WHITE PAPER

TRANSFORMING THE PRODUCTION OF HIGH PURITY LITHIUM CARBONATE

WHAT THE PHARMACEUTICAL INDUSTRY CAN TEACH US ABOUT PROCESSING MINERALS

Telescope Innovation's expertise in developing scalable manufacturing processes for the pharmaceutical industry reshapes how battery-grade lithium carbonate can be produced from lithium brines. Our method simplifies lithium processing flow sheets, increases the tolerance for feed variability, and reduces reagent usage to improve cost efficiency.

This white paper provides a technical overview of our precision crystallization approach, as well as the incorporation of process analytics and automation technologies that ensure battery-grade product, regardless of the feed. Our process is tailored for variable and low quality crude materials. We are eager to expand the use of our technology with new partnerships, and offer to demonstrate our **Recrystallization Refinement Technology (ReCRFT™)** on your lithium brine concentrates for free!

Figure 1. To explore new partnerships, Telescope Innovations provides laboratory demonstrations of its ReCRFT™ system on new lithium brines.

INTRODUCTION

Demand for lithium to use in batteries is anticipated to grow 3-fold by 2030 (CAGR 25-30%).[1] Consequently, mining and refining efforts are focused on building a robust, local supply chain of high purity lithium carbonate (Li_2CO_3) and hydroxide (LiOH).

Lithium is hard-rock mined or extracted from brine. The amount of lithium salt that could potentially be extracted from all sources actually far exceeds even projected demand. Rarity is not the issue – rather, separating dilute lithium from the complex brine matrix is the challenge. For every lithium atom in a brine, there are between 100-1000 atoms of impurity. Energy, reagent, and time-efficient separation methods are needed to access this critical metal, in purities exceeding 99.5% for battery production.

We bring pharmaceutical-grade crystallization technologies to the mining industry, enabling low-cost production of battery-grade lithium carbonate.

To meet this need, Telescope Innovations has pioneered **Recrystallization Refinement Technology (ReCRFT™)**, a purification process that enables the production of high purity lithium carbonate from geographically diverse, low grade brine concentrates. This patent pending approach (US Provisional 63/606,069) is inspired by advanced crystallization methods used in the pharmaceutical industry to purify therapeutics.

INSPIRATION FROM THE PHARMACEUTICAL INDUSTRY

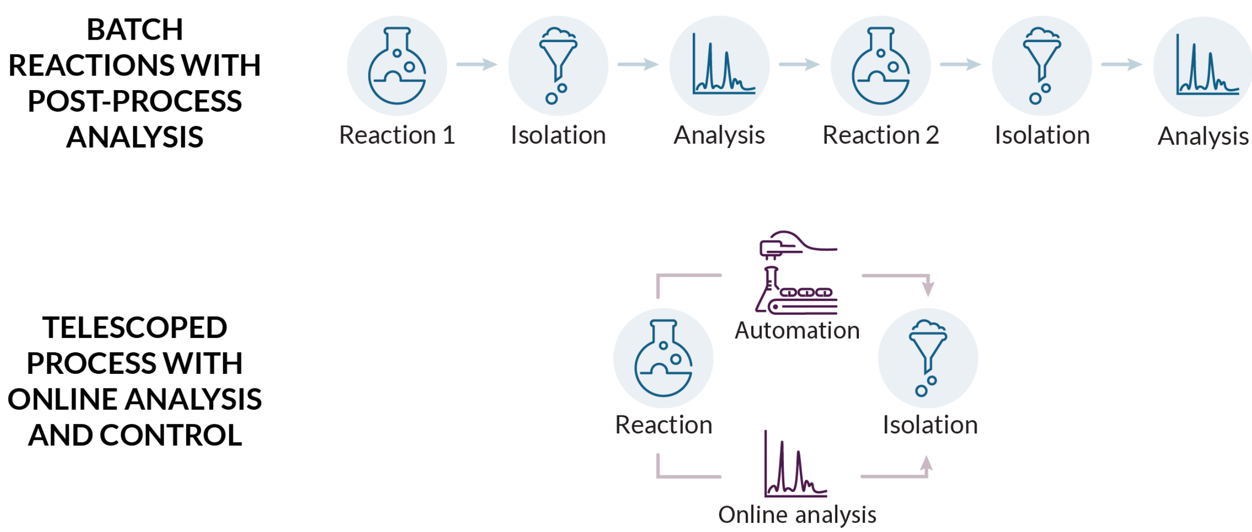

Figure 2. The pharmaceutical industry leverages automation, machine learning tools, and real-time, on-line analytic technology to optimize and "telescope" processes into fewer steps.

