Filters for Lithium Ion Battery Cell Manufacturing

Filtration and classification technology for improving battery quality and reducing cost

APPLICATION PAPER

PILITHCELLEN

Introduction

The transportation landscape is undergoing a revolution with the rise of Electric Vehicles (EVs) powered by Lithium-Ion battery technology. Over the next few years, EV sales are expected to experience significant growth, ramping up from 10.5 million vehicles in 2022 to nearly 27 million vehicles by 2026* equating to the EV market share of new passenger vehicle sales increasing from 14% in 2022 to 30% in 2026*.

As the demand for EVs continues to rise, there is a corresponding increase in the demand for lithium batteries. With the annual lithium battery demand projected to reach approximately 5.7TWh* by 2035, it will be necessary to scale up materials, components, and cell production, which is both challenging but feasible.

One of the key considerations in the EV market is the quality and cost of batteries. Compared to small devices, batteries for electric cars need to meet much higher standards for performance and safety. This is where Pall's filtration products come into play. They play a crucial role in improving the manufacturing process of lithium-ion batteries, ultimately helping to reduce operating costs.

*(*BloombergNEF's Economic Transition Scenario, 2023)*

Placement and benefits of Pall filters in Li ion battery cell manufacturing processes

A lithium ion battery is primarily comprised of electrodes (cathode and anode), separators and an electrolyte solution. The manufacturing process, which is outlined in Figure 1, involves forming the electrodes, stacking the cells, adding the electrolyte solution, charging the battery, aging and final inspection. Pall filtration recommendations are indicated in this schematic. Filtration has been found to significantly improve battery quality and performance. Proper filter selection is required to remove particulate contaminants and gels from solvents, water and the high viscosity slurries used in forming the electrodes.

Filters are also needed to remove particle contamination during the electrolyte filling process. Since the presence of water is detrimental to the electrolyte solution, it is recommended that the carrier gas be passed through a Pall purifier to reduce moisture levels to <1 ppb.

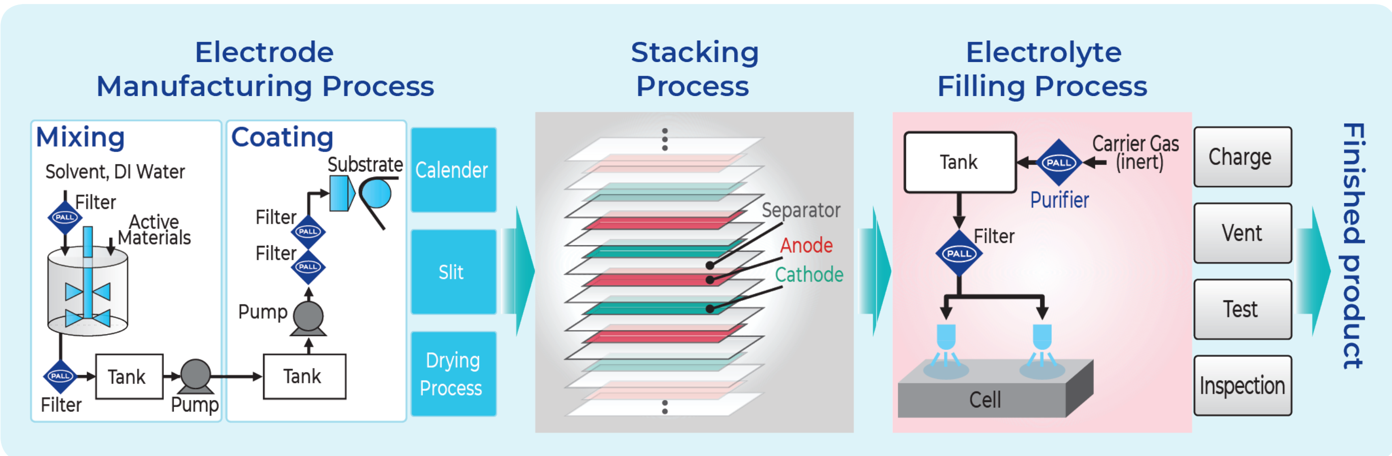

Figure 1: Li ion battery manufacturing process showing the recommended placement of Pall filters

Filtration in the electrode manufacturing process

As indicated in Figure 1, there are two basic steps involved in the formation of the electrodes: mixing of the slurry ingredients and coating of the slurry onto the substrate. Filtration can greatly improve these operations.

