Thermo Fisher SCIENTIFIC

Solid-state batteries

How LISIC technology enables a smooth transition to solid-state battery manufacturing

Lithium solid ionic composite separator (LISIC) helps ease manufacturing transitions

Pam Poulin, Market Development Manger at Thermo Fisher Scientific, and **Dr. Julian Renpenning** conducted this interview with Alex Kosyakov, Cofounder & CEO of Natrion.

Natrion introduction

Natrion Inc. is an solid-state battery technology company founded in 2018 by Alex Kosyakov and Thomas Rouffiac. Headquartered in New York, with operations in Illinois, Natrion is at the core of developing innovative battery components for electric vehicles and other e-mobility applications. Natrion has garnered considerable recognition in the industry. The company was a Gold Winner at The Edison Awards in the Resilient & Sustainable Solutions category, and its co-founders were named to the Forbes Under 30 list. Natrion also won the LG Energy Solution Battery Challenge 2022. On the funding front, Natrion has raised millions from notable investors and contracts from the U.S. Department of Defense. Through its innovative approach to solid-state battery technology, Natrion is poised to play a significant role in shaping the battery industry and other e-mobility applications. In this interview, we speak with Alex Kosyakov and learn how Natrion is advancing solid-state battery technology.

Can you share your story behind the founding of Natrion?

Natrion's beginnings can be traced to 2017, which is when I started work on solid-state Na-ion battery research at the City University of New York (CUNY) Energy Institute. Other fantastic startups have come out of that lab at CUNY—Urban Electric Power being one, for example. I was drawn to Na-ion because of the chemistry's potential sustainability and cost advantages over state-of-the-art Li-ion, which are especially critical parameters for grid energy storage. Even more important for stationary applications, though, is safety, which led me down the path of solid-state.

I began tinkering with a new type of inorganic (ceramic) solid-state electrolyte material and filed patents in 2018. My co-founder, Thomas, was a childhood friend who was studying at Indiana's Kelley School of Business at the time. We were really excited about the innovation and the opportunity to disrupt the market with it and started chatting about commercializing my patents. We made our first pitch at a demo day at MIT that year and Natrion was formed as a company shortly thereafter—the name being derived from the Latin word for sodium.

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Since then, how has Natrion evolved into a leader in solid-state battery innovation?

Between 2018 and 2020 we attempted to scale and market our Na-ion technology. However, we received little interest—mostly because immature Na-ion component supply chains meant that we were not at all as cost-competitive with Li-ion as we intended to be. After all, Li-ion was advantaged by 20 years of industry incumbency and well-established economies of scale. However, the battery OEMs we interacted with kept asking if we could make a lithium-based version of the solid-state electrolyte that was at the core of our Na-ion battery.

That is when we started iterating the Lithium Solid Ionic Composite (LISIC), our primary product offering today. This is a lithium solid-state electrolyte separator which addresses what battery OEMs seemed to want most: a means of transitioning their (giga)factory Li-ion production lines to solid-state cell fabrication with minimal equipment or process modifications while realizing increased energy density, superior cost efficiency, and enhanced thermal safety.

What challenges have you encountered building a battery startup and how have you overcome them?

Building a battery startup is a game of never-ending catch-22s. Investors won't believe that your innovation will deliver on your claims without validation in industry-relevant cell types—which cannot be built without some initial investor capital for the gloveboxes, the stackers, the tab welders, and the sealers needed to make a batch of cells.

Customers won't give you an offtake order if you don't have an established production line turning out some minimum quantity of material, but banks and lenders won't finance a production line without documented customer orders. What all of this means is that even startups with the best technology and personnel can stumble in commercialization without proper execution.

Execution is everything, and this is perhaps the most important bit of advice we've gotten from Mark Cuban, one of our seed investors. We have focused heavily from the outset on the process efficiency and the unit economics of manufacturing LISIC using capex-light approaches. For example, we figured out how to make LISIC using off-the-shelf equipment already employed by the printed circuit board (PCB) industry and began renting time on mothballed equipment at PCB manufacturers' facilities.

