The Importance of Contaminant-free EV Battery Cell Manufacturing

White Paper

Meech

THE QUEEN'S AWARDS FOR ENTERPRISE: INTERNATIONAL TRADE 2019

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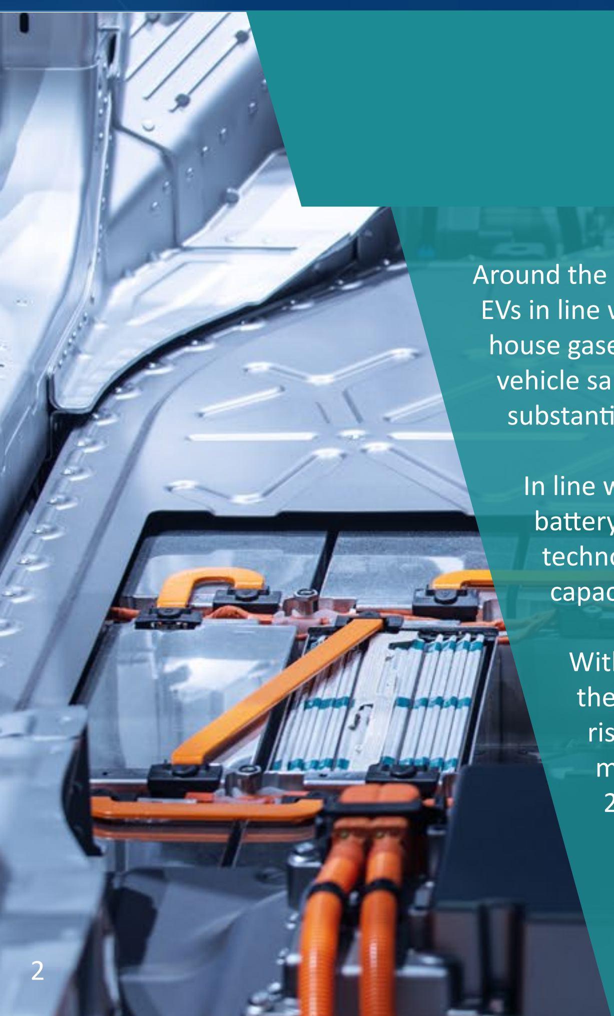
Executive Summary

As global demand for Electric Vehicles (EVs) continues its steep upward trajectory, more and more attention is turning towards the challenges of expanding regional EV battery supply in order to meet future needs.

Battery performance, reliability and safety plays a critical role in the success of any EV – without its beating heart, no matter how good its design – the vehicle is just an inanimate object. And yet, the performance, or in some cases catastrophic failure of its battery, can literally make or break the success of a vehicle and the car manufacturer's reputation as they transition more heavily into this sector. To add to this, the huge demand from EV manufacturers is placing unprecedented pressures on suppliers to keep apace, adding further to the pressure for optimising battery production output and minimising waste.

Within the complexities of cell manufacturing, be that based on lithium-ion or hydrogen fuel-cell technology, there are many processes where either static or contamination can build-up resulting in wide-reaching detrimental effects on the battery's performance and safety, not to mention, profitability and market success.

While many of the challenges and solutions highlighted are relevant to most types of cell technology, this paper will focus specifically on the importance of maintaining clean, neutrally charged components within the manufacture of lithium-ion cells. It will also examine the role that specialist suppliers of contamination removal and static control can play throughout the production process, to ensure clean and safe environments for the optimum manufacture of high-quality, high-performance cells.



Introduction

Around the world, many countries are supporting the move to large-scale adoption of EVs in line with international Treaty agreements on climate change to reduce green-house gases and help meet obligations to decarbonise transport. As a result, electric vehicle sales are experiencing rapid growth, and this growth rate is set to increase substantially over the next decade.

