Blended Electrolyte for Li-Ion Cell R&D and Production

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Abstract

The domestic supply base for liquid blended electrolytes for Li-Ion cell development, and low to medium volume production is currently limited to few options. Current production of Li-Ion cells for U.S. Department of Defense (DoD) applications often relies on electrolyte provided by U.S. foreign entities of concern. To address this market gap, and outstanding DoD production risk, Koura is scaling up a low and medium volume electrolyte facility in Madison, WI. This facility will supply highly flexible and cost-effective domestically blended electrolytes for Li-Ion cell development and production, especially for DoD batteries. The facility will aim to source upstream raw material supply from both domestic sources and free-trade countries.

Keywords

Electrolyte; lithium-ion R&D; blended electrolyte; domestic electrolyte; solvents; salt; additives; electrolyte formulation; electrolyte production; carbonates; electrolyte bottles; electrolyte kegs; $LiPF_6$; lithium hexafluorophosphate.

Introduction

Electrolytes enable Li-ion technology. All traditional Li-Ion cells require an electrolyte to facilitate ion transfer between electrodes (Figure 1) and liquid electrolytes serve that function today in nearly all commercial Li-ion cells. Electrolytes also stabilize the active materials and enable long life cell performance. The electrolyte formulation depends on the active materials and the application requirements (e.g., temperature, life, etc.).

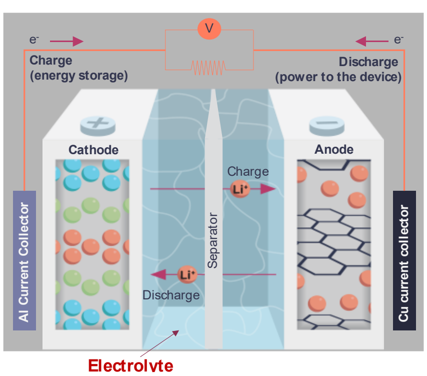

Figure 1: Schematic of a Li-ion cell showing the key components. The electrolyte not only enables transfer of lithium ions between the anode and cathode, but also plays a critical role in stabilizing the active materials and hence dictating cell life.

The composition of the electrolyte is often specified by the battery producer, and blended-to-order by the electrolyte supplier. Electrolytes typically consist of solvents, salts, and additives, carefully blended to a specific formulation, for example: 1.1M $LiPF_6$ in EC:EMC 3:7 vol/vol +1% VC +5% FEC by weight. Electrolyte composition can vary significantly across various target applications, including use of several different co-solvents, cathode and anode film forming additives, and co-salts. This is especially true for Li-ion cells used in DoD applications given the extreme operating conditions often demanded in military missions.

Traditionally, electrolytes for DoD cells produced in the US were supplied by a few non-US electrolyte blenders. However, these suppliers are increasingly focused on the much larger electric vehicle (EV) market forcing domestic Li-ion cell producers serving DoD applications to desperately search for alternate sources. A similar challenge awaits producers of non-EV Li-ion batteries in the US.

Recognizing this business opportunity, Koura has established a blended electrolyte operation (Figure 2) in Wisconsin with the aim of serving the non-EV applications. Our initial customers are Li-ion battery producers for DoD applications. In due course of time, we will expand to serve other non-EV battery applications as well.

Figure 2: Core value propositions for the electrolyte blending operation.

Electrolyte Market Overview

Global Blended Electrolyte Market: Today, most of the blended electrolyte production and consumption occurs in Southeast Asia, logically located close to where most of the Li-ion cell production occurs. As of 2022, the global market for blended electrolytes was approximately 1.1 billion metric tons, generating ~$19 billion U.S. dollars [1]. This market is expected to continue growing at relatively the same rate as baseline Li-Ion cell production.

Domestic Blended Electrolyte Demand: The demand for blended electrolytes in the U.S. is currently developing in line with the continued announcements of new domestic Li-Ion cell production facilities. While many of these announcements for production capacities are for giga-scale EV battery production, there are several existing and announced production sites that will focus on non-EV applications (see Figure 3).

The existing and announced non-automotive capacity in the United States alone totals ~10GWh per year. Applying the conservative estimate that 700MT of blended electrolyte is required per 1GWh of cell production equates to non-automotive domestic blended electrolyte requirement of approximately 7,000 MT per year.

