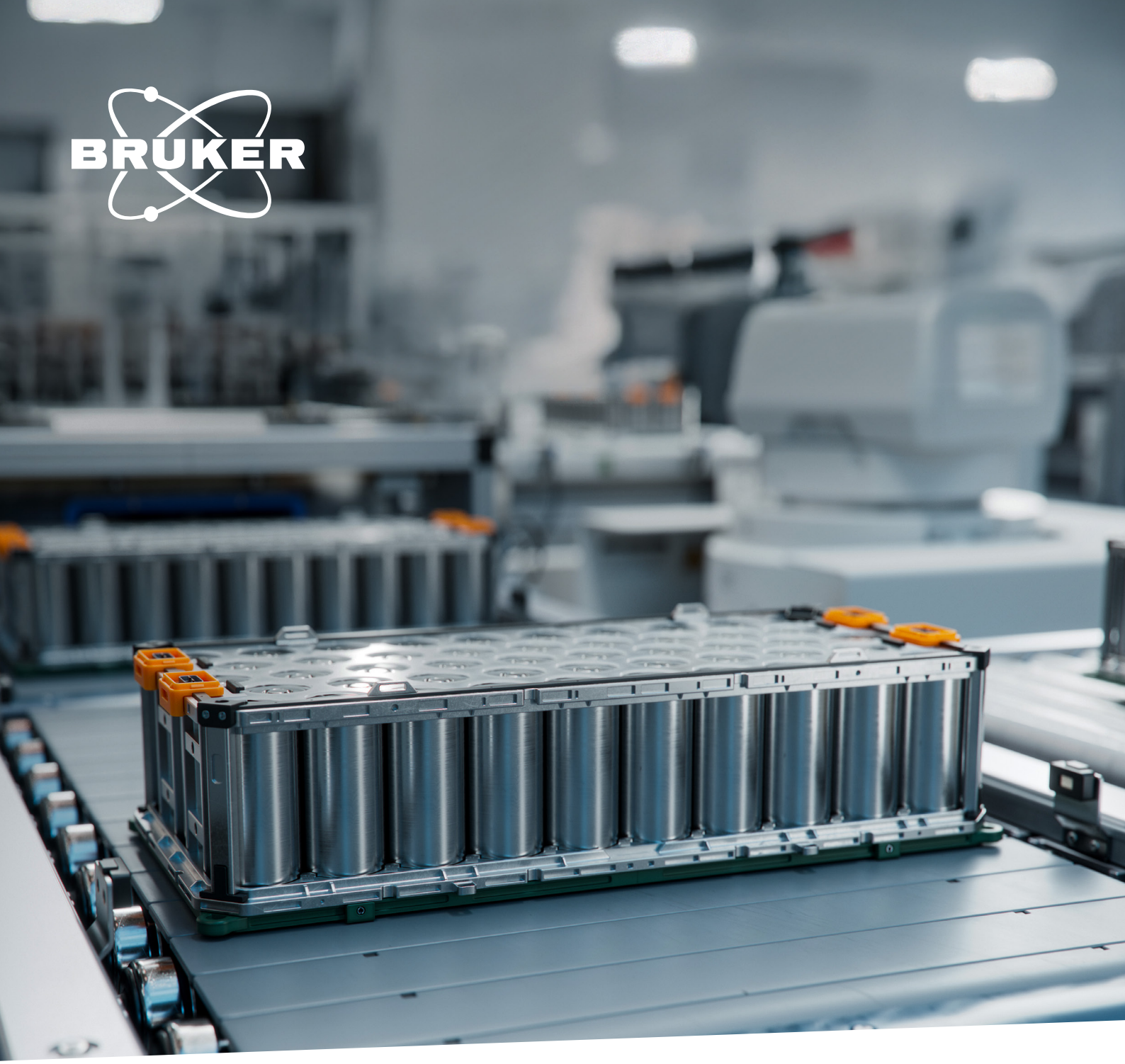

MAGNETIC RESONANCE FOR BATTERY INDUSTRY

Analytical Solutions for Battery Cell Manufacturing

Optimize Processes. Ensure Quality Control.
Reduce Material Waste.

