WHITE PAPER

The Meteoric Rise of Solid-State Batteries: Innovations and Analytical Instrument Breakthroughs

Introduction

All solid-state battery (ASSB) technology, defined as having only solid components, will unlock materials chemistry limitations from traditional battery technologies and enable alternative activities and advanced designs. The costs of battery manufacturing are trending down, and energy density is trending up, however, this trend is plateauing. This plateau in energy density and cost efficiency offers a perfect opportunity for new battery innovations and ASSBs stand to be the primary battery system of the future.[1]

The primary difference between ASSB and lithium-ion battery (LIB) technology is the utilization of a solid electrolyte, which presents its own development challenges. ASSBs will need to overcome unique challenges including market penetration and R&D obstacles. The solid electrolyte interface between the cathode and anode materials generate a variety of electrochemical and mechanical considerations that will require innovative analytical technologies.

The potential of ASSBs to revolutionize the battery industry is resulting in new battery designs and material configuration solutions such as wider electrochemical windows, enhanced ionic conduction, SEI engineering, boosting mechanical properties, anode-less designs, and optimized thermal management innovations. The ASSB market will require the proper analytical testing technology to support these solutions and maintain the pace of development necessary to break into the battery market. Additionally, we are seeing the global push for wide-spread electric battery adoption for a variety of industries. Countries leading ASSB development are positioning themselves to reap the immense benefits, both economic and environmental, of the green revolution.

In this whitepaper, we will look at the factors that need to be overcome by ASSB developers in order to dominant the battery landscape, as well as the newest ASSBs designs, innovations and analytical equipment considerations to support ASSBs' meteoric breakthrough into the battery landscape.

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Factors Driving the Electric Battery Market

As global temperatures continue to rise, campaigns to reduce our collective CO_2 footprint, such as Net Zero initiatives, are some of the primary mechanisms driving the demand for the electric battery market. Nations around the world are recognizing the need for a more sustainable future and electric battery systems are primed to be the cornerstone technology in this green revolution. NetZero initiatives are pushing for 100% of car and 50% of heavy truck sales to be electric by 2035. Additional goals include electrifying buildings, cleaning up the energy grid and investing heavily in green electrical generation.[2-5]

Key Supply Chain Considerations for Solid State Batteries

- Raw Material Acquisition
- Processing Strategy
- Scale Up

Solid State Batteries Market and Applications

The changing energy storage landscape is looking to alternative battery designs to reach the critical requirements needed for a rapidly expanding electric battery market. Of these new battery designs, ASSBs are positioned as one of the most promising developments in the market. Estimated commercial product release of ASSBs is projected for 2023 but will require several optimizations in order to meet this benchmark.[6] The main requirements needed for the solid state battery (SSB) market to reach its full potential include:

- High energy density, High Wh/Kg and Wh/L and large capacity potential
- Fast charging capabilities
- Wide temperature ranges and tolerance
- Constant volume with limited compression
- Cycle stability
- Safe and nonflammable
- Scalability
- Sustainability

The patenting activity in Europe and China are increasing, however, the patent landscape is primarily dominated by Japanese companies from all supply chain levels. For the cathode active materials market, Korea, China, and Japan make up the majority of the top market leaders.[8] On July 7, Japan's Nihon Keizai Shimbun surveyed patent filings related to all solid-state batteries in 10 countries including the US and Europe. The survey found Toyota was the leader in patent registrations from 2000 to March 2022, reaching 1,331 patent registrations. Panasonic Holdings ranked second with 445 registrations and Idemitsu Kosan ranked number third with 272 registrations. In total, Asian markets dominant in patent landscape with six of the top ten leading corporations in patent registrations being Japanese companies, while the remaining four are Korean.[9]

Benefits of ASSBs

Traditional battery designs, such as LIBs, are still demonstrating optimized performance but are starting to plateau in the areas of energy density and cost of manufacturing. ASSBs will enable battery manufacturers to rise beyond energy densities of traditional battery systems and potentially mitigate manufacturing costs with the following projected and observed benefits.