[1] Fleischmann, J.; Hanicke, M.; Horetsky, E.; Ibrahim, D.; Jautelat, S.; Linder, M.; Schaufuss, P.; Torscht, L.; van de Rijt, A. Battery 2030: Resilient, Sustainable, and Circular. McKinsey & Company 2023, 2–18.

The pharmaceutical industry has undergone a major revolution in how it produces high quality medicinal compounds. Traditional production methods are sequential: each synthetic step is followed by a post-process analytical measurement. This approach is rapidly transitioning to continuous processing with real-time analysis of the reaction. These continuous processes can be "telescoped" into fewer steps.

A key step in producing high purity drugs is removing impurities, and this is often accomplished at lab scale using various forms of process chromatography. Chromatography, though effective, is slow, uses large quantities of solvent and is inconsistent with efficient, telescoped processing. Instead, the industry has implemented advanced crystallization methods as a means of purifying drug compounds. Particularly when combined with real-time analytical measurements, crystallization processes can be precisely controlled to isolate high purity products from impure, multicomponent mixtures.

The requirements for pharmaceuticals and battery raw materials are similar — high purity products must be produced at large scale with batch-to-batch consistency. In both cases, crystallization for purification is an effective means to achieve these goals.

> *In partnership with major pharmaceutical companies, Telescope Innovations has pioneered the development of advanced crystallization processes for purifying therapeutic compounds. We have now applied these principles to produce battery-grade lithium carbonate from brine.*

AUTOMATED, CONTINUOUS CRYSTALLIZATION IS A BREAKTHROUGH IN Li_2CO_3 PRODUCTION

High purity Li_2CO_3 is produced via a multi-step process requiring: i) Direct Lithium Extraction (DLE) (for brine), or leaching (for hard rock), ii) feed polishing and concentration, iii) carbonation, and iv) crystallization. Each of these steps is responsible for roughly 10-15% of plant CapEx, while feed polishing alone accounts for 20-50% of total reagent costs. Telescope Innovations' ReCRFT™ process consolidates the polishing and carbonation steps into a single unit operation (Figure 3). We reduce plant CapEx and OpEx by simplifying the lithium purification flow sheet, and yield 99.5%+ purity Li_2CO_3 through fully automated, continuous recrystallization.

Our lithium ReCRFT™ process reduces cost by substantially reducing (or even eliminating) brine polishing, even for feedstocks with high impurity concentrations. Battery grade Li_2CO_3 is produced from low quality (20-90%) Li_2CO_3, while fewer reagents are required, and plant design is simplified by "telescoping" the flow sheet into fewer steps.