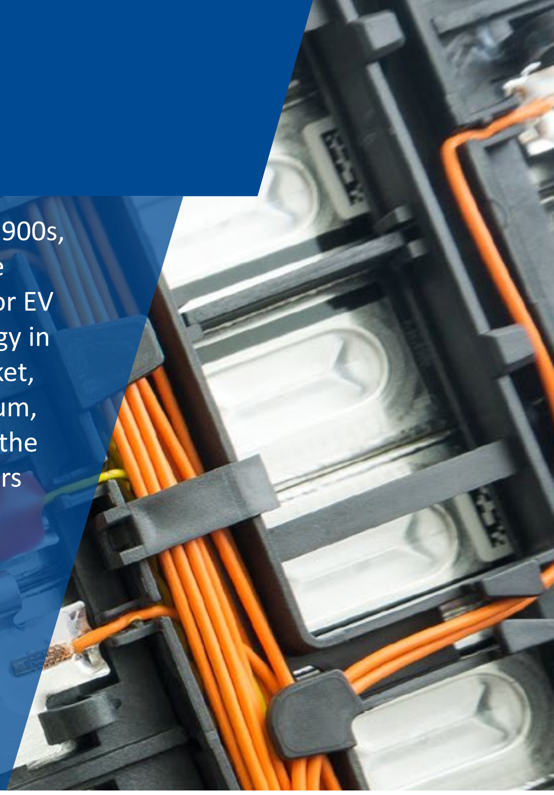
In line with the ongoing demand for EVs, the race for high performance, low-cost battery technology is well underway with major investments in ever-evolving technologies and new supply infrastructures to significantly expand production capacity.

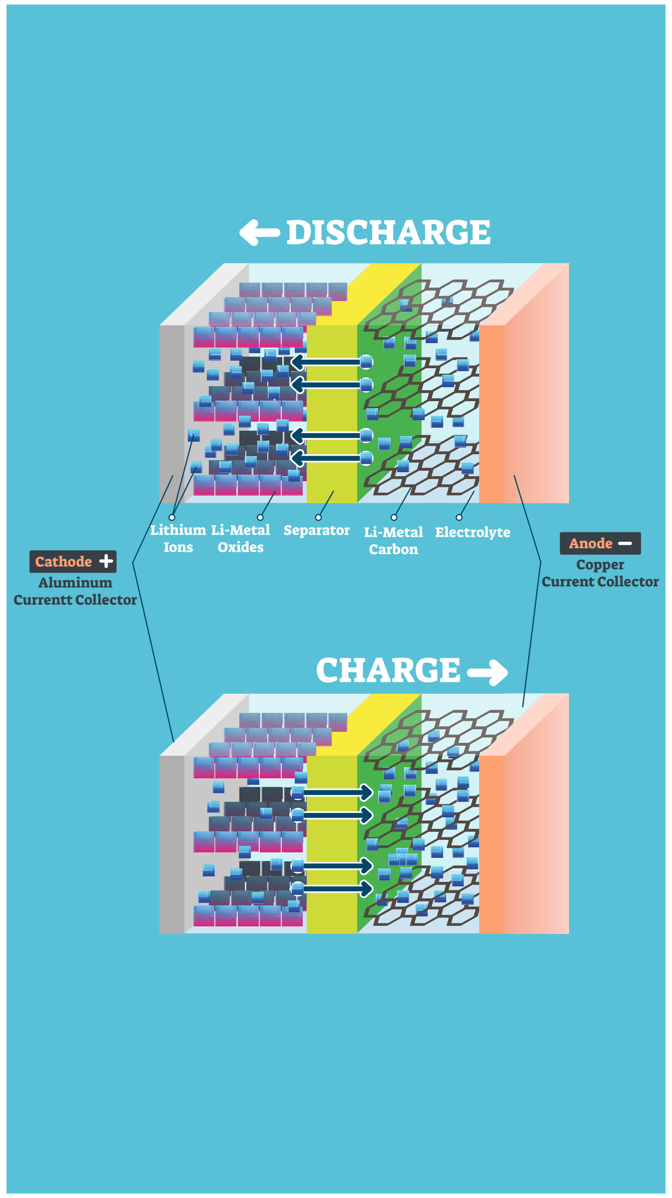
With forecasters continually increasing their predictions from one year to the next, there is no denying the demand for EV batteries will continue to rise sharply. Indeed, according to one of the latest reports[1] the EV battery market is expected to grow at CAGR (compound annual growth rate) of 26% from 2021 to reach $175.11 billion by 2028.

