advantage of four full days of educational sessions, networking opportunities and, of course, explore the latest market innovations from over 1,150 exhibitors across one of the world's largest battery technology trade shows. Become part of this great event!

The Battery Show and EV Tech Expo bring together engineers, business leaders, top-industry companies, and innovative thinkers to discover groundbreaking products and create powerful solutions for the future.

October 7-10, 2024 | Huntington Place | Detroit, MI

BEST Battery Show North America Preview Guide © 2024
Publishing Director: Vic Giles • Sales Director: Les Hawkins • Administrator: Gill Keys
For inclusion in the preview guide, please contact Les Hawkins. Email: les@bestmag.co.uk, Phone: +44 7745 665 513

For more details on the conference including space booking, marketing & alliances and speakership opportunities, please go to: https://www.thebatteryshow.com/en/home.html

Orion S.A. spotlights PRINTEX® kappa 100

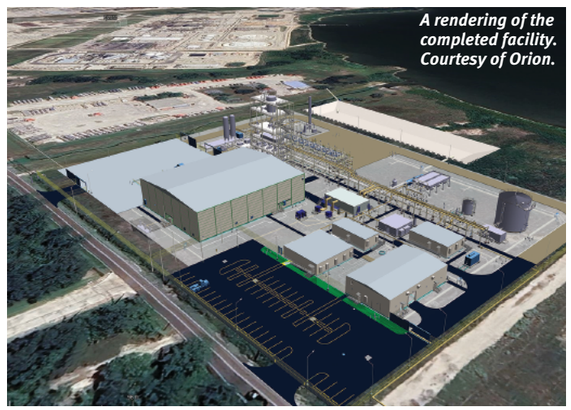
The high-performance conductive additive improves performance of lithium-ion batteries.

Global specialty chemicals company Orion S.A. is spotlighting its acetylene-based PRINTEX® kappa 100 conductive additive, which improves lithium-ion battery performance. Orion will be at booth 5330.

"PRINTEX kappa 100 is helping our customers resolve their battery power challenges," said Kevin Milks, Orion marketing manager for polymers, batteries and special applications. "It is exceptionally pure, highly refined and easy to process."

PRINTEX kappa 100 enables higher electrical conductivity, leading to significantly higher power densities and longer battery life than with other carbon blacks. The high-performance conductive additive forms an excellent percolation network across the cathode surface for effective charging and discharging. It is supplied as powder or beads.

Orion's acetylene black production has a very clean input material and generates a high yield, giving PRINTEX kappa 100 a low carbon footprint. The sustainable chemistry of this process reduces greenhouse gas emissions and helps our customers to reduce their carbon footprint along the battery value chain.



A rendering of the completed facility. Courtesy of Orion.

Sole U.S. acetylene black plant

On April 9, 2024, in La Porte, Texas, Orion broke ground on a plant that will be the only facility in the U.S. producing acetylene-based conductive additives for lithium-ion batteries and other applications vital for the global shift to electrification. PRINTEX kappa 100 and other conductive additives produced at the La Porte plant will be super clean, with only one-tenth of the carbon footprint of other commonly used materials.

Acetylene-based PRINTEX kappa 100 improves lithium-ion battery performance with a low carbon footprint. Courtesy of Orion.

"Our La Porte facility will complement our acetylene-based conductive additives plant in Europe, where we are already the sole producer of acetylene black," said Dr. Adrian Steinmetz, Orion global vice president for conductive additives. "When it goes online, which we expect in the second quarter of 2025, the new plant will quadruple Orion's manufacturing capacity for acetylene-based conductive additives."

Key equipment procurement and off-site fabrication are advancing steadily and field construction activities are ramping up.

Dr. Steinmetz leads a new global organisation within Orion to propel the company's conductive additives business for batteries. He noted that the La Porte plant will fortify the regional supply of conductive additives in the burgeoning U.S. battery market and will offer North American battery manufacturers domestic availability and consistent supply with the lowest possible carbon footprint for conductive additives.

To further serve the market, Orion recently opened its Battery Innovation Center in Cologne, Germany. Equipped with state-of-the-art production, testing and diagnostic capabilities, the Battery Innovation Center accelerates Orion's product and process development in close cooperation with customers.

For more information about PRINTEX kappa 100 conductive additive, contact Milks, the marketing manager, polymers and batteries, at kevin.milks@orioncarbons.com.

Strengthening U.S. Battery Manufacturing with ROSS Mixers

The global demand for batteries continues to grow due to the rapid growth of electric vehicles, renewable energy storage, and consumer electronics. Battery manufacturers worldwide are under pressure to quickly scale up their production and facilities. To keep up with this growing need, US based battery manufacturers are working towards expanding its domestic battery production capabilities and companies like ROSS Mixers are playing a critical role in providing the industrial mixers necessary to meet the increasing demand. By investing in locally built equipment, battery manufacturers can ensure greater reliability and independence while meeting the rising global demand for advanced battery production.

ROSS industrial mixing equipment is helping to drive technological advancements that bolster the nation's energy independence and sustainability goals. ROSS is known for its high-performance mixing and blending systems. The company's extensive experience in engineering and manufacturing mixers specifically for battery applications places them at the forefront of U.S. equipment suppliers ROSS Planetary Mixers, Multi-Shaft Mixers, and High Shear Mixers have been widely implemented by battery manufacturers, both domestically and globally. Engineered for precision, these machines are trusted for their ability to handle the complex nature of the materials involved in battery production while maintaining tight control over temperature, consistency, and dispersion ensuring that every batch of slurry meets the strict quality standards required for advanced batteries.

The Formation of U.S. Battery Machine Builders (USBMB)

Disruptions to the global supply chain have highlighted the risks associated with depending on foreign vendors for critical machinery used in the production of batteries. Trade constraints, logistical difficulties, and geopolitical concerns have resulted in delays, increased costs, uncertainty in production timelines and in some cases, inconsistent end product quality.

In response to these challenges, the USBMB coalition was formed, uniting key players in U.S. battery equipment manufacturing. ROSS Mixers, a founding member of the USBMB, brings over 180 years of engineering expertise to this mission and is committed to supporting the growing US battery manufacturing industry -- from R&D to large scale production. The USBMB serves as a bridge between the government and the private sector, advocating for policies that promote the development of advanced battery technologies and fostering collaboration to build a resilient, scalable supply chain. Additionally, the USBMB works to encourage government officials to prioritise US built machinery when developing rules, guidance, and implementing funding, financing, and tax incentive programs.

