ESJ ENERGY STORAGE JOURNAL

POWERING THE SMART GRID

Issue 24: Spring 2019

Innolith and the next generation electrolyte

Inorganic, innovative and lithium

A special reprint from Energy Storage Journal. Spring 2019

www.energystoragejournal.com

There are not many companies that are less than six months old but backed by a decade of technological know-how and intellectual property rights. Paul Crompton visited Innolith's German R&D centre in December. He came back impressed.

Intellectual property: the key to a next generation electrolyte

The R&D facility covers everything from base to core technology and where they manufacture, develop and test samples, or small scale cells

Launched in October last year, Innolith — the name comes from inorganic (In) innovative (no) and lithium (lith) — has the rights on 156 granted patents, with 39 global patent applications going back to 2004 being processed.

The moniker may sound heavy, but treads a path well worn in the energy storage industry for brand names that define a company's ideology, in this case of an R&D led materials product manufacturer. Markus Borck, Innolith's chief engineer and managing director, says: "We tried to summarize the business of what we are inventing."

Innolith is a Swiss battery technology company that aims to commercialize its inorganic, sulfur based, non-flammable electrolyte for lithium ion batteries. It is headquartered in Basel, but the company's laboratory is in Bruchsal, Germany — about an hour's drive south of Frankfurt and close to the French border.

"We want to do it with a combination of better technology; not by driving down the price but the cost."

The reason for its location is historical and comes from grid-scale storage firm Alevo, the company that filed for Chapter 11 bankruptcy in August 2017. Its $200 million of US battery manufacturing hardware was later sold to Imperium3 for $5 million.

Innolith meanwhile bought the intellectual property — including the IP for the inorganic electrolyte — held by firm's parent company Alevo Group in Switzerland, and its research and development facility in Bruchsal.

Innolith also owns Alevo's only operational battery plant — nicknamed Snook — located in the US and operating on the PJM Energy Market for over a year,

The link between the firms continues with the management of Innolith: its chairman Alan Greenshields was the former company's chief technology officer; its chief executive officer Sergey Buchin was its chief operating officer.

The chain of former employees continues with Borck, director of research Christian Pszolla, chief scientist Laurent Zinck and a handful more of its 60-plus employees; it is fair to say the DNA of Alevo runs through the heart of Innolith.

But lessons have been learnt from the demise of Alevo. Buchin says Innolith's business position is to make batteries that generate value. "It takes a huge amount of capital to deploy batteries, I don't see a need to deploy batteries before they are economically viable," he says.

Part of Alevo's failure was due to investing in a huge manufacturing operation in Charlotte before a regular pipeline of projects was in place (see boxed item).

"Batteries should generate value, pay back Capex and repay investors. So far the revenue model that allows that is the PJM market for frequency management."

Borck says the R&D facility covers everything from base to core technology and where they manufacture, develop and test samples, or small scale cells.

"We are capable of electro-chemical research of cell design and development and integrating them into modules," says Borck.

He is also a key link in Innolith's potential growth. Borck with Zinck, in 2009 invented the new cell technology based on an inorganic electrolyte for lithium batteries. Until that breakthrough researchers were unable to develop a rechargeable, inorganic battery that maintained a long cycle life.

Borck (pictured) with Zinck, in 2009 invented the new cell technology based on an inorganic electrolyte for lithium batteries. Until that breakthrough researchers were unable to develop a rechargeable, inorganic battery that maintained a long cycle life.

The class of electrolyte was first researched by the University of Hannover (Germany) and Duracell (US) during the 1970s and 1980s. But while Sony pioneered the flammable organic electrolyte — and the thermal runaway concerns that plight everything from e-cigarettes to electric cars to this day —Germany's University of Witten and the Fraunhofer Institute continued research into the inorganic variant in the following decades.

The technology was first used in commercial scale by Alevo, which obtained the patent for the technology in 2013, in its Gridbank energy storage system in Maryland, US. The system is still going, providing frequency management service on the PJM market.

