Welcome to theion's Quarterly Newsletter

Welcome to our inaugural newsletter from theion, the game-changing battery company based in Berlin, Germany. We're excited to introduce you to our breakthrough sulfur-powered battery technology, which is poised to reshape the EV battery landscape across multiple e-mobility and stationary storage applications. This quarterly publication is crafted by our CSO and Co-founder, Marek Slavik, alongside the theion team, for partners, customers, investors, and all interested parties. We hope you find it insightful.

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Revolutionizing Energy Storage with Sulfur

As global demand for efficient, sustainable, and cost-effective energy storage soars, traditional lithium-ion batteries are proving insufficient. theion, a pioneering company, is set to revolutionize the battery industry with its innovative sulfur battery technology. By harnessing the unique properties of sulfur, theion is developing batteries that are not only three times more energy-dense but also environmentally friendly and economically viable at one third the cost of current state-of-the-art Lithium-Ion battery chemistries.

theion's batteries depart from conventional lithium-ion designs by using sulfur as the primary active material in the cathode. Unlike cobalt, nickel, and manganese used in traditional batteries, sulfur is abundant and inexpensive, offering multiple advantages:

- High Energy Density: Sulfur's theoretical capacity is 1672 mAh/g, far exceeding the theoretical capacity of NMC by factor 5 and LFP materials by factor 7. This translates to batteries that can store up to three times more energy for the same weight, making them ideal for electric aircraft and vehicles (EVs) as well as stationary energy storage. A gravimetric energy density of up to 1000 Wh/kg is the target.

- Cost-Effectiveness: Sulfur, being a waste material from industrial processes, is far less expensive than the materials used in traditional batteries. theion's technology significantly reduces the cost per kilowatt-hour, which is critical for the widespread adoption of renewable energy systems and electric mobility.

- Environmental Sustainability: Unlike cobalt and nickel, which have significant environmental and ethical concerns, sulfur is a byproduct of the oil and gas industry,

making its use in batteries a form of recycling. Additionally, sulfur batteries require significantly lower CO_2 emissions for production, contributing to a more sustainable lifecycle.

- Safety: Due to the electrochemical properties and the low hazardous level of sulfur compared to batteries with nickel for example, theion's sulfur batteries are designed to be safe.

theion's sulfur batteries are set to revolutionize multiple industries:

- Electric Aviation: With their lightweight and high-energy capabilities, theion's batteries are ideal for powering electric and hybrid aircraft, paving the way for greener air travel.

- Electric Vehicles: These batteries can extend the driving range and lower the cost of EVs, accelerating the adoption of electric mobility and reducing greenhouse gas emissions.

- Renewable Energy Storage: theion's batteries provide efficient, cost-effective solutions for large-scale energy storage, crucial for integrating solar and wind power into the grid.

- Portable Electronics: From power tools to smartphones, theion's high-energy batteries enhance the performance and longevity of portable devices, allowing for extended usage between charges.

theion is excited to lead the charge in this next generation of energy storage solutions. Stay tuned for more updates as we continue to innovate and redefine what's possible in the world of batteries.

Cutting Through the Hype

By Marek Slavik, theion's CSO and Co-founder

Our Lithium-sulfur (Li-S) batteries have been developed as a result of smart thinking and a drive move away from using traditional materials which are expensive and limit the energy density. This article aims to clarify the technical aspects of our proprietary technology and to help our partners, customers, and investors understand what makes theion's batteries different.