One of ROSS' key advantages is its commitment to U.S. manufacturing. With modern facilities located in Florida, Georgia, New York, and a Test and Development Center in Hauppauge, New York, ROSS has the ability to engineer, fabricate, and test their equipment locally, cutting lead times and guaranteeing adherence to US regulatory standards. This regional strategy also fits with the objectives of the USBMB, which aims to reduce dependency on imports and create an independent supply chain for the country's battery market.

Looking to the Future

As electric vehicles become more prevalent and renewable energy storage needs grow, the demand for advanced batteries is set to skyrocket. By working together, ROSS Mixers and the USBMB are making sure that American producers are prepared to provide this need with inventive, high-quality equipment.

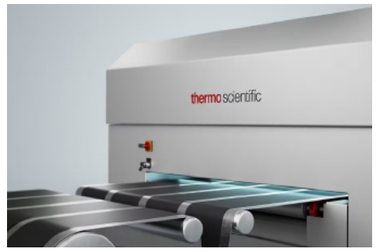
thebatteryshowdetroit // October 2024

Thermo Fisher Scientific

Streamline your energy storage research and manufacturing processes – **Booth #1600**

Improvements in lithium-ion battery technology and manufacturing lie at the heart of society's transition to clean energy. Making safer, affordable batteries that last longer and charge quickly is essential to enable the pivot towards electrified vehicles and renewable energy storage.

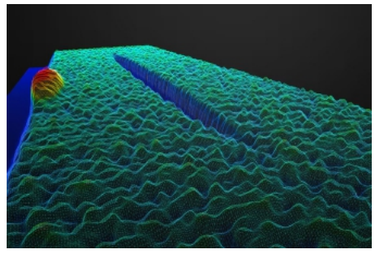
Join us at Booth 1600 where we will be showcasing our newest analytical instruments and advanced metrology options to support and strengthen your activities across the battery lifecycle, from research through manufacturing and recycling.



Tuesday 12:00 PM

- *New Product Showcase: Routine Raw Material Analysis Simplified*

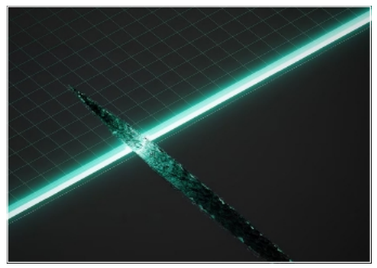
See the new Thermo Scientific™ Dionex™ Inuvion™ IC System that makes active materials analysis simpler and more intuitive within your Battery QA/QC lab, ensuring finished materials meet performance specifications of your battery producers needs. Learn how this leading brand of Ion Chromatography delivers consistent results and detects unwanted contaminates while analysing electrolytes, quantifying raw materials, and evaluating additives that could lead to failure modes and safety risks. Come with questions for a chance to win our latest nanoblock® Inuvion™ IC system kit.



Daily 11:00 AM

- *Technology Spotlight: Twin-screw extrusion for efficient electrode production*

Visit our booth to learn about the Thermo Scientific™ Energy 11 Twin-Screw Extruder and how it ensures high quality dispersion of cathode and anode material. This continuous process has benefits for wet electrode slurries, dry electrode processing as well as solid-state electrolyte applications. In this short presentation you will discover how easy the Energy 11 is to operate and how It can be used for compounding, granulation or sheet extrusion of free standing electrode films. Meet with our experts to discuss your application and see how the Energy 11 can boost your research.



Featured products

In-line metrology for electrode manufacturing

- Thermo Scientific LInspector Edge In-line Mass Profilometer – New!

Elemental analysis for material testing and verification in battery recycling

- Thermo Scientific Niton XL5 Plus Handheld XRF Analyser

Sample Preparation Equipment for Electron Microscopy

- Thermo Scientific CleanMill Broad Ion Beam System

Electron Microscopy solutions for battery materials analysis

- Thermo Scientific Phenom ParticleX Battery Desktop Scanning Electron Microscope

Lithium Ion Battery Slurry Analysis

- Thermo Scientific Energy 11 Twin-Screw Extruder

Imaging data interpretation

- Thermo Scientific™ Avizo™ Software – including new Avizo Trueput software!

Service and support for Electron Microscopes

- Connected Care Services for Electron Microscopes

Materials characterisation

- Thermo Scientific DXR3 Raman Microscope
- Thermo Scientific MarqMetrix All-In-One Process Raman Analyser

Ion Chromatography

- Thermo Scientific Dionex Inuvion Ion Chromatography System – New!

About UK Pavilion

The Advanced Propulsion Centre UK (APC) is thrilled to be hosting the UK Pavilion, showcasing the very best, pioneering, zero-emission battery technologies from the British Isles.

Delivered on behalf of the Department for Business and Trade, the innovators joining our stand will be available throughout the show to discuss their innovative government-backed advanced automotive battery technologies and manufacturing techniques.

The UK's International Events Programme helps to support the next generation of low-carbon innovators, creating a platform to display ground-breaking innovations and gain exposure to investors and prospective customers around the world. The APC is proud to be leading this initiative, and we look forward to welcoming you on **stand number 3222**.

The Advanced Propulsion Centre UK (APC)
Catherine.Prothero@apcuk.co.uk
APC collaborates with UK government, the automotive industry and academia to accelerate the industrialisation of technologies that support the transition to zero-emission vehicles and towards a net-zero automotive supply chain in the UK.

Established in 2013, the APC, with the backing of the UK Government's Department for Business and Trade (DBT), has facilitated funding for 304 low-carbon and zero-emission projects involving 538 partners. Working with companies of all sizes, this funding has helped to create or safeguard over 59,000 jobs in the UK. The technologies and products that result from these projects are projected to save over 425 million tonnes of CO_2.

Anaphite
jennifer@anaphite.com
We develop fully formulated carbon nanotube (CNT) enhanced NMC and LFP composites cathodes powders (inc. the binder) ready for dry coating. They are homogenous powders formulated specifically for direct dry coating with no solvent, additives or mixing required. This enables dry coated electrodes to achieve the better electrochemical performance than wet coated.