Innovation with Integrity

The Future Needs Battery Power

Manufacturers are heavily investing in battery development, especially in the electric vehicle (EV) sector. This surge in investment is driven by a 40% increase in mobile energy demand, which rose to over 750 GWh from 2022 to 2023 [1].

According to Global Battery Alliance (GBA) latest report, the entire lithium-ion battery (LIB) chain is projected to experience "staggering growth," increasing by over 30% annually from 2022 to 2030.

Starting February 1, 2027, EV manufacturers must comply with the GBA's Battery Passport initiative. This program unites leading organizations to develop a battery supply chain ecosystem aimed at enhancing responsible production. All EV batteries over 2 kWh sold into the EU will require a unique 'battery passport', which provides information about the battery's composition and lifecycle [2].

Enhance Your Battery Manufacturing with Bruker's Advanced Analytical Solutions

In the competitive landscape of the battery industry, the right analytical tools are essential for success. Bruker recognizes the challenges in creating high-performance, reliable batteries. Therefore, we offer a comprehensive suite of advanced analytical solutions to support every stage of the battery life cycle, from raw material analysis to recycling and data management

Our high-performance instruments and software are customized to meet your specific needs in research, development, manufacturing, and quality control. These solutions provide essential insights into material properties, structural integrity, and chemical composition, ensuring your batteries perform optimally and last longer.

Real-Time Monitoring and Big Data Solutions

Our operando analysis solutions enable real-time monitoring of cell chemistry and ionic conductivity, giving you the data needed for swift, informed decisions. Furthermore, our big data solutions boost the efficiency and accuracy of your R&D and quality control processes, empowering you to innovate and excel in battery technology.

Customer-Centric Development

We develop our solutions in close collaboration with our customers, addressing the unique challenges and requirements of the battery industry. This customer-focused approach ensures our tools meet the evolving analytical challenges across the battery value chain. Scan the QR and watch the video interview

NMR-Based Solutions for Battery Cell Manufacturing for all level of expertise

Bruker's NMR-based solutions are user-friendly, designed for daily use by non-expert operators without the need for sample preparation. Automated instrument calibration ensures rapid, reliable results, facilitating prompt decision-making in your production facility. Our operator-independent results allow for comprehensive comparisons between laboratories, maintaining consistency and quality across your operations.

Supporting Innovation at a Lower Cost

Bruker solutions aid researchers and manufacturers in discovering new advancements in battery technology, promoting more efficient production. Partnering with Bruker allows you to streamline processes, reduce costs, and enhance the overall quality and reliability of your battery product.

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Supply Chain Coverage and Efficiency Increase for LIB Industry

Active materials are a significant contributor to overall battery cell cost structure. Therefore, innovating testing methodologies and reducing waste or total scrap-rates offers a competitive advantage to every stakeholder involved.

Improving, automating, and harmonizing battery active material testing along the supply chain increases process efficiency while matching agreed quality standards.

Linking failure analysis of post-mortem cells with R&D methodology and closely monitored raw materials deepens the understanding of the critical formation step. Corrective measures can be defined and applied in a timely manner.

Key focus areas for improvement include:

- Harmonizing testing standards to easily monitor agreed material performance standards
- Combining multiple incumbent and manual methods into one automated workflow
- Reducing costly material waste (cathode, anode, and electrolyte) by automated testing routines before application or usage of precious materials
- Enhancing raw material characterization and quality control to ensure consistent, high-quality batch-to-batch consistency
- Linking failure analysis to existing raw material quality data to understand the chemical and structural changes of failed components
- Automating sample and data flows for overall LIB production process improvement