Improved Energy Density

ASSBs offers the potential of high energy densities due largely to its stability at high voltages. At the cell level, engineers can replace graphite with Li-metal and increase cell size. At the pack level, engineers can implement higher volume utilization removing the need for cooling and reducing battery failure.[10]

Improved Working Temperature

ASSBs will utilize solid electrolytes that are less flammable (~200 °C) and tolerate higher temps (80-150 °C). This will allow manufacturers to design systems without cooling and battery management systems components, such as cooling subsystems, exhaust ducts, and blowers.[11] Additionally, researchers have established ASSBs can operate within favorable thermal parameters: -40 °C workability, 25 °C high-power, and 100 °C cycling.[12,13] Currently, ASSBs cannot match the same level power as LIBs but should be able to function at higher temperatures, thus improving safety and performance.

The Primary Applications of SSB Technologies Include:[7]

- Internet of Things (IoT) Applications
- Medical Technologies
- Smart Cards
- RFID
- Sensors
- Wearables and E-Textiles
- Portable Electronics
- Transport and Logistical Applications
- Large Scale Energy Storage

Improved Fast Charging

Fast charging capability, especially for electric vehicles, is crucial for ASSB market penetration. ASSBs maintain better efficiency and stability at high temperature for the cell level, which translates to a no step-profile at the pack level. This key feature of ASSBs was established by researchers at QuantumScape and demonstrated the following ASSB fast charging capabilities.[14]

For 4C charging:

- 0 - 80% charge in 15 minutes
- 10 - 80% charge in 12 minutes
- And maintained repeated 4C charge cycle life to 400 cycles

Safety

Increased projected safety due to the removal/reduction of flammable liquid electrolytes, thus reducing the need for certain safety measures such as a heat shield and crash zones.

Improved Abuse Conditions

ASSBs have also demonstrated improved abuse tolerances and thermal abuse.[15,16] Key abuse tolerances that are optimized with ASSBs include overcharge protection, mechanical robustness, overheating protection and short-circuit protection.

System Simplicity and Improved Engineering Efficiency

The optimized energy density and improved working temperatures of ASSBs eliminate the need for redundant cell voltage sensing and reduce (if not remove) the need for a cooling system. Additionally, this will allow ASSB designs to simplify the thermal management system, lowering cost of manufacturing.

Reduce Battery Pack Size and Weight

Due to the potential higher energy density and power density, ASSB designs have the potential to decrease the size of the battery pack by as much as 20% and reduce the weight by as much as 25%. This would enable high energy throughput with controlled weight and size optimizations, producing higher range electric vehicles and batteries with more power and energy density.[17]

Cost and Supply Chain Issues

As mentioned in the previous section, the potential for ASSB technology to revolutionize the battery industry is there, but in order for developers to drive the supply of materials needed to build out the ASSB industry researchers will need to demonstrate ASSBs are not just a theoretical player but can meet the market requirements and appeal to investors.

Perhaps, one of the greatest challenges in the coming years will be as the demand for battery energy systems rapidly expands, companies involved in the electric battery industry will be racing to keep up with this demand.[18] This will only exacerbate the existing issue of raw material prices.[19] Raw material quality needs to be clearly defined and the appropriate supply chain for ASSB raw materials have not been established.

Global Response to Battery Supply Chain Development

In the global battery market, South Korea, Japan, China, and Germany continue to position themselves as industry leaders in innovation and development. As a result, many other countries have expressed their intent to secure domestically-controlled supply chains. Of global importance, is the United States government has expressed its intent to secure critical minerals for the battery industry and recognizes the importance of this industry as a core pillar of economic competitiveness, national security, and sustainability. The United States has stated several strategic elements to catch up and eventually lead in battery innovation and development.[20]

These strategies include:

- Implement legislation to support and foster the demand of battery-based technologies
- Applying supply chain initiatives to support increasing demand of battery-based technologies, such as electric vehicles
- With the implementation of supply chains and domestic manufacturing, the United States is hoping to catalyze the auto industry's transition into electrification

According to the National Blueprint for Lithium Batteries, thereare five goals for the battery industry stratum set fourth by the United Sates that are designed to enable long-term U.S. economic competitiveness and job creation, the ability to reach decarbonization goals, and meet national security requirements.[20]

These five goals are outlined below:

1. Secure access to raw and refined materials and support the discovery of alternate sources of critical minerals for commercial and defense applications.
2. Promote the growth of a U.S materials-processing base that is capable of meeting domestic battery manufacturing demand.
3. Stimulate the U.S electrode, cell and pack manufacturing sectors.
4. Support U.S. critical materials recycling at scale and a full competitive value chain.
5. Continue to advance U.S. battery technology leadership via strong support of scientific R&D, STEM education and workforce development.