Avocet
r.johnston@avocetmaterials.com
Avocet Battery Materials (ABM) are a manufacturer of lead tabs for high performance lithium ion cells. The company are pioneers in this technology having established the first manufacturing facility of its kind located outside of Asia. The company's world class R&D team is focused on improving the lifespan and performance of lead tabs, using innovation to drive cutting edge battery technologies. ABM is at the forefront of a sustainable philosophy and believe that profits do not have to be compromised for sustainability.

Breathe
emily.atkinson@breathebatteries.com
As product leaders and battery experts, you constantly have to make impossible trade-offs between charge speed, cycle life, energy density, and profit margins. Until now. Breathe's physics-based battery management software increases charge speed and cycle life, never compromising on safety. That's why some of the most iconic electric vehicle and consumer electronics brands trust us.

We're more than a battery performance company. We help you do more with the power you have. Because we believe that an electrified future requires superior customer experiences. With Breathe physics-based battery management software, you can deliver products with faster charging, greater cycle life and zero compromise on safety.

Brill Power (see page 12)
peter.freedman@brillpower.com
Established in 2016, Brill Power is a founder-run start-up with roots in the Engineering Department at the University of Oxford. Our first product for the stationary storage market launched in 2021 and we are expanding into new markets such as electric vehicles.

Brill Power successfully achieved a Series A round raising of $10.5m in 2022 to support their mission to make batteries smarter, cleaner, safer and longer-lasting as a critical element of the shift to zero emissions energy. The funding supports team growth and new product development to expand presence in both static energy storage and the automotive sectors.

Cambridge Vacuum Engineering
tslater@camvaceng.com
Cambridge Vacuum Engineering (CVE) design, build, and service electron beam welding and laser welding systems. In addition to our main design and manufacturing site in the UK, CVE has two regional offices in Beijing, China, and Massachusetts, USA, as well as a global network of agents.

CVE applies professional engineering skills to customer requirements, resulting in innovative solutions to technical problems. We have a highly skilled workforce, an experienced engineering design department, and an extensive service team – all supported by a range of in-house test and diagnostic facilities.

CPI
Jojo.Wade@uk-cpi.com
Powering the future, CPI is your portal to leading-edge energy storage and alternative fuel technology innovation. Improving battery performance, lifetime, and recyclability is essential to improving the sustainability of carbon-neutral technologies; however, batteries are currently costly and complex to make.

With the UK under pressure to produce an ever-greater proportion of each vehicle domestically under new EU trade agreements, building momentum on battery innovation and recycling within our borders has never been more pressing.

We can help companies to improve battery sustainability, performance and longevity. This starts with optimising raw materials, designing for disassembly, reuse and recyclability, and identifying how best to recover the value of these materials when the battery reaches end-of-life.

Danecca
amy.strudwick@danecca.com
Danecca are a leading design and manufacturer of custom-engineered sustainable battery systems; helping organisations bring their products to life and delivering better performance for our customers. We're a team of engineers, advisors and technologists taking organisations on their electrification journey, from concept to launch and through the whole life cycle of your product.

Wherever you are on the learning curve of electrification, our knowledgable team can support you with experience, design, prototyping and testing for your battery packs and modules, to meet your needs and budget.

E+R group
s.cheung@eandr.com
Over 100 years spent in the relentless pursuit of quality, innovation and reliability, we are Emerson and Renwick, known to many as E+R, a privately owned, independent equipment engineering company. The company has grown and developed across a number of market sectors and is positioned as a leading manufacturer of sophisticated roll-to-roll production machinery.

We have built a reputation for engineering, technology and process innovation and use the experience gained across a hugely diverse range of applications to support developments for ever more demanding processes and products.With more than 50 world-first's our engineering and research teams can be depended upon to deliver Innovation + Industry

Eatron
anette.soyer@eatron.com
Making future mobility safer, smarter and more efficient. Our intelligent software platform approach significantly reduces cost, risks and time to market. Eatron offers embedded applications for High and Low Voltage Battery Management that are not only automotive grade, safe and robust but also integrated with AI & cloud layers with analytics, offering OTA updates and continuous software improvements to enable its customers to achieve superior performance and reliability over the lifetime of the vehicles.

Echion
kelvin.bathe@echiontech.com
The world's leading niobium anodes for lithium-ion batteries – safer, faster, longer – Echion's XNO® niobium-based anode material enables lithium-ion batteries to fast-charge safely in less than 10 minutes, with high energy density and a cycle life of more than 10,000 cycles.

Echion's battery anode materials deliver exceptionally long cycle life, superfast charging capability, and outstanding safety. This leads to uniquely high operational efficiencies and record low total cost of ownership, which enables end users to sustainably electrify heavy duty transport and industrial applications. These include rail, high-power off-road vehicles, high-utilisation fleets of trucks, buses, or delivery vans, mining equipment, high-performance hybrids, motorsports, and many more applications requiring outstanding performance.

Electrified Automation
rob.kress@electrifiedautomation.com
Combining high volume manufacturing technology with high performance electric motor technology drives everything we do. The Electrified Automation team work with some of the world's largest OEMS.

We achieve a global reach by providing a flexible approach to accessing our out-of-the-box manufacturing technology. For our customers this means we deliver reliability, power and performance every time.

Talk to us about our next generation permanent magnet motor technology and how Electrified Automation can help drive your electrification journey.

Grayson Thermal Systems
cbarnett@graysonts.com
Grayson Thermal Systems designs, tests, manufactures, supplies and services innovative heating and cooling systems for OEMs in the bus and coach, commercial vehicle, rail, off-highway, defence and stationary battery energy storage system sectors.

INEE
michelle.duggan@inee.co.uk
Our highly experienced team is the first point of contact for companies looking to locate and invest in our region. The team connects businesses to the region's network of specialist organisations and individuals, and provides the information, support and advice essential for businesses looking to locate in North East England.

We co-ordinate investment enquiries on behalf of our region's local authorities to ensure businesses are able to make the best decisions based on a wide array of information.

Ionetic
james@ionetic.uk
IONETIC is a UK-based start-up specialising in EV battery pack technology. We produce highly optimised and cost-effective battery pack solutions thanks to our bespoke, state-of-the-art design platform and in-house production strategy.

Our mission is to help accelerate the mobility industry's journey to net-zero emissions by supporting niche vehicle-makers and automotive OEMs to overcome the challenges of transitioning to electrification.