For frequency regulation services aggregators want 10,000 cycles, the equivalent of around 10-12 times' use a day. Conventional lithium ion batteries will give you around 2,000 cycles, so it doesn't take long before they lose their functionality, says Borck. "By contrast an Innolith battery can take that kind of treatment over a 10-15 year period. If we made iPhone batteries, they would last 100 years."

To put that in a real-world context, the PJM signal corresponds to 3,500-4,500 full cycles for a 2C charge 2C discharge system; conventional lithium ion cells would need replacement after one year of operation (unless shallow-cycled to extend life).

"Our battery will have virtually no change in internal resistance after 50,000 cycles; residual energy is 50% and residual power is the same," says Buchin.

"If you took this energy throughput during cycling it would be 60GWh from a 1MW system. This will be by far the cheapest system; over 50,000 cycles it will be a third of the cost of traditional lithium ion batteries."

Real world testing

The technology is proving its worth in the 2MW/1MWh Maryland system, and has secured third party validation from independent laboratories, including Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW).

But what makes it a potential game changer for the stationary energy storage market?

Conventional lithium ion batteries use organic solvents. They contain solid electrolyte interphase insulating layers (created from reaction products during the degradation of the

organic electrolyte) on the negative electrode. While this is important in the functioning of the battery, they cannot be prevented from developing on the positive electrode or thickening the solid electrolyte interphase on the negative side.

This ages the battery as the increase in the internal resistance of the cell stops the system from meeting its required performance needs.

In the consumer world this means batteries need replacing every two to three years; in electric vehicles, this equates to a usable life of around 10 years, although there is a growing market using the batteries in second-life energy storage systems from grid-scale projects to powering water treatment facilities.

Unlike the 18650 cells used in laptops, high power applications require cells to be built using multiple tabs — this increases both the manufacturing complexity and number of potential failure modes, which results in around one in every million laptops developing a fault.

While reports of combusting consumer goods litter mainstream media the relatively small capacities do not pose a great threat. When you get to MW-plus scale the dangers are more pronounced: 1MWh has approximately the energy content of around a tonne of TNT.

The development of large batteries using conventional organic electrolytes must therefore consider that the probability of failure is higher and the consequences of failure more serious.

A number or firms have tried to develop larger prismatic cells for automotive and grid storage applications to combat this threat, but to date have failed to bring a product to commercialization. Tesla, for example, still uses more than 7,000 18650 cells in its 85KWh packs.

Innolith's cells using its inorganic materials are, by contrast, non-flammable, display high electrical conductivity and high thermal stability.

The conducting salt is made of lithium tetrachloroaluminate (LiAlCl4), while the inorganic solvent is sulfur dioxide (SO2). Combined they form a solvate (low viscosity liquid). However, the density of the electrolyte is higher (1.6–1.8 g/cm3) compared to organic variants (1.3g/cm3), as is the viscosity (4–16cP) compared to its rival (0.625cP).

PJM AND THE VALUE CHAIN: SNOOK

Innolith will continue to reap the benefits of the PJM Energy Market. PJM is a regional transmission organization that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia.

Buchin sees this market, which buys electricity to meet consumers' demands in real time (five minutes) and Day-Ahead Market (one day forward), as the most economic business model for battery storage to date.

The purchase and sale of electricity to resellers is done in the wholesale market, while the purchase and sale of electricity to consumers is done in the retail market.

The PJM market is proving to be one of the world's most economically feasible systems; so far 350MW-400MW of battery storage has been deployed.

In October 2017 when Alevo's first gridbank was tested by PJM's Compliance Department it received a 98.5% score, Alevo said at the time. Effectively this meant the battery was one of the first to be used on the network, allowing it to earn more money than less efficient competitors.

"PJM is by far the largest working market," says Buchin. "Most of the other markets are lagging behind. Look at Europe, there's no real market and India and China are working on their models. In the US there are two conflicting trends; there is the established cost of PJM, so California saw that and thought they would be able to do it via government subsidies. But PJM, for us, is the market demonstrating the best value a battery can bring.