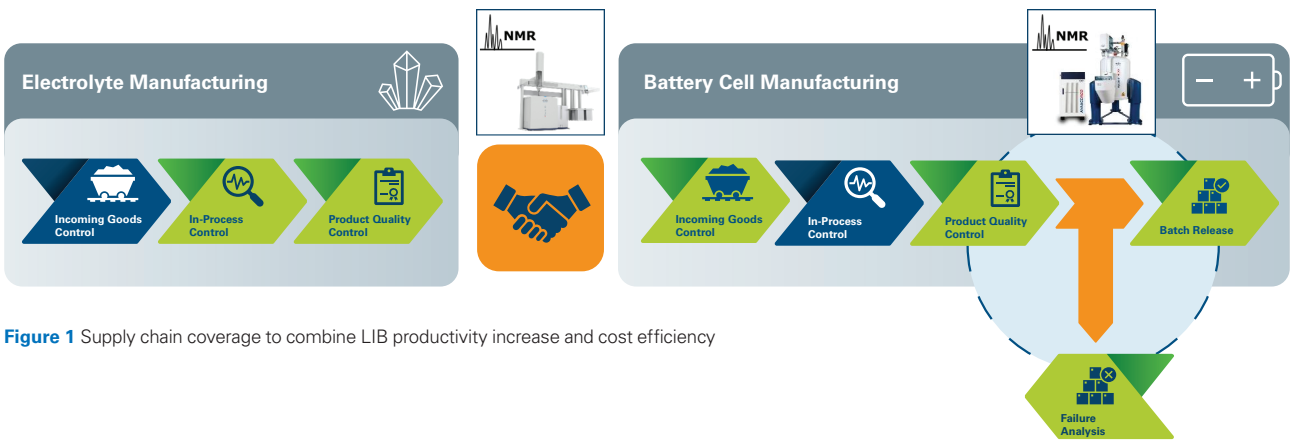


Figure 1 Supply chain coverage to combine LIB productivity increase and cost efficiency

Electrode slurry analysis

A significant factor driving the cost of LIB production is the material expenses. According to the Journal of Energy Storage [3], electrode processing faces challenges such as costly and hazardous solvent recovery, cut-off waste, coating inconsistencies, and microstructural defects caused by the solvent drying process.

Optimizing the coating process of electrodes and assessing the physical and chemical properties of slurries is critical, as their uniform application is affected by mixing parameters and conditions like screw speed and mixing time, as well as ingredient dosage rates and dosage precision. Monitoring the homogeneity of the slurry is essential for material stability, enhancing both the safety profile and lifetime of the battery cell. This, in turn, contributes to overall cost reductions.

Currently, the assessment of a successful slurry mixing process relies on evaluating mechanical parameters from the mixer, including internal pressure, temperature, and energy spent per particle, or afterward, by rheology or other laborious chemical methods in the lab.

The Bruker minispec delivers time domain NMR (TD-NMR) in a compact benchtop instrument, offering valuable insights into molecular structure, dynamics, and interactions. Its user-friendly design makes it suitable for non-NMR experts, enabling rapid and accurate results with minimal sample preparation. This method is particularly effective for early identification of sedimentation in slurry samples, solid content determination, recipe monitoring (balance between active material, conductive additives, and binder fractions), homogeneity evaluation, and de-mixing detection measurements.

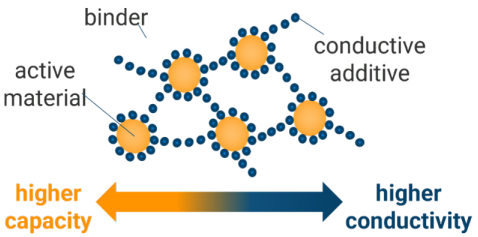


Figure 2 Overall scheme of slurry composition. The balance between active material, conductive additive and binder defines electrochemical and rheological (coating) properties of the slurry.

Electrolyte quality control

Electrolytes are crucial to the lifespan of LIBs, and they represent a significant expense in cell manufacturing, primarily due to the requirement for high purity levels. Consequently, the material quality is vital not only for the functionality and safety of the LIB but also for the overall production cost.

These components are moisture-sensitive and degrade over time at elevated temperatures and high numbers of charge cycles. Therefore, assessing the stability and degradation of the electrolyte components is crucial for evaluating battery lifespan and operational safety. Implementing quality control for well-defined electrolyte formulations in LIBs can significantly reduce failure rates and lower overall manufacturing costs.