Ricardo
rebecca.roper@ricardo.com
We are a global consultancy, delivering strategic, environmental and engineering solutions that are at the intersection of transport, energy and global climate agendas. We shape the markets in which we operate through solutions that are built on technological innovation that is sustainable.

Putting our values into action is what binds us together and makes Ricardo a great place to work and a company with which our clients want to do business.

Spark BD
john.fox@spark-bd.co.uk
Spark Business Development is a group of consultants formed to seek potential business opportunities to which it can add value with its expertise by providing skills that help the business grow and flourish, by providing support when seeking funds, and by forming partnerships with our clients, thus assisting in growth.

TeraView (see page 13)
andy.bell@teraview.com
An important challenge in lithium-ion battery production is to optimise the manufacturing process for electrode coatings (cathode & anode) to improve and optimise capacity whilst reducing and controlling manufacturing costs. Key performance indicators that determine electrode performance include coating density, coating thickness and conductivity.

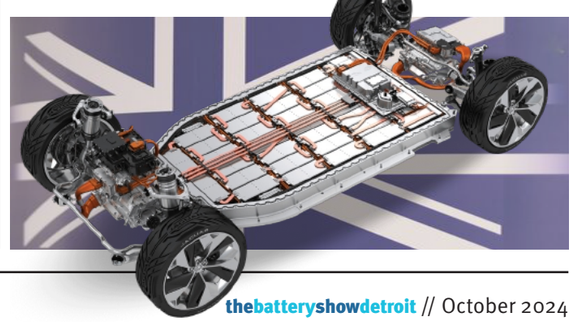
To date, there is no sensor technology capable of simultaneously measuring all three of these quantities accurately and rapidly during the in-line coating process. Terahertz sensors offer a solution that provide density, thickness and conductivity in one measurement, allowing for real-time feedback and control.

Transense
anice.mcnamee@transense.co.uk
World-leading sensor technology and measurement solutions. Transense Technologies plc. has two divisions that develop and supply world-leading sensor technology and measurement solutions: SAWsense, proven Surface Acoustic Wave (SAW) sensor technology and solutions, used in demanding applications to accurately and reliably measure torque, temperature, force, and pressure to improve performance, efficiency, and safety.

Translogik, tyre inspection and data capture tools, used by the world's leading fleet managers, tyre suppliers, and service centres to rapidly and accurately capture and digitalise safety-critical tyre condition data, that can then be used to reduce operating costs and improve safety.

UKBIC
faye.holloway@ukbic.co.uk
The UK Battery Industrialisation Centre (UKBIC) is the national manufacturing development facility providing battery manufacturing scale-up and skills to support the transition to an electrified future. We can be described as a 'learning factory' for organisations to develop blueprints for manufacturing processes and prototyping-at-scale of new electrodes, battery cells, module and pack structures.

Our objective is to help organisations to increase confidence in manufacturing plant investment for new battery-related technologies. We achieve this by bridging the gap between R&D and manufacture, massively reducing the level of risk for investors.



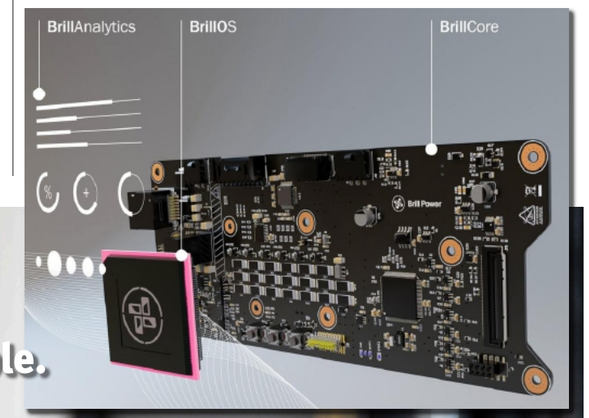
Brill Power

Brill Power's Battery Intelligence Platform brings transformational advances in longevity, performance, cost and sustainability to electric vehicles and stationary energy storage.

Brill Power is a company with roots in the Engineering Department at the University of Oxford. It brings together a unique team of world-class experts in battery and power management, edge computing, and data analytics, delivering its pioneering Battery Management System to the market aimed at stationary energy storage and electric vehicles.

The Battery Intelligence Platform comprises of three technologies: BrillCore, BrillOS and BrillAnalytics. Our unique patented active loading technology extends battery lifetime by up to 60% enabling our BMS+ to reduce the total cost of ownership by up to 30% and improve availability of the battery system.

Brill Power's technology benefits integrators, owners and operators by improving the business case and total cost of ownership for C&I and Utility scale BESS, for both existing chemistries (e.g. LFP) and more novel chemistries (e.g. sodium-ion). In addition, Brill Power's BMS improves safety and reduces the likelihood of thermal runaway, helping build confidence in BESS. Website: https://brillpower.com/



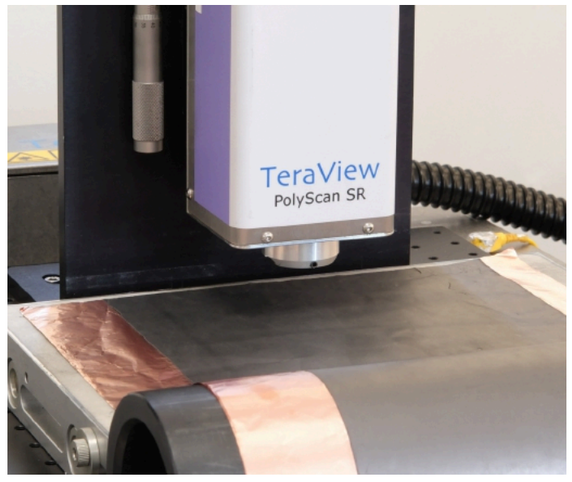
TeraView

TeraView is the world's first and leading company solely focused on the application of terahertz light to provide solutions to customer issues. TeraView has developed its proprietary technology across a number of markets. These include fault analysis and quality assurance for semiconductor chips used in mobile computing and communications, as well as non-destructive inspection of high value coatings used in the automotive industries.

TeraView, based in Cambridge UK, are launching a sensor specifically for the measurement of key parameters on anodes. Measurement of cathodes has been available for some time now, but this sensor, which is unique to the market, enables advanced control of anode quality during manufacturing.