Similar initiatives are underway around the world, such as the action plan from the European Battery Alliance led by the European Commision, which aims to enable 90% of the Union's demand for batteries to be met with domestically made products by 2030.[21]

It is evident that the U.S. battery industry is playing catch up, but the aggressive government and private industry initiatives driving the security of raw materials, reinforcing supply chain, and advancing scientific leadership, indicates a dramatic shift necessary for battery development in the United States.[20]

Scalability Considerations to Support ASSB Development

The four factors that need to be considered for adequate scalability of ASSBs are supply chains, materials properties, processing costs and the battery ecosystem. Analytical technologies enhance several key drivers with regards to these four factors, specifically material acquisition and processing, process rate and process yield. In addition to proper analytical support, scalability of ASSBs will be heavily influenced by key outcomes such as scaled technology performance and reproducibility.[22]

Scale Up Challenges

Upscaling to large cell designs will present issues that lead to delays, these scale up challenges include:

- Finding the right material suppliers at scale
- Difficulties in regulatory approval for production facilities or product launch
- Development of new and different manufacturing processes for ASSB catholytes and electrolytes

Higher complexity in material handling, production processes and production steps may lead to increased product costs. Dependent on type of solid electrolyte, new additives, doping or coatings, materials costs could have a significant impact on total cell costs. Exacerbating scale up challenges further is the availability of sustainable resources, equipment, and talent in this sector.

Fast Charging Obstacles

Fast charging capability is perhaps one of the most attractive features for ASSBs and is critical to its market penetration potential. Currently, the major obstacles fast charging ASSB development must face is:[23]

- Sluggish Electrochemistry
- High Hysteresis
- Internal Temperature Rise
- Accelerated Aging
- Useful Capacity Losses

Safety Considerations

Comprehensive testing of ASSBs will be required to validate its largely theoretical safety benefits. However, there have been several noteworthy developments evaluating thermal properties and crush comparisons to conventional LIB systems.

Crush Testing Comparisons

Crush Comparisons were performed with ASSB cell designs against conventional LIB pouch cell configurations in an automotive battery module. Findings demonstrated higher peak force could be achieved with ASSBs and event-free intrusion in x and y directions were significantly higher for ASSBs. Thus, ASSBs could enable future designs to load modules with higher intrusion and mechanical forces.

This may lead to higher overall safety standards, cost mitigation, simplification in design, higher energy capacity and better range, and optimized volume utilization.[24]

Thermal Evaluation Comparisons

Potential temperature rise increases significantly with energy density and must be a critical consideration for future ASSBs. Considering temperature rise as a metric of safety, researchers should rely on thermal modeling studies to assess safety using thermogravimetry analysis (TGA), differential scanning calorimetry (DSC), and thermomechanical analyzer (TMA).

Key Safety Testing Technologies

TGA and DSC
- Thermal characterization to identify and characterize binders and solid electrolytes

TMA
- Measure thermal and mechanical properties

TGA
- Thermal stability and decomposition profile
- Battery failure analysis

Pressure Considerations, Cell Dimensional Changes and Cell Breathing

The potential of a battery systems to produce varying degrees of pressure over its lifetime plays a crucial role in its marketability. Low pressures are considered desirable for battery systems as the cell pressure is transferred to the module and pack frame. Large forces, derived from these pressures, can lead to deformation to the battery frame and battery failure. Engineers can address higher pressures with heavier frames but will add significant weight and decreased performance on products like electric vehicles.

Traditional liquid battery configurations can generate high amounts of pressure due to the swelling of electrodes and gas generation. The design of ASSBs will help mitigate this pressure concern as they do not have the same swelling and gas generation issues as traditional liquid batteries.

To ensure the integrity of the battery system over a lifetime, low volume changes as well as pressures are required. Traditional LIBs are vulnerable to cell dimensional changes during charging and discharging, where one electrode is expanding while the other is contracting. Depending on the materials used, a battery cell can be exposed to significant degrees of expansion.