Removal of metal ions from solvents and DI water

The active materials used to make the cathode and anode electrodes are different, but each is suspended in solvents or water containing binder powder. Solvents and water are typically transported from facilities through metal piping. The pipes may release particles and metal ions that can contaminate these liquids and affect battery quality.

Figure 2: *IonKleen purifiers*

These ions can be effectively captured by membrane purifiers. The Pall IonKleen™ membrane purifier consists of a micro-porous, ultrahigh-molecular-weight polyethylene substrate with covalently bonded, strong acid cation exchange groups. Configured as a standard cartridge or capsule (see Figure 2), the IonKleen purifier has a very large effective surface area but a small footprint, enabling it to be placed right at or close to the point-of-use.

Pall IonKleen purifiers are highly efficient because they do not rely on slow diffusion into a resin bead to achieve ionic adsorption. Rather, due to the intimate contact of the solvent or water with the densely packed ion exchange groups on the membrane, rapid kinetics occur with immediate and spontaneous removal of the trace contaminants. Trace ppb levels of cations can be reduced to ppt levels. This is schematically depicted in Figure 3.

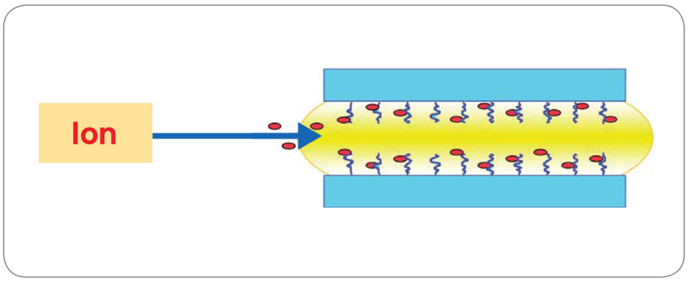

Figure 3: *Schematic of a cross section of a pore in an IonKleen purifier membrane*

Reduction of gels and particle contamination in electrode slurries

During the manufacturing of electrode slurries, filtration is highly recommended at the following points in the process:

- During the mixing of the slurry components to remove extraneous particles and undissolved gels
- Immediately before die coating the slurry onto the electrode substrate

In the latter step, filtration is required to remove aggregated slurry particles and reformed gelatinous material to protect the narrow space between coater and substrate. Filtration can also remove oversized particles, creating a narrow slurry size distribution. This results in a more even coating, as illustrated in Figure 4.

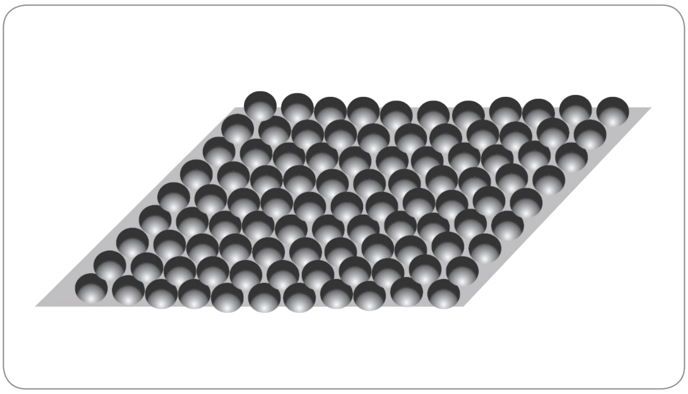

Figure 4: *Schematic of an ideally coated electrode*

Filtration of slurries is not as straightforward as simply removing a small number of particles from a solution. When filtering slurries, filter selection is critical. The filter must allow the desired particles to pass through, while simultaneously retaining oversized particles. This must be accomplished without plugging the filter and consequently shortening its service life. Pall's Profile® II depth filters, shown in Figure 5, are ideal for this type of application.