Bruker's Fourier 80 is a high-performance benchtop NMR spectrometer designed for hydrogen fluoride (HF) content monitoring, carbonate ratio determination, and lithium salt concentration measurement—all without the need for sample preparation or NMR expertise. The solution delivers pass/fail results in a single run at the quality gates during production, enabling quick decision-making. Results are operator-independent, ensuring reproducibility between battery manufacturers and electrolyte component suppliers. This consistency is vital for maintaining critical quality control throughout the battery supply chain, ultimately reducing scrap rates and overall costs.

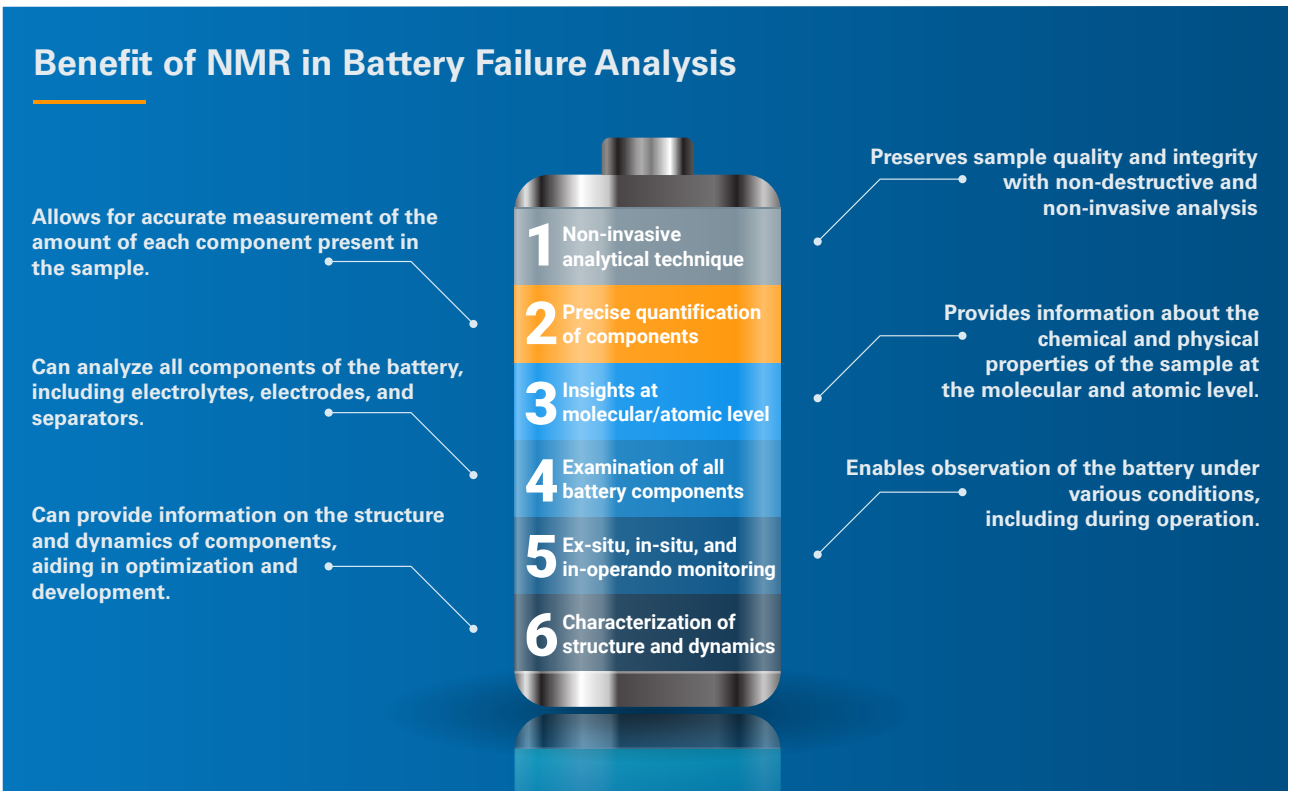
Failure analysis

In battery cell manufacturing, failure analysis is essential for identifying and addressing potential issues that may lead to premature battery failure or safety concerns. By pinpointing the root causes of failures, manufacturers can implement corrective measures during the manufacturing process, effectively preventing similar issues from recurring. This proactive approach not only enhances productivity and efficiency but also results in significant cost savings.