For instance, when Lithium alloys with silicon in the anode the volume changes are significantly greater. The volume changes can cause decreased functionality at the particle level, electrode, and SEI layer. Volumetric changes can be greater when utilizing lithium metal anodes as their cycling produces dendrites formation.[25,26]

The effects of cell dimensional changes include:

- Diminished energy density
- Reduced Cycle Life
- Increase in Impedance
- Safety Concerns

Therefore, cell dimensional changes should be a top priority for manufacturers. Pressure can improve performance of lithium metal cycling and the variation in lithium foils perform differently under varying pressures. Lithium foils all perform differently with variations in capacity fade, dimensional changes and electrolyte sensitivity.[25,26]

The main variations in lithium foils include:

- Thickness, where thinner is typically optimal
- Deposition method
- Coatings and pre-treatment of the lithium
- Underlying composition as seen in doped lithium and lithium alloys. Commonly doped and alloyed elements are In, Sn, Zn, Si, Al, Ag, and Mg. Potential benefits of utilizing doping and alloying elements include better capacity retention

Compressive Loads and Requirements

The majority of the current ASSB designs require loads 5 - 200x that of Li-ion batteries. This dramatic increase in compressive load requirements will add to the cost of manufacturing and increase the volume and weight of the system. There is an urgent need, and opportunity, for solutions to cell breathing and volume expansion issues for ASSBs.[25,26]

Solutions to Cell Breathing

1. *Compression Pads and Spring Elements*
   Compression elements will need to be designed for long term compression at elevated temperatures.
2. *Thin Ceramic Electrolytes*
   The nonflammable and low-cost ceramic electrolytes provide a thin and electrolyte material for a separator with a porous scaffold.
3. *Lithium Metal Anode*
   Lithium plating within porous scaffold for high rate and low resistance at room temperature, without compression or external expansion
4. *Cathode-Flexible Platform*
   Compatible with existing and next generation cathodes that will further enhance energy density and power

Our understanding of cell dimensional changes is still not complete and there is an urgent need for research to map out the effects and develop a greater understanding.[25,26]

Solid-State Electrolytes

Removing the liquid electrolyte causes several unique design challenges such as interfacial resistance and voids. As Li-ions are transported during cycling, electrochemical interactions between battery components will result in the formation of dendrites and voids. Solid electrolytes require the malleability to fill in small voids and porosities while maintaining the ionic conductivity required to be better than liquid electrolytes.[27]

There are many types of ASSB electrolytes, all with varying properties and considerations. Each electrolyte is analyzed based on its mechanical properties, ion conductivity, anodic and cathodic stability, electronic and ionic low area-specific resistance (ASR), stability (thermal, chemical, oxidation, reduction), and processability. Depending on the configuration of the ASSB, each type may offer a unique benefit to the manufacturer. It is based on this uniqueness of each electrolyte, that manufacturers must carefully assess which type is optimal for their own applications.

ASSB electrolytes include:

Polymers
Polymers are scalable and stable electrolytes with good electrochemical properties and one of the easiest electrolytes to process into cells. They are also compliant, enabling compact arrangements to address cell dimensional changes during cycling. Polymers have already established their functionality in EV applications. However, their mechanical properties are not as good as oxide and sulfide electrolytes with[28]

Oxides

Oxides are air stable electrolytes with good mechanical and electrochemical properties. However, they are challenging to scale up, lack flexibility, and often have compatibility issues.[28]

Sulfides

Sulfides are scalable, slightly flexible, and have good mechanical and electrochemical properties. However, they are unstable in air and have combability issues to account for.[28]

Halides

Halides possess desirable properties such as high ionic conductivity, high oxidation voltage and good stability toward oxide cathode materials. However, there are still challenges in scalability, stability, and achieving high humidity tolerance.[28]

Ceramic

The company QuantumScape is currently in development of a solid-state ceramic electrolyte, tens of micrometers in thickness, that also doubles as the separator. The solid ceramic is designed to suppress the formation of dendrites while enabling lithium ions to pass back and forth.[32]

Key Analytical Testing Technologies Include:

ICP-MS and ICP-OES

- Analyze electrolyte for elemental and compound impurities (ppb and ppt range)

GC-MS and LC-MS

- Analyze solvent composition
- Identify volatile semivoliatile and chemical compound impurities
- For compositional and purity/impurity analyses
- Content in electrolytic solution

Hyphenation

- Hyphenation combines two or more technologies to answer what gases evolved and when
- TG-MS, TG-MS, TG-GC/MS