Lithium-ion battery technology

Pioneering lithium-based battery technology was first introduced in the early 1900s, but it wasn't until the 1970s that the first rechargeable lithium batteries hit the market. Since then, lithium-ion battery technology has become the mainstay for EV vehicles due to its practicality, efficiency, ability to store large amounts of energy in a small space and long life. Recognising its significance to the growing EV market, the mining industry's own predictions forecast a 400% increase in copper, lithium, nickel battery demand to the year 2030[2] while BloombergNEF predicts that by the same year, annual demand for lithium-ion batteries will pass 2.7 terawatts-hours per year, with passenger vehicles representing 72% of the overall market sales.

Although much of the manufacture of lithium-ion batteries, to date, has been centred in Asia, notably China, significant investment is already underway to ramp-up production facilities, most notably in North America and across Europe. It is estimated that the European share of global EV gigafactories will reach 33.4% from just 8% in 2021[3].





Battery composition

Despite the dynamic nature of EV battery technology, a lithium-ion battery typically comprises a lithium compound – a cathode (comprising Aluminium foil ranging between 8-18 microns in thickness), a graphite anode (typically a 10 micron thick copper foil) and an active electrolyte. An anode is the negative or reducing electrode that releases electrons to the external circuit and oxidizes during an electrochemical reaction. The cathode is the positive or oxidizing electrode that acquires electrons from the external circuit and is reduced during the electrochemical reaction. Simply put, lithium-ions move from the cathode to the anode when charging, and move back in the opposite direction when discharging.

Separator film

A critical component within lithium-ion cells is the separator film, with its composition and integrity absolutely fundamental to the performance of the battery. The separator film is a micro-porous membrane placed between the electrodes. Its key function is to keep the two electrodes (the anode and the cathode) apart to prevent electrical short circuits. Made from Polyethylene, polymer gel or microporous ceramic, the separator film is permeable to ionic flow. This is required to create a charge and close the transfer loop, but crucially, it prevents the electrical contact of electrodes, which can result in a short circuit, whilst also carrying the all-important electrolyte.

[1] EV Battery Market forecast: Meticulous Market Research Pvt. Ltd – March 2022
[2] Mining.com; Battery Metals Intellligence Market Study – June 2021
[3] https://www.eukor.com/news/supporting-the-rise-of-ev-battery-gigafactories - January 2022

Contamination in production

To produce lithium-ion batteries, a number of common process stages are required. If, however, there are any stages where even a trace amount of particulate or ionic contamination becomes embedded into the internal layers of the battery, it can damage the separator film. This poses a serious and significant threat to both production output and battery performance. And, given the complexities of battery manufacture, there are many areas throughout production, where contamination can occur through electro-static attraction.