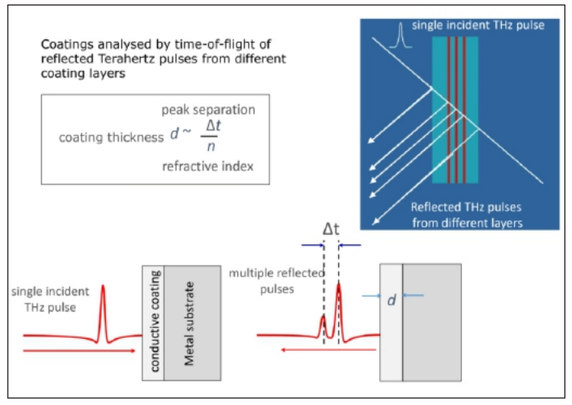
TeraView will also be showing their innovative & unique solution for measurement of cathode coating thickness, density & conductivity via non-contact methods. The technology on show has been developed over several years with the core technology in use in over 250 installations globally. Several battery manufacturers and leading industry research teams are now implementing terahertz based solutions.

The Terahertz measurements enable assessment of the quality of battery electrodes and detection of any deviation from the design parameters during the manufacturing process and additionally detection of de-lamination, buried defects and contamination.



Terahertz Pulsed Technology for Coating Thickness, Density and Conductivity

Terahertz pulsed technology, operating between microwaves and infrared, offers a solution; a single sensor that measures all three key performance – coating density, thickness and conductivity. Over the last decade, Terahertz has become an established inspection tool in process control and production in a variety of industries including advanced semiconductor packaging, automotive paint thickness measurements on car production lines as well as in-line coating thickness measurements on automotive parts.



The Terahertz technique uses highly accurate time of flight measurements to determine coating thickness based on multiple reflections of Terahertz pulses from different coating interfaces. The technique operates as a high frequency pulsed radar system, where time of flight is converted into coating thickness.

Contact: Andy Bell, VP Business Development
Email: andy.bell@teraview.com
Visit: www.teraview.com

Spectroscopy leads the charge in battery development

Lithium-ion batteries have quickly become ubiquitous in our everyday lives. Stephan Woods of Thermo Fisher Scientific explores the role of spectroscopy in this development.

There is constant demand for higher energy densities, faster charging and smaller battery sizes, driving the rapid development of alternative electrode materials. For example, all lithium salts have their limitations; $LiPF_6$ generates corrosive hydrogen fluoride in the presence of moisture, $LiAsF_6$ is toxic, $LiSO_3CF_3$ has low ionic conductivity, and $LiBF_4$ forms high resistivity barriers at the electrode surfaces.

These negative traits highlight the need to develop new electrode materials with improved functionality and stability.

Any changes in battery design must be thoroughly characterised and tested under operating conditions before they can be included in commercial products – a process that can be extremely time consuming and expensive. Another barrier to progress is the fact that many existing analytical technologies require highly skilled personnel to interpret the results, limiting the pool of operators qualified to run analyses. This hinders productivity and slows the rate at which novel battery components can be developed and released for commercial manufacture.

Cutting-edge analytical technologies

Fortunately, modern vibrational spectroscopy solutions – such as Raman instruments – are capable of identifying everything from compositional changes and crystallisation to ionic dispersion and electrolyte degradation within lithium-ion batteries. They can be applied throughout research and development, production and quality control.

Raman spectroscopy uses the interactions of light and molecular vibrations to produce spectra that are used to identify materials, characterise molecular structures, evaluate morphologies and monitor dynamic processes.

It can be applied for the analysis of many different types of battery components, including cathode materials, anode materials and electrolytes. Raman imaging is a viable alternative to traditional single-point measurement techniques, enabling users to quickly make thousands of measurements over an area of the component. Each pixel is a complete Raman spectrum, so the operator can tell if changes are heterogeneous or just hot spots, and this data can be correlated with electrochemical performance. Raman technology is non-destructive and fast – often providing measurements at intervals of 30 seconds or less. It requires minimal sample preparation and can be used both in situ and ex situ. ***(Box 1)***

In situ analysis provides valuable information supporting the research and development of new electrode materials. For instance, Raman instruments can be used in situ to map spatial and temporal changes in anode composition – such as the distribution of different phases of the same material with different performance characteristics – and to map anode degradation and compositional changes throughout charge and discharge cycles.

This is helpful in the investigation of lithiation, where the interaction of positively charged Li^+ ions with the anode causes a swelling of the graphitic structure, irreversibly damaging the anode and significantly reducing battery lifetime. ***(Box 2)***

Recently, other allotropes of carbon besides graphite have been investigated for anode materials, due to their novel physical and chemical properties. Raman spectroscopy is an excellent choice for analysing the presence, molecular structure and quality of different carbon allotropes, including in hybrid materials.

For example, Raman spectral data can be used to determine the number of sheets of graphene in a stack, provide information on defects or disorder in the structure, as well as to determine diameters of single-wall carbon nanotubes. Raman spectroscopy can also be used to study the degree of association of electrolyte ions in both solutions and polymer materials – which directly affect battery performance – to characterise electrolyte additives designed to partially immobilise the anions and improve cation charge transfer, and to study of membrane component distribution. ***(Box 3)***

Turning to manufacturing, Raman spectroscopy is a valuable tool for assessing the metal oxide and lithium compounds in raw materials, as well as for identifying any contaminants before beginning the manufacturing process. With available material libraries, Raman instruments can automatically detect these elements and quickly indicate if the desired compounds are present or not, and whether the material fits within pre-set tolerances.

This prevents bottlenecks in raw material quality control and enables real-time process modifications later on, helping to avoid coating and discarding unsuitable goods, ultimately reducing financial losses. Raman spectroscopy can then be used in

Raman spectroscopy for ex situ characterisation of lithium-ion battery anodes

Anode samples from a disassembled lithium-ion battery were cut and mounted in a transfer cell ***(Fig 1)*** so that a cross-section of the anode could be imaged. A 90° stub was used to hold the cut edge of the anode facing the window. A cap containing a CaF_2 window was used to seal the sample under an argon blanket, which was screwed on until the window height was just above the sample. This provided a minimum working distance between the microscope objective and the sample, allowing the use of high magnification objectives having a large numerical aperture.

Fig 1: A transfer cell keeps the sample in an inert environment during ex situ analysis, allowing the cross-section to be imaged.

Raman spectra were collected over a single 76µm x 160µm area at a spatial resolution of 1.0µm per pixel using a Raman imaging microscope. Laser power at the sample was 2.0mW at 532nm, with a 0.2-second exposure time and four spectral scans per image. A 50 x long working distance, 0.5 NA microscope objective was used to focus through the transfer cell window.