"A battery is ideal because when ramping up and down you do not need to idle-run peakers. With frequency response applications it is feasible because our cost per cycle is the lowest.

Innolith also owns Alevo's only operational battery plant — nicknamed Snook — located in the US and operating on the PJM Energy Market for over a year

This allows Innolith's electrolyte to reach electrical conductivity of 60-100 Millisiemens cm-1 at room temperature, compared to conventional organic electrolytes that are around 10 Millisiemens cm-1.

Innolith says the electrolyte's high conductivity allows cells to be built with intrinsically higher power, when charging and discharging, and its relatively high thermal conductivity is helpful when designing cells and packs with optimized thermal performance.

The cells are designed for an operating temperature range of 20°-25°C, but the window is 10°C-40oC. That said, Borck and his team have tested the cells up to 350oC with no flash point, a huge jump from the 60oC flash point of conventional lithium ion electrolyte.

Innoliths' cells also use nickel foam current collectors rather than aluminium and copper foils. This is more expensive but the material is highly stable, and paradoxically the total cost of ownership is competitive because of the cell's longer cycle life and deep-discharge resistance.

Using nickel electrodes also allows the cells to be stored in a state of full discharge because there is no risk of damaging the electrode.

The cells are hermetically sealed in heavy stainless steel housing, making the company's first generation cells heavier than those using an organic electrolyte.

The housing is stainless steel because Innolith expects the batteries to last a long time, says Borck. "One way of not degrading the batteries is to have the seals of the casing airtight so it doesn't allow water and moisture into the cell, which is why we use laser welding."

When held, one's first thought is whether the cell's weight would hinder their use in consumer or mobile applications, but that will be of little concern in the stationary markets the company will target in the short term. The housing and long cycle life means the cells in the Maryland ESS have an estimated working life of more than 15 years.

The current system range is 70Wh/kg because the modules are relatively heavy. But Borck says they are developing the system further, with the company's researchers working on a cell with a higher energy density.

The cells have a capacity of 86Wh with a goal of expanding that to 90Wh-100Wh. "The final target is as high as possible, says Borck. "There are some internal boundaries in regard to energy, but we think we can develop cells with a lot of power.

"There are companies that can do 5C or 10C, but when you look closer it can only do 10c for 30 seconds. With ours you can use 2C (2C is around 60A and can be tested to 100A to accommodate customer requests)."

Take a trip into the unknown

The next part of the tour of was through the two main sections of the R&D department: innovation and testing.

The first section includes the development of new chemistries. Although the electrolyte is produced in Switzerland, work to develop the technology is undertaken in Bruchsal.

The researchers make around 20 batteries a day using pouch cells.

These are then tested over the year, with Innolith testing 1,500 batteries at any one time, with a single experiment taking months to go through, sometimes years and they have so far reached 55,000 cycles in the testing phase. "We try to make as much of the variants of the electrolyte as possible per test to get faster results, which leads the pathway to our R&D," says Pszolla.

Those 1,500 test channels generate lots of data, which allows the company to make decisions based on that the most up to date information. Buchin says he is proud of the laboratory

CHAPTER 11 AND ALEVO'S DEMISE

Energy storage system start-up Alevo USA and Alevo Manufacturing cited the challenges of bringing a new product to market and poor financial resources on its decision to file for Chapter 11 bankruptcy on August 18, 2017.

A Swiss headquartered company owned the two firms, which operated from Charlotte, North Carolina. Alevo completed its only commercial unit in Hagerstown, Maryland for frequency regulation in the PJM system.

A statement at the time of the Chapter 11 announcement stated that, through Bankruptcy Court supervision, Alevo USA and Alevo Manufacturing hoped to achieve an orderly liquidation of their assets and maximize value to pay their creditors.

At the time, Peter Heintzelman, chief financial officer of the Alevo group, said: "The chapter 11 filings are a very difficult, but necessary decision."

He said the decision was driven by the challenges of bringing a new technology into commercial production and lacking the financial wherewithal to continue through repeated manufacturing delays.