In these efforts, our team concentrated on just two key performance indicators: line speed (m/min.) and bill of materials ($/square-meter). It is very rare that a Series A-stage battery startup will have a mature understanding of their cost of goods sold at an elevated manufacturing readiness level—we are proud to be an exception.

An example of a battery using Natrion's lithium solid ionic composite (LISIC) separator technology.

Can you explain your technology for solid state batteries and how it differs from traditional lithium-ion batteries?

Every Li-ion cell today uses a porous polymer membrane imbued with liquid electrolyte as the separator layer between the electrodes. The liquid is typically highly flammable—hence the concern of fire risks with current batteries. Meanwhile, because the separator is porous, it is permeable to not only Li ions but also any other species which dissolve into the liquid, including cathode components. Cathode constituents can migrate to the anode side of a cell and participate in parasitic chemical reactions in a phenomenon known as "electrode crosstalk."

The first time that a cell is ever charged and discharged, a significant portion of the available inventory of cyclable Li ions can be irreversibly lost to crosstalk and related processes.

In over 30 years of Li-ion technology development, the separator and liquid electrolyte have remained mostly unchanged, while other parts of the battery cell have been substantially improved. We like to think of LISIC as the separator layer of the cell finally getting a major upgrade. Unlike normal separators, LISIC—as a solid-state electrolyte—is non-porous and moves charge intrinsically without depending upon the addition of liquid.

By removing liquid from the separator layer, cells lose their propensity to respond to abuse with thermal runaway and instead fail via benign modes. Furthermore, the selective permeability of LISIC to only Li ions blocks electrode crosstalk to prevent lithium inventory losses. This is the largest contributor to the energy density boost that is attainable by implementing LISIC.

Perhaps LISIC's most key feature, though, is that it still mechanically mimics normal porous polymer membranes in every wayit is just as thin and flexible and behaves the same when folded or wound. The net result is that manufacturers can drop rolls of LISIC into production lines in place of traditional separator rolls using existing equipment and infrastructure—a near-term, low-cost, high-volume way to achieve solid-state cell production.

What are the key benefits of your solid-state battery materials for industries like automotive, aviation, and mobility?

Across most industry-relevant Li-ion cell types and chemistries, replacing traditional separators with LISIC—even without making any other alterations—can increase energy density by 10%–15%. This corresponds to a 28-45 Wh/kg augmentation, which is not as incremental as it may seem—the Li-ion industry, on average, only improves by 8-9 Wh/kg annually. This is almost always coming from electrode innovation as opposed to electrolyte breakthroughs as well.

LISIC's presence within a cell also mitigates thermal runaway (i.e., fire risk), as the material effectively prevents short circuits from dendrite formation, manufacturing defects, or abuse and diminishes the volume of combustible material within a cell.

LISIC's benefits are not just limited to current-gen Li-ion, however. The material also enables manufacturers to implement next-gen anode materials like Li-metal. Li-metal has yet to see widespread commercial success due to its instability with current liquid systems, but has proven to be highly compatible with LISIC.

Natrion has demonstrated with its customers how LISIC-based Li-metal cells can deliver over 450 Wh/kg at ambient conditions—that's over 50% more energy density than Li-ion can manage today.

A further evolution of Li-metal is to add a sulfur cathode, which can further augment energy density to in excess of 500 Wh/kg. Sulfur has the added benefits of being transition metal-free and readily sourceable anywhere in the world. Lithium-sulfur cells are especially prone to cathode dissolution and related capacity degradation, though, and thus particularly benefit from LISIC's selective permeability.

How does Natrion's team expertise contribute to your success?

We have worked hard to build a rockstar team and our engineering staff today includes battery scientists and process engineers with experience from institutions like Bell Labs, Imperial College, Stanford, Tesla, GM, Corning, and Navitas. One way in which we set ourselves apart is in our computational and analytical capabilities.