Figure 5: *Profile II filters*

Filtration of high pressure and high viscosity liquids

Electrode slurry characteristics and viscosities vary greatly and are specific to each Li ion battery manufacturer. Viscosities of some cathode slurries may be greater than 10 Pa.s (10,000 cP), making the use of Profile II depth filters impractical because of the resulting very high pressure drop or, conversely, low flow rate.

Pall's Rigimesh® filters, shown in Figure 6, can easily handle these high viscosity slurries. The pleated, metal mesh cartridges can filter about 10 times the volume of an equivalently rated, depth-style, cylindrical filter. Because of their relatively high surface area, Rigimesh elements typically have a much longer service life compared to traditional strainers.

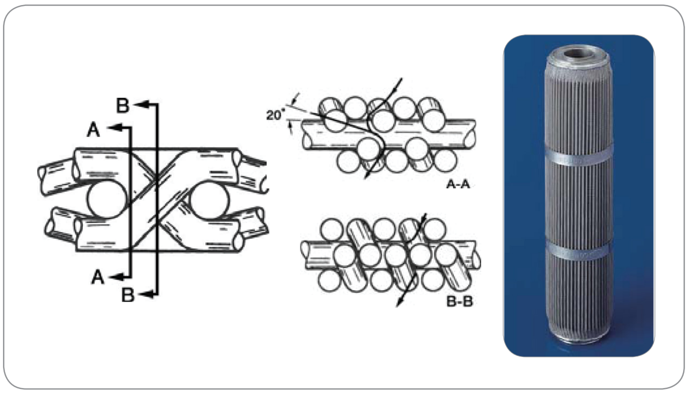

Figure 6: Rigimesh filter element

Particle Classification with Profile II Filters

The Profile II cartridge is an absolute rated depth filter. This all-polypropylene filter has a continuously graded pore structure for built-in prefiltration and long service life. Figure 7 is a composite SEM photo of a cross section of this filter showing the larger pores on the outside of the filter, where the fluid first comes in contact. As the fluid goes through the filter, the pores become finer, removing ever smaller oversized particles. Because of the filter's very sharp particle size cut-off, virtually all of the desired active slurry material is able to pass through the filter. Profile II filters are available with removal ratings from 0.2 to 120 microns (μm). Selection of the appropriate filter will depend, for the most part, on the particle size distribution of the slurry. These Profile II filters are successfully used with other liquids containing suspended solids such as chemical mechanical polishing (CMP) slurries in semiconductor applications and color resist for color filters in LCD manufacturing.

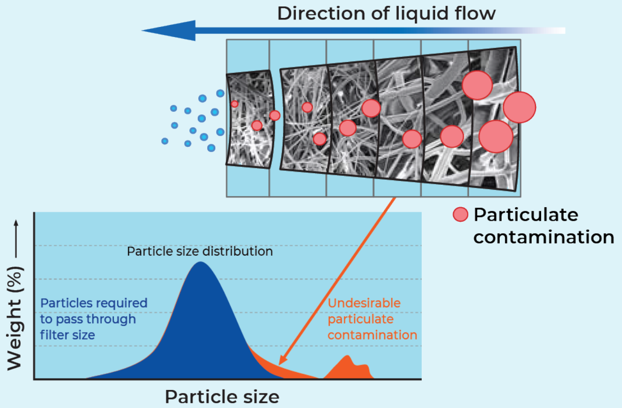

Figure 7: SEM composite photo of a cross section of a Profile II filter medium

Filtration for the Electrolyte Filling Process

Filtration of the electrolytic liquid

The electrolyte is typically comprised of lithium salts (e.g, $LiPF_6$ or $LiBF_4$) in organic solvents, such as ethylene carbonate (EC) or dimethyl carbonate (DMC). These salts may not completely dissolve in the solvents, and consequently must be removed by filtration. Since electrolyte constituents vary considerably among battery manufacturers, the appropriate filter needs to be determined in each case.