Image contrast was generated by multivariate curve resolution analysis to find the major components within each image, and a different colour was assigned to each component. Multiple regions of the sample were imaged and the Raman spectral data within each region was averaged to produce a single spectrum, homogenising any differences in the electrode area. This average spectrum represented a single-point measurement, with each point representing a 30µm square compared to a typical 1µm sample area represented by a standard Raman microscope.

Fig 2 is a micrograph of the anode cross-section, superimposed with the Raman image created from the spectral differences shown by the inset Raman spectra. The Raman image clearly shows that the coating on one side of the copper current collector is dominated by carbon black (red), whereas the other side has a much greater density of the active graphite phase (blue). The major differences in the two coatings could easily have been missed by single-point measurements.

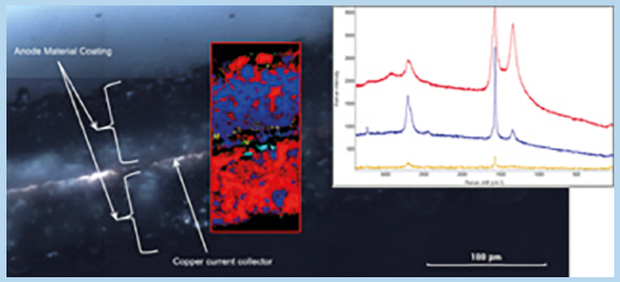


Fig 2: Micrograph showing a cross-section of a Li-ion battery anode. The Raman image indicates a difference in the anode coating on each side. Inset Raman spectra are colour coded to the areas in the Raman image.

Raman spectroscopy for the in situ characterisation of lithium-ion battery electrodes

Electrode material – graphite powder – was spread onto a copper grid, serving as the current collector. This was then sandwiched between a glassfibre separator soaked with the electrolyte solution and lithium metal as the counter electrode (CE) from below, and a sapphire (Al_2O_3) window from above. The Raman beam from the Raman imaging microscope objective impinged onto the back side of the material through a sapphire (Al_2O_3) window ***(Fig 3***).

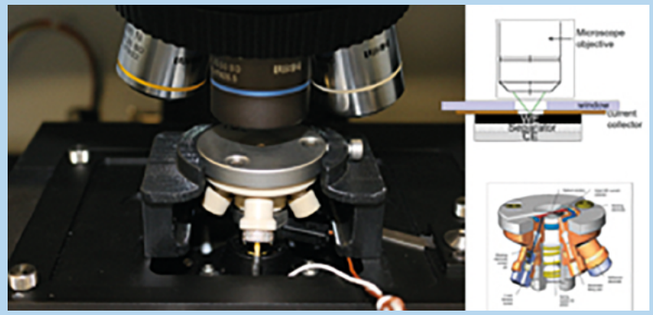


Fig 3: Experimental set-up showing the electrochemical cell mounted on the stage of a Raman imaging microscope.

This minimised the pathway for the Raman beam, allowing the use of high magnification objectives and optimising spectra quality. The electrode was charged very slowly to minimise the gradient of lithiation concentration along the depth of the electrode. The graphite electrode was cycled at a constant rate of approximately 0.06C, corresponding to 33 hours for a full charge/discharge cycle between 1.5 and 0.005V against Li/Li^+.

Raman imaging was carried out during the initial 480 minutes of the charging (lithiation) process only. Raman spectra were collected over a 30µm × 30µm area at 1µm pixel spacing using 2mW of 532nm laser excitation, a 0.01-second exposure time for each pixel, and 50 scans per image. Higher laser powers and/or longer exposure times resulted in burning of the graphite and boiling of the electrolyte.

Changes in the Raman spectrum

In ***Fig 4***, the 3D view (bottom left) shows changes in the Raman spectrum as a function of time over 8.3 hours (1–500 min). The spectrum of graphite exhibits a prominent peak at 1580cm^{-1}, attributed to the E2g2 mode (G band). At potentials between 0.42 and 0.31V (specific charge 33 and 45mAh/g), the band gradually disappears along with the simultaneous emergence of a peak centred at 1590cm^{-1}.

This peak shift was attributed to the Li^+ ions intercalated into the graphite structure. This is more easily seen in the centre, 2D Raman image. The inset shows Raman spectra before and after the change. Towards the end of the charge cycle at 8.3 hours (496 min), where the voltage was less than 0.15V (specific charge greater than 146mAh/g), a strong Raman band centred at 154cm^{-1} begins to appear.

This Raman band had not been previously reported so its assignment was not conclusive; strong Raman bands in this region have been attributed to TiO_2, Sb, and metal chlorides. In ***Fig 5***, Raman images are presented in which the image contrast was generated by MCR analysis. The blue MCR component is indicative of the 1580cm^{-1} band; green, the 1590cm^{-1} band; and yellow, the 154cm^{-1} band, with red representing carbon black. This experiment demonstrated that in situ Raman imaging techniques effectively show the spatial distribution of phase changes in electrodes over time.

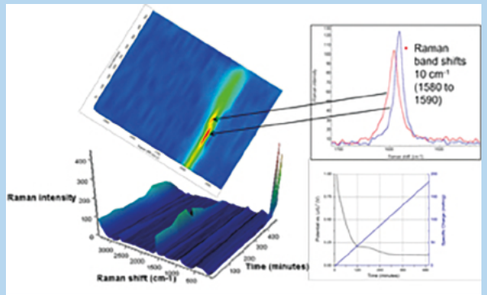


Fig 4: Different views rendered from the time lapse hyperspectral Raman data provide a wealth of experimental information.

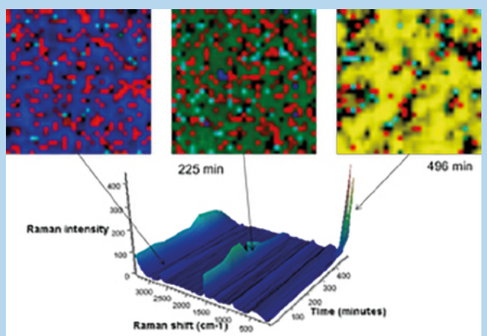


Fig 5: Raman images from different time slices in the graphite lithiation experiment.

post-production quality control to profile individual battery components without missing variability across an area, consolidating measurements of a cross-section to flag up inconsistencies and defects before commercialisation or assembly of a finished battery.