Understanding the causes of battery cell failures allows for continuous process improvements, ensuring that manufacturing operations are both streamlined and economically viable.

As battery recycling becomes increasingly important globally, early identification of defects in the manufacturing process is crucial. This proactive approach not only reduces waste but also minimizes the costs associated with scrapping defective battery cells. By leveraging failure analysis results, researchers can innovate and develop new battery technologies that overcome current limitations, paving the way for future advancements. This continuous improvement cycle ensures that the industry moves towards more sustainable and efficient battery solutions.

The Avance NMR spectrometer from Bruker has an automated workflow to enhance user efficiency, requiring little to no time for instrument setup, calibration, and validation. The user-friendly interface ensures smooth operation with minimal NMR expertise needed. The solution includes a pre-built and validated method for measuring ionic conductivity, identifying and quantifying product degradation, and establishing breakdown pathways throughout the cell lifecycle. In situ NMR spectroscopy provides atomic-level insights into battery materials, enabling manufacturers to optimize electrode compositions, electrolytes, and separators



A new integrated testing workflow

Nuclear Magnetic Resonance (NMR) technology offers a method of battery testing that packages research-grade analytical power in a user-friendly push-button system for high-throughput, high-performance, failsafe testing throughout the battery cell manufacturing chain.

Bruker's Distributed Laboratory Topology (DLT) means integrating high-resolution NMR instruments with benchtop units, enabling real-time data sharing, consistent audit trails, and reduced time-to-result, significantly lowering operational costs and enhancing efficiency and innovation in battery manufacturing and quality control processes.

Distributing harmonized methods, data, and resources across an organization enables significant improvements in workflow efficiency and, ultimately, product quality.

METHODS that are developed in an R&D environment with the Avance series instrument can be effortlessly transferred into the manufacturing environment on benchtop Fourier units. Method validation of novel product testing is very much streamlined by staying within the same technology: NMR. Both, the transfer of R&D testing methods to manufacturing testing methods and the validation of the latter by the first one significantly reduces time-to-market of new products.

DATA from benchtop units in manufacturing facilities can be easily accessed , analyzed, and interpreted by expert users at R&D centers utilizing a very familiar software package: TopSpin. The real-time availability of readable manufacturing affiliated testing data allows for new product roll-out monitoring and production efficiency increase measures.

RESOURCES can be more efficiently managed by running routine samples remotely on benchtop devices while freeing up high-investment NMR systems for more sophisticated analyses.