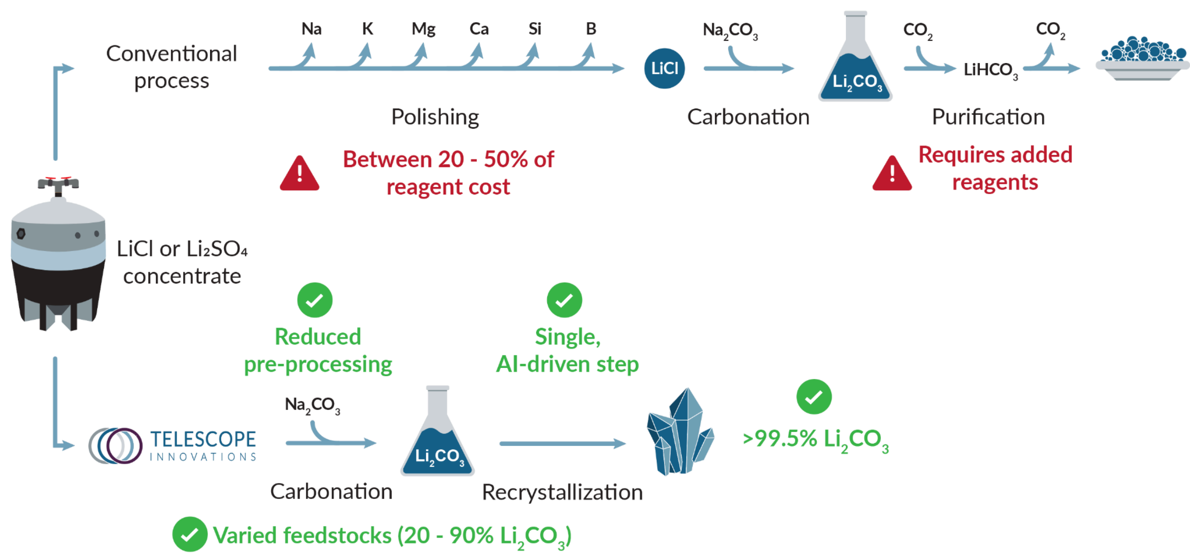

Figure 3. Telescope's ReCRFT process for lithium carbonate production is more cost- and reagent-efficient than conventional production of Li_2CO_3 from brines.

ReCRFT™ replaces the conventional bicarbonate loop, used to purify lithium carbonate, with a temperature-driven recrystallization. In the carbonation step, solid Na_2CO_3 is added to the Li-rich brine, forming a slurry of crude Li_2CO_3 solids and aqueous NaCl. Our process takes advantage of the unusual, inverse solubility of Li_2CO_3: at higher temperatures, Li_2CO_3 is actually less soluble, while impurity salts like NaCl dissolve more readily (Figure 4, right). The slurry from the softening step, which may vary in Li_2CO_3 concentration (20-90%), is transferred to a dissolver vessel that is held at a constant, relatively low temperature to dissolve the crude Li_2CO_3 (Figure 4, Step 1). After filtration, the solution is passed to a crystallizer vessel held at a higher temperature (Step 2), which encourages crystallization of Li_2CO_3. Here, the Li_2CO_3 forms needle-like crystals ~1 mm in length, (Step 3) which are harvested by filtration and are of >99.5% purity. In our continuous crystallization process, the lithium-depleted solution is recirculated back to the dissolver vessel (Step 4). This dual-reactor recirculation method mitigates the trade-off between Li_2CO_3 purity and yield, a characteristic of single reactor crystallization processes.

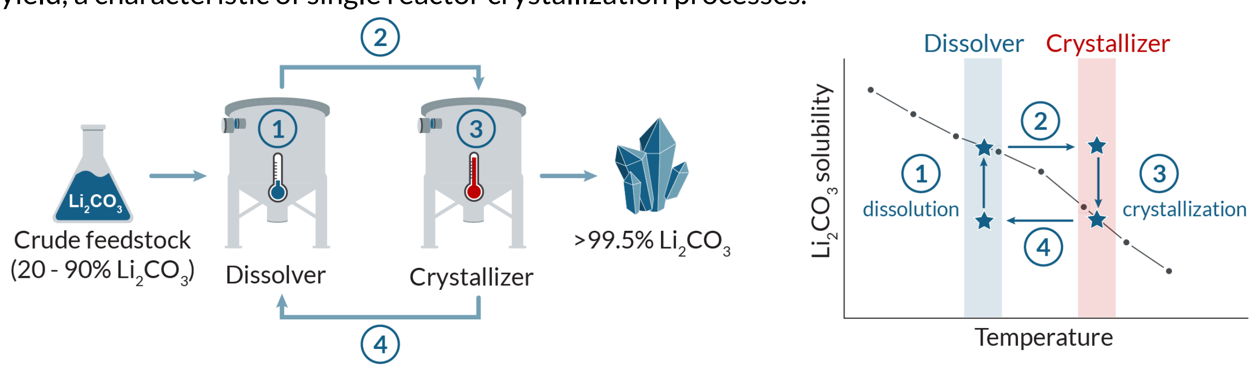

Figure 4. ReCRFT™ relies on a two-vessel system with finely tuned control of Li_2CO_3 solubility. In the low-temperature dissolver vessel, Li_2CO_3 dissolves while impurity salts remain solid (Step 1). Supersaturated Li_2CO_3 solution is transferred to a warmer crystallizer vessel (Step 2), where batter-quality product crystallizes and can be harvested (Step 3). Solution is recirculated to the dissolver vessel in a continuous process (Step 4).