We have a Material Informatics Engineer (MIE) role, for example, that is at the intersection between material science, data science, and computer science. All of our R&D and production approaches are highly data- and analytics-driven, so it's critical for us to be able to sift through data and make sense of it quickly. Our MIEs build intelligent cloud-based automated tools which rapidly and accurately synthesize mountains of data to empower our leadership to make frequent, well-informed determinations that advance our various workstreams.

Overall, how does Natrion differentiate itself in the solid-state battery market?

Simply put, our differentiation is the ease of implementation of our technology. As a business our aim is to make large numbers of LISIC rolls and sell these to downstream cell manufacturers. We have a pilot production line in operation today which has demonstrated that we can sell cell-quality, IRA-compliant LISIC to customers at price points that enable them to maintain cost parity (on a $/kWh basis) with their prior Li-ion cell products or even realize cost efficiencies. Moreover, an OEM which uses LISIC will not see an increase to their cell bill of materials.

In contrast, all alternative solid-state solutions, to our knowledge, require bottom-up redesigning and reconfiguration of battery assembly methods and cell architectures—these are not drop-in innovations like LISIC. Recent reports estimate that it would cost about $60 million in additional capital expenditure per GWh to convert current battery production assets to solid-state. This equates to $2.5 billion, on average, for each of the 38 planned or operational gigafactories in North America alone.

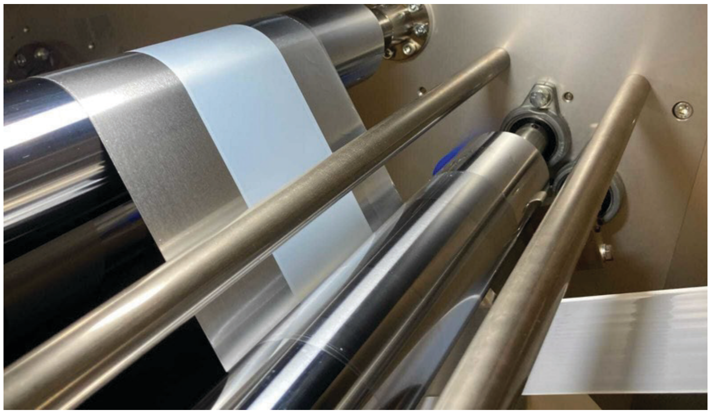
LISIC is unique in its ability to seamlessly integrate with current production lines and cell fabrication techniques. Whereas other solid-state tech would substantially enlarge production bills of materials, on top of the added capex, manufacturers implementing LISIC will realize efficiencies in their unit economics that will diminish their costs on a $/kWh basis with no added capex.

Can you share any notable projects or case studies that highlight the effectiveness of your technology?

Our U.S. Department of Defense contracts with the Air Force and Navy are in the public record. One of the things we've been working on is a new battery pack for military handheld radios which integrates LISIC-based Li-metal pouch cells. The specific unit which was the customer for the batteries happened to mostly operate in cold weather climates, facing temperatures as low as -40 °C/-40 °F. At such cold conditions, most Li-ion cells will be rendered inoperable as the liquid electrolyte inside of them would freeze. We are showing how LISIC-based Li-metal cells' performance can be much more resilient when faced with such challenging environments.

In another project for the US Air Force, we're heating LISIC-based Li-metal cells up to 60 °C/140 °F to extract more performance from them than is available at room temperature. Usually, these elevated temperatures would cause rapid degradation in conventional Li-ion cells. However, we're finding that in our Li-metal cells it instead unlocks faster charging speeds, allowing us to charge to 100% capacity in as little as 12-15 minutes.

This is potentially a game-changing capability for military operators who require a high level of mission readiness and operational endurance, as battery packs can be designed to incorporate heating elements to raise the temperature of LISIC-based cells for more optimal performance delivery.



Manufacturing of Natrion's LISIC separator technology for solid state batteries, which can be seamlessly integrated into production lines to solid-state cell fabrication with minimal equipment or process modifications while realizing increased energy density, superior cost efficiency, and enhanced thermal safety.