A solid-electrolyte interphase (SEI) layer forms on the battery anode as a by-product of the charge and discharge process. It is key to battery performance as it stabilises the electrode by preventing further decomposition, and also promotes reversible capacity. In situ Raman spectroscopy can be used to monitor and characterise the formation of the SEI layer, contributing to knowledge about its impact on lithium-ion battery function.

Complementary techniques for comprehensive insights

Fourier transform infrared (FTIR) spectroscopy is another technology being increasingly employed for numerous applications in battery research and manufacturing, and provides molecular information that is complementary in nature to Raman.

Its non-destructive nature makes this an ideal technique for examining the behaviour of different regions of energy storage cells in situ, aiding the rapid identification of changes that could affect battery life and safety. It can also be applied during raw material quality control to assess incoming goods, and is widely used for ex situ characterisation of lithium salts, electrolyte formulations, and catalytic systems.

FTIR again comes into play during final product quality control, helping to confirm that regulatory and stakeholder specifications have been met. The technology is also an important tool for analysing gaseous emissions released during battery operation under different environmental conditions, forming an early warning system before other visible signs of damage appear. This helps to establish the susceptibility of the battery to damage by overheating, overvoltage and mechanical damage, informing the development of safer, more resilient products.

Removing barriers with a new class of technology

State-of-the-art Raman and FTIR analysers are becoming increasingly intuitive and user friendly, while still offering high performance, removing many of

Raman analysis of lithium-ion battery electrolytes

Raman spectroscopy was used to characterise the additives and electrolytes in the polymer membranes and to study the distribution of the components within the membranes prior to use in an active battery cell. Raman mapping of the polymeric materials using a dispersive Raman spectrometer with a motorised stage and a 780 nm laser provided images based on the Raman spectra that showed the spatial distribution of the additives and electrolytes in the polymer membranes.

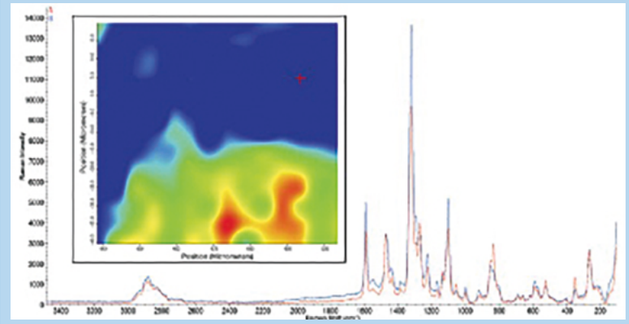


Fig 6: Spatial distribution of Cx2 in a PEO membrane. This figure was generated from data sent by the author.

Fig 6 shows the spatial distribution of the supramolecular additive, 5,11,17,23-tetra-p-tert-butyl-25,27-bis(((N-pnitrophenylureido) butyl) oxy)-26,28-dipropoxycalix[4]arene (Cx2), in a poly(ethylene oxide) (PEO) matrix ex situ. The image is based on the ratio of a peak from the supramolecular additive (1598 cm-1) to a peak associated with the PEO (840 cm-1).[3] The red colour indicates a higher concentration of additive and the blue, a lower concentration. Representative spectra from each of the areas are displayed as well.

the obstacles that have historically made routine use of these spectroscopy techniques arduous for individuals with limited expertise or specific technical knowledge. This is allowing a greater number of operators to quickly become confident in using Raman and FTIR instruments in daily workflows, lightening the workload on more experienced team members and helping to speed up analyses for increased plant throughput.

These highly sensitive technologies are more accessible than ever before, and greatly streamline battery development and production, offering unparalleled insights into the performance of novel materials and enabling the early detection of more defects during manufacturing.

This reduces both material wastage and financial losses for the manufacturer, and improves product robustness and regulatory compliance. The latest generation of Raman and FTIR instrumentation is playing a huge role in accelerating the design and commercialisation of new lithium-ion batteries with increased storage capacities, lifetimes and safety, both satisfying consumer demands and paving the way towards a more sustainable future.

Fig 7: The Thermo Scientific DXR3xi Raman Imaging Microscope (left) and Thermo Scientific Nicolet iS50 FTIR Spectrometer.

LInspector Edge In-line Mass Profilometer supports battery manufacturing

Designed specifically for battery manufacturing, the Thermo Scientific LInspector Edge In-line Mass Profilometer breaks new ground, enabling the user to analyse the entire coated area of the electrode at previously unattainable levels of resolution and precision. Whether you are conducting battery research and development or mass-producing electrodes, LInspector Edge In-line Mass Profilometer gives you the confidence to achieve consistent uniformity in your electrode coatings.

Research and development
Achieving electrode coating weight targets of a cell product design determine many critical performance and safety characteristics of a finished battery cell. Failure to optimise coating uniformity can result in excessive waste and lowered energy capacity, resulting in potentially unsafe battery cells. The LInspector Edge In-line Mass Profilometer enables inspection of 100% of the entire electrode, providing information-rich data on electrode coating uniformity.

Pilot scale manufacturing
Pilot scale manufacturing is designed to produce small quantities of battery cells for testing and validation prior to mass production. It is critical for researchers and process engineers to understand the mass loading distribution of electrodes to improve the quality and performance of their product and process. With 1000X more mass loading uniformity data available in real-time, this technology enables production of higher performance batteries, confidently and cost-efficiently.

Mass production
Battery manufacturers face the challenge of increasing throughput while reducing scrap material. In electrode coating production, coating uniformity is critical to the performance, reliability, and safety of finished battery cells. While current metrology methods only measure 2-4% of the electrode, LInspector measures 100% of the coated electrode in real-time. Complete edge-to-edge loading uniformity profile data is collected at a millisecond rate, providing insights and traceability not previously achievable.

(Not) made in America

US battery equipment makers have taken their battle to Washington DC to defend their markets by promoting a “Made in America” approach and claim they are gaining the government’s ear. Andrew Draper reports.

The Battery Machine Builders coalition was formed with six members last October and their spokesperson, Bennett Resnik, said the lobby association has been working with the Departments of Energy and Defence in pursuit of activities that will promote domestic battery equipment manufacturing.