ASSB Cathodes

ASSB cathodes provide the positive ion sources, such as lithium ions, in the ASSB battery. Common materials used in cathodes include:

- *NMC (NCM)* – Lithium Nickel Cobalt Manganese Oxide (LiNiCoMnO2)
- *LFP* – Lithium Iron Phosphate (LiFePO4)
- *LNMO* – Lithium Nickel Manganese Spinal (LiNi0.5Mn1.5O4)
- *NCA* – Lithium Nickel Cobalt Aluminum Oxide (LiNiCoAlO2)
- *LMO* – Lithium Manganese Oxide (LiMn2O4)
- *LCO* – Lithium Cobalt Oxide (LiCoO2)

Analytical techniques are necessary to analyze some of the raw metals using the manufacturing of battery cathodes and impurity detection in R&D and QA/QC. This ensures high quality of the cathode materials and optimized battery performance.[28]

LIBs utilize nickel rich cathode materials that have oxygen problems, especially at higher temps where we see thermal events. In many ASSBs, cathode materials will be similar, so the risk in ASSBs will still be applicable.[28]

Transitional Metal Oxide (FePO4)

FePO4 is an inexpensive, earth-abundant cathode material that can provided with a domestic supply chain. It is also less expensive and safer than many of the cathode materials but provides a lower energy density.[30]

High Nickel and Cobalt Free Cathode Active Material

Utilizing high nickel and Cobalt-free cathodes can provide higher voltages and energy densities. However, to find the right match of materials surface properties and pore properties much be tailored together.[30]

ASSB Cathode Analytical Testing Technologies and Considerations

ICP-MS

- High sensitivity for quantifying impurities in anodic and cathodic materials
- Battery failure analysis (cathode materials)

ICP-OES

- Impurities and elemental analysis
- Characterize and develop anodic and cathodic materials

TGA and Hyphenation

- Battery failure analysis- used to look at what happens to any battery components during failure

ASSB Anodes

The ASSB anode provides the negative ion sources in the ASSB battery. Graphite is one of the primary anode materials utilized in many battery systems, due to its ability to reversibly place lithium ions between its layers. Fully charged batteries position Li-ions between the graphite sheets, then during discharging, electrons move from the anode to the cathode. The negatively charged cathode is then stabilized by the Li-ions migrating from in between the graphite sheets of the anode to the cathode.

ASSB batteries, like LIBs, can be made up of graphite, a binder, and a conductive addictive that is coated on copper foil. Anode materials should demonstrate optimized porosity and conductivity, durability, low cost and a voltage that is matched with the desired cathode. Methods that ensure material quality rely on ICP-MS to analyze impurities and hyphenated technologies to detect molecules absorbed to the surface of the electrodes.[29]

ASSB Anode Variations

There are several ASSB anode configurations that are being developed, three of those variations include ASSB graphite-silicon anodes, ASSB lithium-metal anodes, and ASSB anode-free configurations.

ASSB Graphite-Silicon Anode
The addition of silicon to conventional graphite anodes provide greater battery capacities and energy densities. However, silicon becomes problematic as it expands to nearly a factor of 4 after repeated cycling. The solution to this silicon-graphite expansion issue is instead of utilizing a large piece of silicon, you replace it with nanoparticles of silicon. Nano-silicon materials can limit cracking due to differences in surface area to volume ratio.

Pure Lithium Metal Anode
Silicon-graphite anodes, although offer better energy density than pure graphite, are nowhere near the energy densities provided by pure lithium metal anodes. Lithium metal anodes have been around for a long time in liquid battery systems but are notoriously difficult to develop. While they offer greater capacity and energy density, they are subject to dendrite growth across the electrolyte.[31]

It was proposed that solid-state technology offers a potential way to block dendritic growth and capture the true potential of pure lithium metal anodes. However, dendrite growth is persistent and if the solid electrolyte is polycrystalline and has grain boundaries, then dendrites will grow through the grain boundaries and short out the battery. There are two solutions currently in development to solve this dendritic growth issue for pure lithium metal anode applications.[31]

Dendritic growth solutions include:

- Utilizing a glassy solid-state electrolyte, with no grain boundaries
- Utilizing a Ceramic electrolyte that has a low ionic conductivity