We're on the brink of a transformation in the battery industry, with new technologies like lithium-sulfur taking the lead and pushing the current technologies, such as NMC and LFP cells, into the past.

theion's lithium-sulfur batteries are a significant leap forward. While traditional lithium-ion batteries rely on transition metal-based cathodes that can only release one electron per molecule, our technology uses a monolithic monoclinic gamma allotrope sulfur cathode capable of releasing 16 electrons per molecule. This increase in electron release translates directly into a targeted higher energy density—up to 1000 Wh/kg—which is over three times higher than the best available lithium-ion cells today.

theion's innovative approach is rooted in a legacy of groundbreaking discoveries. Just over a century ago, in 1916, the Czochralski method for growing silicon crystals was invented near our headquarters in Berlin. Today, 95% of the world's silicon mono-crystals are still grown using this method. Continuing this tradition of innovation, theion has developed the Direct Crystal Implanting (DCi) method for growing poly-crystalline sulfur wafers, a process that

could define the future of electromobility, including electric aviation and space applications. Despite of talking about “crystalline wafer in our cathode” like in the semiconductor industry, our processes are much simpler and cost efficient.

theion's sulfur cathode technology is based on seeded Liquid Phase Epitaxy (LPE) growth of self-standing poly-crystalline sulfur wafers with desired thickness/porosity/shape, never previously achieved. The sulfur content exceeds 88% weight of the cathode for high power applications and above 92% for ultra-high applications. DCi direct crystal implanting uses different dielectric properties of sulfur. Seed carriers such as CNT carbon nanotubes or other seed carriers create an ordered artificial electron percolation network inside the already crystallized wafer-like pcS cathode using DEP dielectrophoresis principles.

The working principles of the state-of-the-art lithium-ion batteries and lithium-sulfur are fundamentally different in short: energy in existing li-ion cells as example NMC 811 is stored and released by changing the oxidation number such as Ni^{3+} charge to Ni^{4+} discharge to Ni^{3+} this means that energy in state-of-the-art Li-ion batteries is stored by de-lithiation of crystalline lattice structure of cathode and raising its oxidization number to Ni^{4+} where opposite in lithium sulfur energy is stored on charging S^{2-} to zero-valent S^0 which is ground state of material and S^0 to S^{2-} discharging.

Energy is stored in the ground state of the material meaning that sulfur is the one of the safest materials for the energy storage reactions.

While sulfur batteries offer numerous advantages, they also present unique challenges. One major issue is the polysulfide shuttle effect, where intermediate compounds formed during charging and discharging migrate to the anode, causing capacity loss and reduced battery life. theion addresses this by arresting sulfur in its monoclinic crystalline form and applying a conductive coating that cross-links with the sulfur, creating a stable, glass-crystalline allotropic transition layer that prevents degradation.

Another challenge is the volumetric expansion of sulfur during the redox conversion process. Sulfur expands by 79% during this process, so that internal porosity of the cathode must provide partial buffering volume for the expansion and shrinkage to take place, but at the cost of increasing its porosity which is filled with electrolyte and key factor defined as E/S electrolyte to sulfur ration in ml/g.

Electrolyte is the non-redox active material within the li-ion battery where it moves charge carriers back and forth between the electrodes, so its weight and volume content must to be minimized yet sufficient to cell to operate and this is usually reached with E/S of ≥5 ml/g. theion invented a process where poly-crystalline sulfur wafer is pre-expanded to the state where its density is approximately equal to the density of Li_2S 1.66 g/cm3 so that the electrolyte’s accessible porosity is within 20% which is one of the most sensitive pieces of information for the lithium-sulfur battery company to provide.
The volumetric fluctuation of the sulfur cathode goes hand in hand with structural defragmentation and fusing of high redox active surface nano-sulfur into low surface hard redox accessible macro-sulfur globules and our “fish-scale” glass/crystalline layer block the nano-to-macro fusing process, ensuring the structural integrity is preserved and performance of the battery over many cycles.

Applications

theion’s sulfur batteries have the potential to transform multiple industries. In electric aviation, their lightweight and high-energy capabilities make them ideal for powering electric and hybrid aircraft, paving the way for greener air travel. On the ground, these batteries

could extend the driving range of electric vehicles while lowering costs, accelerating the adoption of electric mobility and reducing reliance on fossil fuels.

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