“While a young organisation, we’ve found quick success and strong partnership with the government in considering equipment supply chain for federal funding opportunities. It is our goal to continue efforts that will place an emphasis on American-made machine procurement in all federal funding, financing and tax incentives,” he said.

One of its founders is New-York based Charles Ross & Son Company, which makes mixers for a range of industries including batteries. Sales Manager Christine Banaszek (right) said the company is consistently losing out when new battery plants are being built and fitted out in the US with equipment that more often than not comes from Asia.

“For now, for us here in the US…there are opportunities from these battery plants being built, but they are maybe joint ventures with Chinese battery companies. Or they're using technology from China,” she said.

"In the US, it has been commonplace to work with large engineering companies that provide the design, procurement and installation of a turnkey system. However in Asia, a single provider of the entire turnkey system is contracted to

handle everything. What we are finding today is that US JVs that have aligned themselves with Asian battery manufacturers are incorporating this ideology by bringing foreign equipment and the labour to install the systems here in the US," she added.

Ross does not provide turnkey systems. It has a holding in a mixer manufacturer in China. That in turn has a separate company providing turnkey solutions.

Cutthroat prices

New plants are opening throughout the US to build batteries. But the equipment and the machinery are still coming from China at cutthroat prices, according to Banaszek. “So that's why we formed this coalition with Ross as a founding member,” she said.

The coalition partners are trying to convince US politicians that for plans receiving federal funding, it should be written into grant applications that the machinery should be sourced in the US, or a percentage of it at least, she said.

That is a requirement for raw materials under the Inflation Reduction Act, she said. “But somehow it was forgotten to put it in and to also include the machinery.”

Still dependent on China

That has to change, she told BEST. “This is actually money from the government that we are spending to stimulate the market and, they say, so we won't be so dependent on China. “But in truth, you're still being dependent on China because you're getting the machinery from there and you know, they have the the password to the code and recipe software. The end users aren’t even allowed to have access to the programming for whatever controls the mixers or the machinery.”

Banaszek said the coalition’s work is bearing some fruit in alerting the government and its agencies to the issues around national security.

Fishing expeditions for information

She added that many of the new plant owners were requesting quotes but it seemed like fishing expeditions for information. “So we found this flurry of new plants. There was a time in 2022 where almost every week there was an announcement, or people were asking us for quotes. But they were all turnkey systems and they wanted somebody like a single vendor type.”

Such vendors do not exist in the US, she said. Traditionally, when a new plant opened, the owners would hire an engineering firm which would design and contract all the specialised vendors needed, and then put everything together.

“But this time the battery plants were expecting a quote from us, it’s basically like, ‘quote me a plant that has to produce 10GWh of work,” she laughed. “And so that trend was just so obvious and nobody here got the order. Everything was coming from Asia.” And there is nothing to stop that happening, but it still looks great PR for the US and American jobs, she said.

The concern is what might come next, she said. “Because it could start with battery manufacturing now. But what's stopping them in the future if they want to import machinery to make other critical components – do they just import them from Asia too?” And the battery market opened that possibility, she said. “So we want to stop that trend of shipping US dollars and jobs overseas.”

Ross learned that many Asian equipment manufacturers were planning to set up in the US – not manufacturing, but rather service centres. That is an understandable development, she added, but it might threaten the existence of established US players.

She points to her company’s established and loyal customer base, which she believes will ensure its survival, but also notes the challenger companies from Asia are coming in with prices that are maybe a quarter to a third of theirs.

You get what you pay for

The old adage of you get what you pay for seems to apply, she added with a smile. She has heard of companies who went with the cheaper goods and found “everything that could go wrong, went wrong.”

The job of the coalition, she said, is to call attention to the fact that US companies can also build those machines at home.

It wants clauses in funding contracts, legislation even, that the battery plants must buy American. “Yes, they should be required to buy American. And we even say it doesn't have to be Ross, it could be any American company as long as it's kept here.”

The coalition was established with six members. They include Siemens, Abbot Furnace, Bechtel, BW Papersystems, Ross and Dürr. It is under the umbrella of Venn Strategies, which also lobbies on behalf of the Battery Materials and Technology Coalition.

Its stated strategies are to:

- increase awareness of US battery machine manufacturing
- obtain preferential treatment in federal funding, financing and tax credits
- build capacity in the US through market growth.

Its targets are the Departments of Energy, Defense, Commerce, Treasury and the White House; and it lobbies individual politicians and officials.

Many initiatives over the years

Another coalition member is Dürr Systems. Clean technology systems business development director David Ventola (right) told BEST there have been many initiatives over the years to stimulate the industry, including the American Recovery and Reinvestment Act following the financial crash of 2009. Some 5–6 battery factories were built in the US with that government funding, he said. More than half of the machinery for these factories was imported from Asia, as the funding agreements did not require US-built machinery, he added.

Then came the Infrastructure Investment and Jobs Act, and the Inflation Reduction Act. There is a basic funding requirement that by 2026, 75% of the content of the battery – the materials and the components – need to be produced domestically.

“And so that's kicked off a significant wave of investment from mining to active materials production, to cell

manufacturing. And again, the the regulations leave out the source of machinery. Even though the materials and the components need to come from North America, as for the machinery, there's no comment.”

With the new gigafactory projects, many of them have either a joint venture partner or a very strong technology partnership with an Asian company, he added.

Not much of a look-in

In some cases, especially ones involving Chinese companies, Asian battery manufacturers have invested in Asian machine builders and co-developed products. It means US machine builders do not get much of a look-in when trying to gain business.

Ventola said: “So I think there are barriers to entry and what we hope to get is a chance to bid. We want to be competitive. And so the objective that we have, at least

from Dürr, is to let the US government – if they're going to give out taxpayer dollars, which they are – at least give a preference to companies who say 'We'll purchase the machinery in North America, because then it's stimulating the economy in North America and not sending that capital investment to somewhere across the Pacific.'"

He pointed to two funding opportunity notices from the DOE:

- DE-FOA-0003099, which refers to 'domestic manufacturing equipment' funded under the Infrastructure Investment and Jobs Act (known as BIL). That is set to invest more than $7 billion in the battery supply chain from 2022–26
- DE-FOA-0003236, on battery manufacturing. It noted most of the world's suppliers of battery processing machines are outside the US and added 'It is important to develop adaptable and versatile domestic processing machines that are also easily integrated into domestic manufacturing lines.'

"Our advocacy to DOE is moving the needle," said Ventola.