Alevo entered the US with a splash in 2014, investing more than $68 million in a 3.5 million-square-foot former tobacco factory outside Charlotte. It said it planned to recruit up to 2,500 workers over three years, with a potential maximum workforce of 6,000 capable of turning out thousands of megawatts of electricity storage products annually.

However, without a regular supply of projects only a small part of the facility was ever used or the workforce enabled.

With hindsight the attempt to move from small laboratory scale production in Germany to mass manufacturing was over-ambitious. The cost of the plant sent the US firm into Chapter 11 and led to the demise of the parent company in Switzerland.

Despite its ambitions, the company ultimately could not demonstrate the advantages of its ground-breaking battery technology, and Alevo Manufacturing had production challenges and insufficient revenue to continue operations.

With hindsight the attempt to move from small laboratory scale production in Germany to mass manufacturing was over-ambitious. The cost of the plant sent the US firm into Chapter 11 and led to the demise of the parent company in Switzerland.

and the team. "It's one of the best in Europe for developing batteries and applying theoretical knowledge to see how to put them into production."

One term that pops up in more and more announcements by firms is battery agnostic. A term used to show the company is open to all technologies — but in reality means it is only going to use, or is developing, a lithium ion battery or that as an aggregator its only concern is with supply.

"In this space, a huge amount of people want to be technology agnostic with virtual batteries, but very few people want to work on the hard stuff, such as bringing batteries to market," says Buchin.

"We want to offer the world the new battery platform and are beginning with the development of our inorganic electrolyte."

Another important factor in a company's success will be in managing the costs especially in manufacturing; the ghost of Alevo's production challenges haunts any discussion of subsidies.

Buchin says China is heavily subsidizing its battery manufacturing to disrupt the market similar to the way the country used in the PV markets.

"I'm often in China and Taiwan and talk to battery makers and they are not making money, although they will not admit it, even though the China government is giving them funding.

"It's a vicious circle where governments are pouring in money to subsidize batteries. We don't want subsidies or charity; instead we are building a business model based on viable economic models.

But that is not in the Innolith business plan. "We want to do it with a combination of better technology; not by driving down the price but the cost," says Buchin.

"In reality, talking in hard economics, batteries are not quite there. So what we want to achieve with the company is to start with a product for green applications and build our technology to become a global supplier."

The company's ambitions include becoming the top global supplier of batteries for grid stabilization storage in the next five years. Its ambitions also stretch to gaining more than a 20% market share; becoming a rapid technology innovator; licensing the technology; and having three cell-manufacturing partners in Asia, Europe, and North America.

In the coming years the firm aims to have 10 to 20 product partners throughout the world's major markets and 25 to 50 local sales partners.

The foundation on which this growth will be built is the Gridbank ESS in Maryland, which begun operations in 2017 when it was owned by Alevo.

On paper the electrolyte looks to be a game changer; allowing ESS developers to cycle more and for longer, which opens bigger and better revenue streams. It's safety credentials will also be welcomed in the consumer and mobility markets, if and when the weight issues can be addressed.

But the real key will be to see if the lessons learnt from the rise and demise of Alevo are put into day-to-day management of Innolith. ■

LONG TERM STORAGE, LIMITED POTENTIAL

In a world that is adopting renewables at a fast rate, the topic of long versus short-term storage is also one of whether network operators will be able to store that excess power. The goal of long-term storage is to provide higher stability to the grid because it allows a smoother integration of solar and wind generated power.

However, the question hanging over long-term storage is how to make the batteries — which are still expensive despite rapidly falling costs — economically viable if they are only cycled once per day, which in business terms means there's only one opportunity to make money each day.

"If talking about frequency management you can cycle 10 times per day so in terms of the market, right now, long-term storage is very limited," says Buchin.

"It's a vicious circle where governments are pouring in money to subsidize batteries. We don't want subsidies or charity; instead we are building a business model based on viable economic models"
— Sergey Buchin, CEO