Anode-Free ASSBs

The company QuantumScape is implementing an anode free ASSB application that instead of utilizing a graphite anode to store lithium ions, their anode free design utilizes an electrical contact in leu of the anode. The ceramic electrolyte provides a high dendritic resistance and the lithium metal anode enables high-rate cycling. The cathode contains the lithium ions that during battery charging the lithium ions migrate through the separator and form a flat, dendrite-free layer between the electrical contact and separator. This application has the potential to reduce the weight and cost of the battery significantly.[32]

ASSB Anode Analytical Testing Technologies and Considerations

ICP-MS
- High sensitivity for quantifying impurities in anodic and cathodic materials

ICP-OES
- Impurities and elemental analysis
- Characterize and develop anodic and cathodic materials

Separators

The ASSB separator divides the anode from the cathode, forming an isolator for electrons and allowing the migration of ions. Traditional battery separators are porous polymer membranes are saturated by a liquid electrolyte. Separators for ASSBs, do not require liquid saturation and, in many cases, utilize the solid electrolyte itself as the separator.[29 30]

ASSB Separator Analytical Testing Technologies and Considerations

IR
- Identify and characterize advanced materials used for separators, cell housings and pack enclosures

TGA and DSC
- Thermal characterization
  Separator performance (melting point, crystallinity, thickness, chemical composition, porosity)

Analytical Technologies for Thermal and Mechanical Properties

Thermal and mechanical properties offer key insights into battery performance and safety and are critical in the manufacturing process. These insights are gained from analyzing properties such as crystallinity, melting point, thermal stability, and decomposition profiles.[29]

Oxygen at the cathode becomes a key risk for ASSBs, for example in lithium continuing batteries that utilize nickel rich cathode material there is the potential for oxygen derived issues, especially at higher temperatures where thermal events occur. Therefore, it is critical that manufacturers include robust instrumentation, such as a DSC, to monitor thermal conditions.

Key Analytical Technologies to Consider for Thermal and Mechanical Property Analysis Include:

TGA and DSC

- Thermal characterization to identify and characterize binders

TMA

- Measure thermal and mechanical properties

TGA

- Thermal stability and decomposition profile
- Battery failure analysis

Recycling of All Solid-State Batteries

With nearly 11 million tons of previously used LIBs estimated to exist by 2030, ASSBs will no doubt reflect a similar volume of waste after its adoption. Currently, the motivating drivers of recycle LIBs include mitigating raw material acquisition and optimizing supply chain, reducing the negative environmental consequences of battery development, and ensuring the battery industry maintains a healthy impact on society and vulnerable groups. ASSBs, with demands for similar raw materials, are already being designed with recyclability as a key process in its lifecycle.[33]

The recycling process of ASSBs will begin with deactivating and shredding of the old battery modules. After removing electrolyte residues, hydrometallurgical and pyrometallurgical procedures need to be carried out to recover materials like lithium and cobalt. The characterization of ASSB materials using elemental analysis and cell chemistry are also critical to ensure effective recycling efficiencies.[34,35]

ASSB recycling will rely on a collection of physical processes and analytical methods to provide the information necessary to begin the initial assessment of the recycling scrap. Thus, analytical testing equipment will play a fundamental role in both the characterization of the re-synthesized recycled ASSBs and the crucial reduction in the environmental and social impact of ASSB development.[35]

Key Analytical Testing Technologies Include:

ICP-MS and ICP-OES

- Determination of all elements of interest

AA, TXRF, EDX

- Composition of recycled scrap materials

IC

- Characterize anionic components of scrap metal

GC, GC-MS, LC, LC-MS

- Identify original used electrolyte components and information about additives

IR

- Identification and advanced material characterization

TGA and DSC (Thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC)

- Investigate mixture of anode and cathode materials (black mass)

Hyphenation

- Greater insights by combining two or more techniques, enabling reverse engineering and a better understanding of evolved gases. i.e. TGIR, TG-MS, TG-GC-MS

The Future of All Solid-State Batteries

2023 marks the projected role out of ASSBs into the energy market and presents an incredible opportunity for manufacturers to break through the energy density plateau. As this technology begins to mature, the opportunities to implement ASSBs in applications like medical devices, sensors and electric vehicles will significantly increase demand.

Thus, ASSB manufacturers will need to prepare for this anticipated demand by securing raw materials, reinforcing supply chains and utilize key analytical technologies to optimize battery development.

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