AI-GUIDANCE AND PROCESS ANALYTICAL FEEDBACK

We leveraged artificial intelligence (AI) to optimize the ReCRFT™ process 40 times faster than with traditional optimization approaches. Feedback from the AI-model is used to adjust crystallization conditions based on the composition of the feed. This approach ensures that the narrow operating window required to produce battery-grade lithium carbonate is maintained for a wide variety of input feeds.

There are 12 crystallizer variables that influence the purity of lithium carbonate. Traditional process optimization would follow a Design of Experiments (DOE) approach, wherein each variable is independently adjusted. A conventional DOE matrix for a 12-variable system would require at least 4096 discrete experiments to draw relationships between each input and output variable. With the use of an AI-model, we achieved a similar level of understanding in fewer than 100 trials, with a Gaussian Process Regression model determining correlations between operating conditions and final product purity.

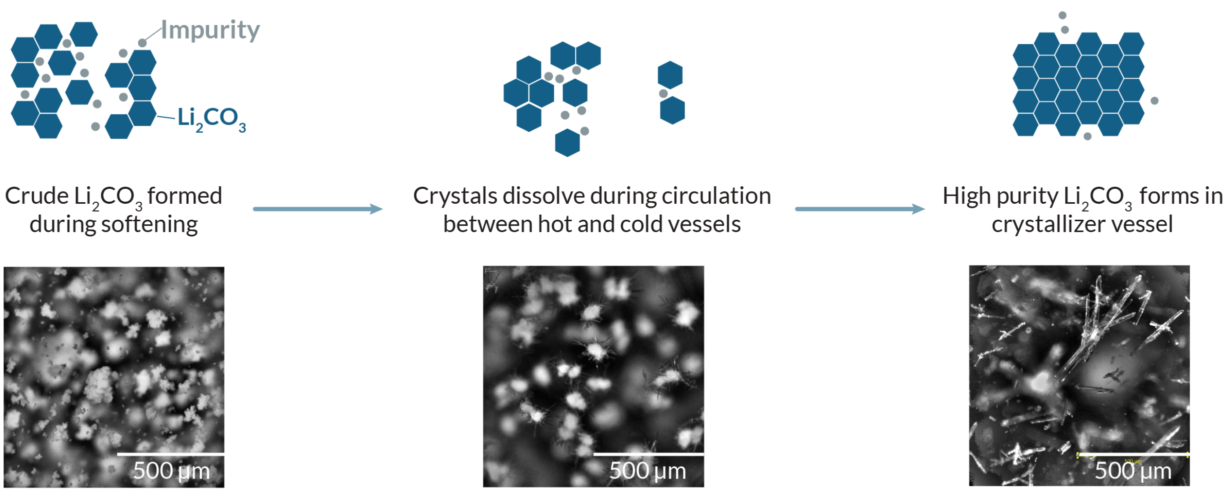

Figure 5. In situ microscopic imaging tracks particle formation to provide real-time feedback on the ReCRFT™ process.

Feedback from real-time sensors including flow meters, thermocouples and analysis devices such as online microscopes (Figure 5), and online ion chromatography is passed to the model to control the process for AI-assisted optimization.

SEND US YOUR BRINE

For a limited time, we are offering to process a brine sample sent to us for **FREE** as a demonstration of our continuous crystallization technology. With a low risk and rapid turnaround, we aim to demonstrate the effectiveness of ReCRFT™ on your brine feedstock. Email info@telescopeinn.com for details.

High purity lithium carbonate: Your brine, our solution.

TELESCOPE INNOVATIONS