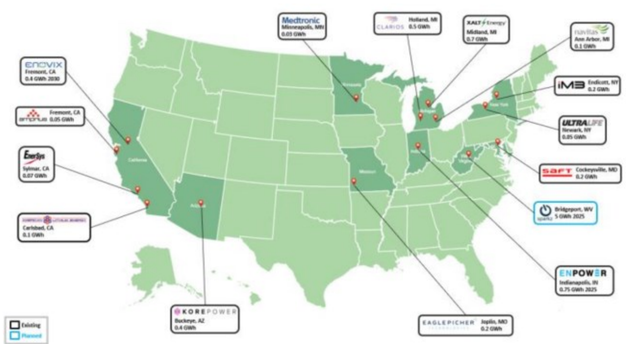

Figure 3: Data from Avicenne Energy shows existing and announced non-automotive domestic cell manufacturing capacity totaling ~10GWh / year.

Domestic Blended Electrolyte Supply Challenges

Existing blended electrolyte suppliers from Korea and Japan have announced plans for significant capacity installation within The United States; however, these facilities are primarily being scoped to support high volume EV battery demands and are not expected to be equipped to service the market demands from cell manufacturers for DoD and industrial applications:

- Automotive manufacturing scale requires supporting high-volume, low mix blended electrolytes and can be delivered to cell manufacturing facilities via rail car.
- DoD and industrial batteries require more varied electrolyte formulations at much lower volumes. For these applications material is to be delivered in bottles, kegs, or IBC totes at the high-end. This low volume market is where the largest supply gap exists domestically.

Koura will maintain inventory of all common commodity electrolyte materials including carbonate co-solvents (EC, PC, FEC, EMC, DEC, DMC, etc.), Ester co-solvents (EP, PP, MA, etc), Lithium salts ($LiPF_6$, LiTFSI, LiFSI, LiBOB, LiDFOB, $LiPO_2F_2$, etc.), and additives (VC, VEC, PS, DTD, AN, SN, HTCN, EGPN, OS3® etc.). This list is not all inclusive and additional electrolyte materials can be sourced as needed for specific customers.

New Domestic Electrolyte Blending Facility

To address the current domestic supply gap, Koura | Silatronix will scale up a new electrolyte blending facility, specifically designed to meet the needs of the non-automotive cell manufacturer volumes. The facility will be centrally located in Madison, WI. Initial production of blended electrolyte has already started, leveraging expertise, capabilities, and facilities at Silatronix (built over a decade of commercializing organosilane electrolyte additives) [3].

Current production assets can support bottle and keg scale, with a production line with larger batch size capability scheduled to come online in late 2023. The production line is being designed to support low-volume and high-mix requirements based on the wide range of specific cell design requirements. The production facility will incorporate new semi-automation techniques designed to reduce labor content and improve end-product quality.

Voice of Customer Feedback

Market Survey Input: Prior to launching the initial phase of the Koura | Silatronix blended electrolyte business, an extensive 'voice of customer' survey was conducted surveying domestic producers of low and medium volume Li-Ion cells, including cells for DoD applications. Feedback noted that lead-times for custom blended electrolytes were highly variable but generally longer than desired. Prices had been increasing, and some suppliers had exited the business entirely. Customers also noted that even though blending could be done domestically, the upstream production of solvents, salt, and additives was and still is dominated by supply from foreign entities of concern.

Voice of Customer Actions: Based on the results of the voice of customer survey, the core value proposition of this new blending facility will be modeled around maintaining four key aspects (Figure 2).

Consistent 4-week or less Lead-time: Customer feedback supported strong desire for lead-time of four weeks or better. This requires stocking a broad range of individual components and designing operations to support blending of materials, performing quality checks, and shipping on a rapid schedule. A key driver in the desire for shorter lead-times is that blended liquid electrolytes, in most cases, have limited shelf-life. Liquid electrolyte that has degraded in quality or picked up moisture can significantly compromise the performance and quality of the Li-Ion cell it is used in.

Domestic Sourcing: While establishing blending operations domestically is an important first step towards building a domestic supply chain, it will be equally important to have the ability to qualify and use domestic raw material supply or at a minimum supply from free trade countries. The current operation is focused on building a raw material supply chain that is both lowest-cost and domestic focused.

A critical component of the electrolyte is the $LiPF_6$ salt, of which 90% of the world's $LiPF_6$ is produced in China today. With support from the US Department of Energy under the Bipartisan Infrastructure Law funding, Koura is establishing the first $LiPF_6$ plant outside of Asia at out industrial complex in St. Gabriel, Louisiana [4]. This plant is expected to be operational in late 2025.

The Wisconsin electrolyte blending facility will use domestically produced $LiPF_6$ from Koura's facility in St. Gabriel, LA when that facility becomes operational.