How do your facilities in Binghamton, NY, and Champaign, IL contribute to your development process?

Binghamton, NY is our HQ and production center while in Champaign, IL we have our R&D. Practically, what this means is that we make LISIC rolls in NY and in IL we prototype and test cells as well as iterate new LISIC variations. The University of Illinois is where I studied, and our offices in Champaign are located in the college's Research Park just south of campus. It is a wonderful community of startups, academics, and industry partners.

Our proximity to the university affords us an excellent talent source as well as access to on-campus facilities like the Frederick Seitz Materials Research Laboratory (MRL). For instance, we are able to rent time on key characterization instruments at MRL that would otherwise be cost-prohibitive for us to purchase ourselves.

At the center of our IL facilities is our semi-automated pouch cell fabrication line under inert argon gas atmosphere. This line allows us to make small batches of high-fidelity Li-ion and Li-metal cells for customers to evaluate.

In Binghamton we are part of the Koffman Southern Tier Incubator which is likewise a fantastic community of cleantech startups. We maintain close ties with Binghamton University and its leading battery research program led by Nobel Laureate Prof. M. Stanley Whittingham, as well as the college's Center for Advanced Microelectronics Manufacturing (CAMM) led by Professor Mark Poliks. Together with CAMM we have stood up a pilot line for making rolls of LISIC with a projected annual capacity of up to 55,000 square meters—enough for 24 MWh.

How has media exposure in prominent outlets like Forbes and TechCrunch impacted your company?

Our PR strategy has likely been more expansive and comprehensive than most others run by similarly positioned companies. This is another way in which we have tried to set ourselves apart.

Unfortunately, I think a few years ago the battery industry went through a period where there was simply too much media and press coverage of battery breakthroughs that ended up being exaggerated or straight up vaporware. Understandably, followers of the industry have become jaded and will not react to another announcement of someone finding the battery holy grail.

So, how does a small early-stage company that is gaining substantive traction for building something real earn name recognition among decision makers within the large OEMs that will ultimately be our customers?

We have found that substantive features in high quality media outlets attained through precise and intentional PR is highly effective. Cultivating these opportunities takes persistence and patience, but in the long run it is well worth it as we can get quality coverage that tells our story best. In fact, most of our customers today approached us first as opposed to us approaching them.

Can you share with us your future plans for product development and expansion?

Our hope is to close on some new financing between now and the first half of 2025 to build out what will be our first full-scale production capability. This new line will have nearly 20 times the annual capacity that our resource in Binghamton possesses today and will be capable of servicing almost 400 MWh per year of cell production volume.

How do you see the future of solid-state batteries, and what role do you think Natrion will play in shaping that future?

Like most other solid-state batteries, cells made with LISIC still contain some amount of liquid electrolyte within the porosity of the electrodes. This is because we are only swapping the separator layer with LISIC and are not introducing a solid material in lieu of liquid to transport Li ions inside of the electrodes.

Technically, then, LISIC-based batteries are just "solid-state," "semi-solid," or "quasi-solid" as opposed to "all-solid-state." From our perspective, however, we are improving cell safety and performance by introducing solid-state electrolyte material. At the most fundamental level, this is the core motivation for innovating solid-state batteries.

Critically, though, our solution remains deployable at giga-scales in existing factories. It is impossible to completely remove liquid from cells without compromising their manufacturability and requiring all-new expensive processes and equipment to make them. Simultaneously, removing liquid beyond what would be found in the separator comes with diminishing marginal return for safety and performance.

As the battery market continues to become more price-sensitive and realistic to the incredible challenges of making batteries in large quantities, I expect OEMs to become more and more convinced of the necessity to retain a small proportion of liquid within cells when making the solid-state transition. We will be ready with a turn-key solution available at low costs and high volumes for these manufacturers to integrate and take their battery product offerings into the next epoch of capability.

Contact us for more information on our chemicals for battery applications

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