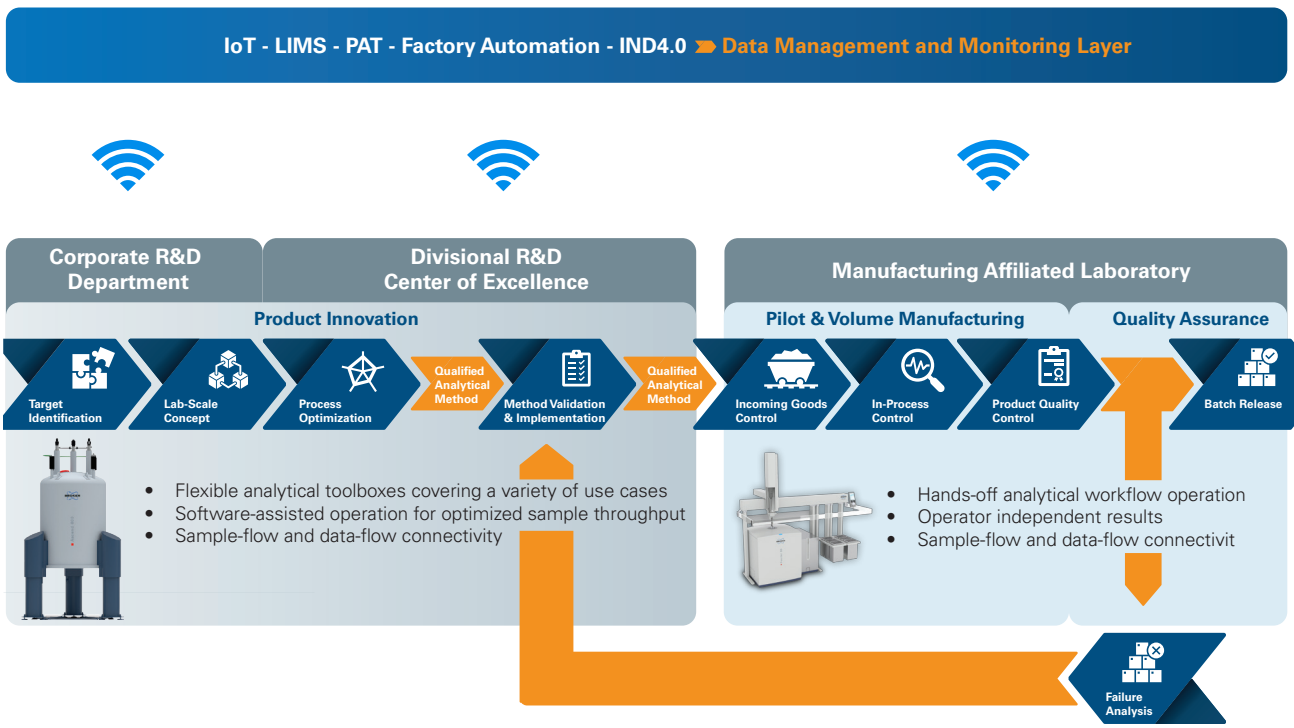


Figure 2 Comprehensive Cross-Compatible NMR Solutions: Bruker Distributed Lab Topology. Scan the QR code to learn more

Analytical Toolbox for Battery Cell Applications

Cell Manufacturing

Bruker NMR instruments can be used throughout the entire battery research and manufacturing chain for materials analysis, including electrode compositions, electrolytes, and separators. They can also enhance battery cell manufacturing productivity, optimize processes, and reduce material waste.

Here the use case for you

How to optimize the coating process for lithium-ion batteries

- Slurry separation and de-mixing detection and quantification
- Time stability evaluation
- Slurry mixing content monitoring
- Homogeneity dispersion analysis

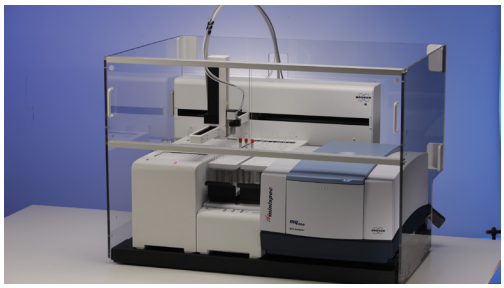


Figure 3 Benchtop TDNMR: the minispec MQ20

Implementing quality control for well-defined electrolyte formulations

- New formulation analysis
- Electrolyte component quality check
- Goods-in quality control
- Process control of electrolyte analyses
- Process intermediates analysis for troubleshooting and failure analysis

Figure 4 Benchtop NMR : Fourier 80

Preventing Future Failures

- Integrated interface with R&D to feedback and close failure loop
- Predefined acquisition and processing parameters
- Automated workflow
- Reliable hydrofluoric acid (HF) and water quantification at levels below 50 ppm
- Reference samples supplied for system check and calibration

Figure 4 Floor Standing NMR Avance 400Mhz

Bruker's Dedication to the Industry

- **Cost-Effectiveness:** Bruker has innovated to reduce the cost of MR systems, making advanced technology more accessible for industrial applications.
- **User-Friendly Design:** Our modern MR systems are designed for ease of use by non-experts, featuring automated calibration and minimal sample preparation.
- **Real-Time Monitoring:** We provide enhanced capabilities for real-time monitoring and analysis, enabling immediate decision-making and quality control.
- **Compact Size:** Bruker has significantly reduced the size of NMR systems, making them more practical and versatile for various industrial environments.
- **Sustainability:** Our new MR systems are more energy-efficient and environmentally friendly, with some models even reducing the need for helium.

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