Competitive Pricing: Competitive pricing will be achieved in several ways. Raw material cost considerations are a significant factor, and optimizing the upstream supply chain is a critical consideration. Operationally, blending production lines are being designed to align to specific batch size targets. Additionally, multiple lines are used in parallel to allow for constant workflow in between line cleaning and formulation changeover. Lines will also be designed to allow for semi-automation of the process, which historically has been quite manual, specifically for low and medium volume production.

High Purity Material: Electrolytes require low water content, low contaminants, and correct blending ratios. We are establishing a quality control process to ensure all these metrics are met with consistency as well as adding special measurement equipment to provide regular quality control monitoring.

Package Size Options and Timing

Blended Electrolyte Packaging: Customer packaging requirements for blended electrolyte fall into four main categories: bottle, keg, drum, and rail. These various package sizes support the progressive stages of a Li-Ion cell from development into production.

Figure 4: Example of blended electrolyte 1L container.

Figure 5 Example of blended electrolyte 16L container.

Bottle Service: Bottles of electrolyte are typically used in the research and development phase of battery cell development (see Figure 44 above). They are also sometimes used for low-volume production. During the development of a Li-Ion cell, several different electrolyte formulations will be tested to optimize cell performance. Small bottles in the 100mL – 1L size range help to facilitate evaluation of several formulations. Koura | Silatronix is currently supporting several customers with bottle service now.

Keg Service: Kegs, approximately 16L in size, are used to facilitate low and medium volume production requirements (see Figure 5 above). These kegs contain up to 20kg of blended electrolyte material and feature quick-connect couplers to facilitate quick and easy interchange of kegs and production plumbing lines. Koura | Silatronix is currently supporting several customers with keg service now.

200L Drums: Between kegs and full-size ISO or intermodal containers, 200L drums will be available starting later this year in conjunction with the installation of a higher-capacity blending line.

ISO Containers: Longer term, planning is underway to support 20,000kg ISO containers as part of a second phase scale-up in 2024. This would potentially enable rail-shipment of large volumes of blended electrolyte.

Material Quality

Quality Control: Quality control of blended liquid electrolytes starts by ensuring that both the input raw materials as well as final product are dry and pure, and blended accurately to customer specifications.

For incoming raw materials, certificates of analysis are reviewed and verified for KF moisture (which must be < 20ppm), purity (GC, HPLC, IC, NMR, ICP), and acid content. Finished goods blended electrolyte are tested for moisture (KF), acid content (titration), and composition by High Performance Liquid Chromatography. Density and weights are all verified as well. The Koura | Silatronix Madison Technology Center has dedicated equipment installed for electrolyte blending QC, including Karl Fischer titrator, Color comparator, Acid Titrator, HPLC, GC-FID/TCD, and GC-MS.

To support a robust quality assurance process, all blended batches produce a hold-back sample, which is kept in storage for a minimum of six-months. In the event a customer reports a potential quality issue, a sample provided by the customer can be returned to the quality assurance lab to be analyzed against the hold-back sample. This process supports identification and validation of any potential quality issues with blended materials.

Shelf-Life and Logistics Considerations

Shelf-Life Considerations: Blended electrolytes have a limited shelf-life. The specific shelf life for various formulations can vary significantly based on the specific materials used.

The physical location of the Koura | Silatronix facility helps to optimize the supply chain and logistics considerations for domestic cell production. By being centrally positioned in the United States, materials from the Madison, WI facility can reach to both coasts of the country in a matter of days vs. imported materials having to travel by sea freight or high-cost air freight.

Transport Considerations: Material being imported by air will be subject to a significant shipping cost penalty. Material being transported by sea freight avoids that cost penalty but incurs a much longer transit time ranging from 6-12 weeks depending on the destination. That additional lead-time puts pressure on cell manufacturers to consume the delivered materials faster as the shelf-life clock has already started counting down on the blended materials.

Potential Improvements: While supporting shorter transit times for materials is key to cell manufacturing operations, we are also keen to drive improvements in the shelf-life of blended electrolytes to provide greater flexibility for customers. One area of current investigation underway at Koura | Silatronix is the application of Silatronix organosilicon electrolyte materials to improve shelf-life stability of blended liquid electrolytes.

Summary

The electrolyte blending being scaled up by Koura | Silatronix in Wisconsin will enable domestic Li-ion cell suppliers to support DoD applications without disruption. The facility is currently supplying up to 20kg drums of electrolytes blended to DoD cell suppliers' specifications. Ongoing expansions will enable production of 200 kg drums of blended electrolytes towards the end of 2023. By the end of 2024, the planned facility expansions will enable the production of ton-size batches of blended electrolytes.

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