As indicated in Figure 8, Pall has a number of different filter media that are suitable for use with battery electrolytes: polytetrafluoroethylene (PTFE), high density polyethylene (HDPE) and polypropylene (PP). For applications Pall recommends either our PTFE or HDPE membranes. Our polypropylene media, available in a variety of different configurations (Figure 9), are most suitable for greater than 1 μm filtration. Contact your local Pall representative for recommendations for your specific electrolyte.

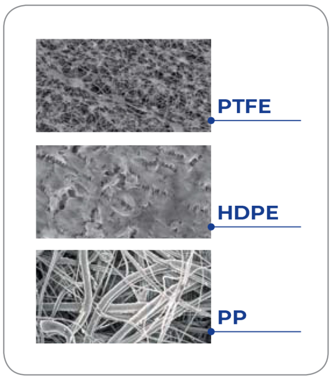

Figure 8: Filter media for electrolyte

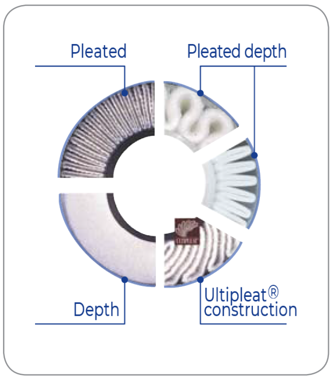

Figure 9: Filter media configurations

Moisture removal from carrier gases with Pall Gas purifiers

Nitrogen (N2) and argon (Ar) are typical inert carrier gases used in the electrolyte filling process. Moisture in either the carrier gas or the electrolyte can result in the formation of hydrofluoric acid (HF) from fluoride lithium salts. Since HF can corrode certain metals, such as piping on equipment or internal battery components, it is critical to prevent moisture from coming in contact with the electrolyte. Pall gas purifiers can reduce ppm levels of moisture from inert gases to less than 1 ppb, as demonstrated in Figure 10. The large spikes are due to the initiation and stopping of the test. In addition, all Pall gas purifiers contain an integral particle removal filter for added protection. Pall offers a range of gas purifiers to handle flow rates from 1 to 1,000 slpm.

In addition to the filtration and purification products for lithium ion battery cell manufacturing, Pall offers other advanced filters for the production of electrolyte liquid and separator material.

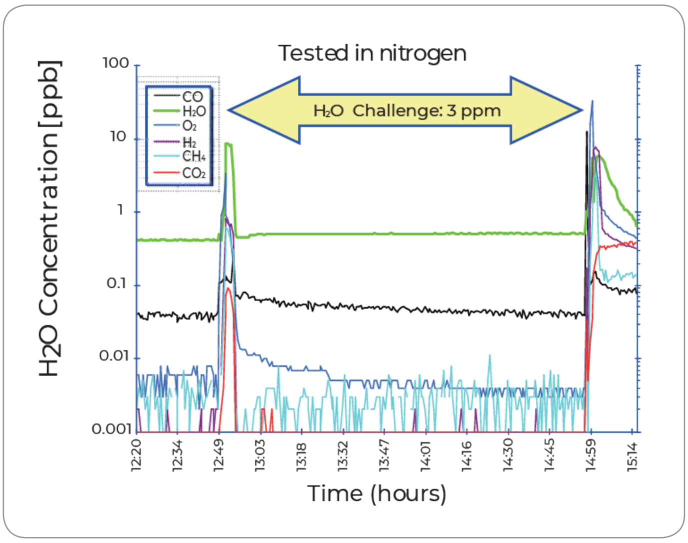

Figure 10: *Gaskleen purifier results after spiking with moisture in nitrogen gas*

PALL CORPORATION

Visit us on the Web at www.pall.com/industry
Contact us at www.pall.com/contact

Corporate Headquarters
Port Washington, NY, USA
+1-800-717-7255 toll free (USA)
+1-516-484-5400 phone

European Headquarters
Fribourg, Switzerland
+41 (0)26 350 53 00 phone

Asia-Pacific Headquarters
Singapore
+65 6389 6500 phone

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January 2024