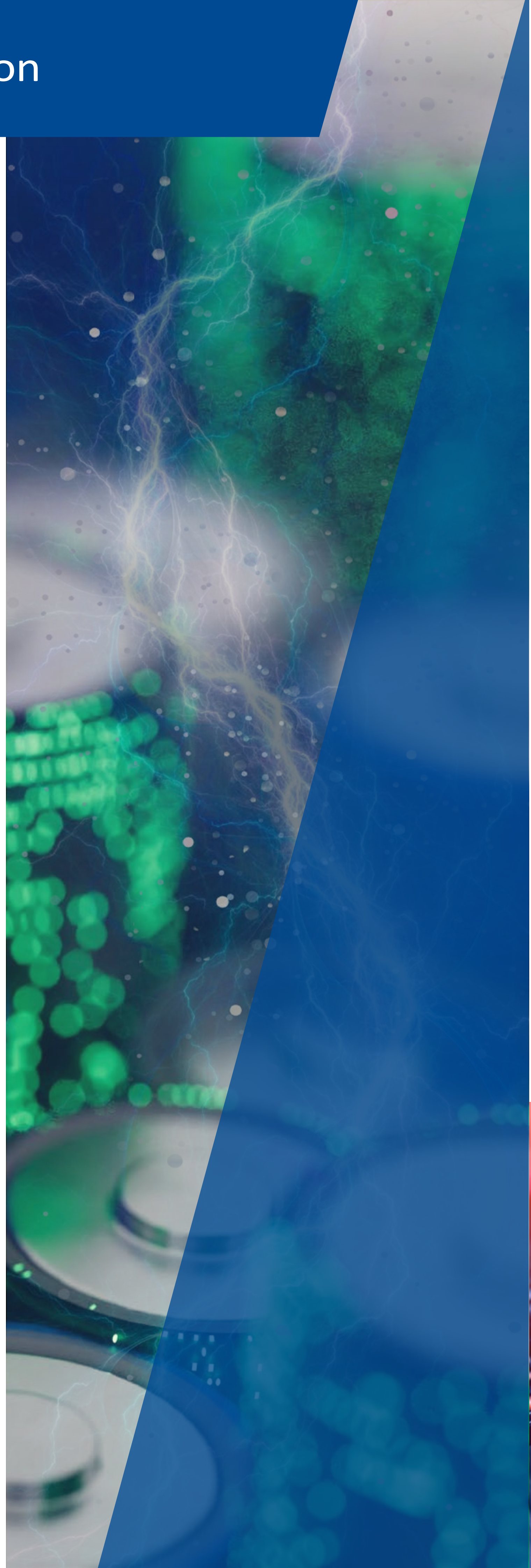
Neglecting the consequences of static charges and surface contamination during manufacturing can result in a number of serious risks. These range from poor performance, material defects and product recalls to overheating, spontaneous ignition and even explosion with cataclysmic consequences for the manufacturers and consumers. In fact, nearly all cases of EV fires have been linked to the malfunction of their lithium-ion batteries.

As battery production increases, so too has the number of costly recalls due to battery malfunction. General Motors, for example, one of the largest automotive manufacturers in the world, has been hit by a string of recent vehicle recalls due to lithium-ion battery defects linked to fires, with all the major manufacturers such as Ford, BMW, Audi and Tesla suffering a similar fate. When Hyundai had to recall around 82,000 of its vehicles for expensive battery replacement, it cost the manufacturer an estimated $900 million[4].

Causes and consequences

With high quality, high value and sensitive materials being used in the latest high-performance cell designs, the manufacturing environment is vitally important and must therefore be very carefully controlled to avoid contamination issues. Contaminants can range from metallic and non-metallic particulates as well as water or organic substances, which can reduce critical tolerances in coating processes causing reduced charge density, or damage the separator film resulting in shortages in the circuitry as well as poor wetting of the electrolyte.

[4] Electric Vehicle fire catastrophe: It is not a matter of if, but when – Gregory Wrightstone, August 2021



Reduced performance

The performance, charge capacity and length of the battery life are essential fundamentals for EV batteries. To maintain the highest performance, the energy transfer of ions within the battery cells needs to remain uniform as it passes through the separator film. The presence of contaminants on the film or a build-up of particulates and debris in the cell layers may hamper or distort this transfer process resulting in reduced battery output. Equally important, uneven coating will result in a loss in battery efficiency and capacity.

Temperature & humidity

Lithium is extremely sensitive to temperature inconsistencies and even the smallest amounts of moisture in the air. Even the slightest exposure to air and temperature fluctuations can lead to reduced performance that will impact on the product life of the battery. Therefore, the manufacturing environment has to be maintained at ultra-low humidity and at a constant temperature, it is essential that manufacturing equipment is designed and tested to operate in such demanding conditions.

Capacity

It is essential the final battery delivers its quoted KWh output. Therefore, any process risks such as contamination or unwanted electro-static charges that can cause product defects and reduced performance, must be controlled.

Reduced down-time

Installing the correct contamination removal and static control equipment will help to optimise process flow and minimise downtime risks for high scale production.

Material defects

Particulate contamination on the surface of the electrode can distort ionic transfer, reducing charge and battery performance.

Circuit shortages & breakages

A short circuit or defect within the battery cell can have explosive ramifications as the chemicals within the lithium-ion battery can be highly flammable. Often caused by metallic and other contaminants damaging the separator film, the resulting short circuit can generate intense heat, which in turn, can cause the cell to ignite.

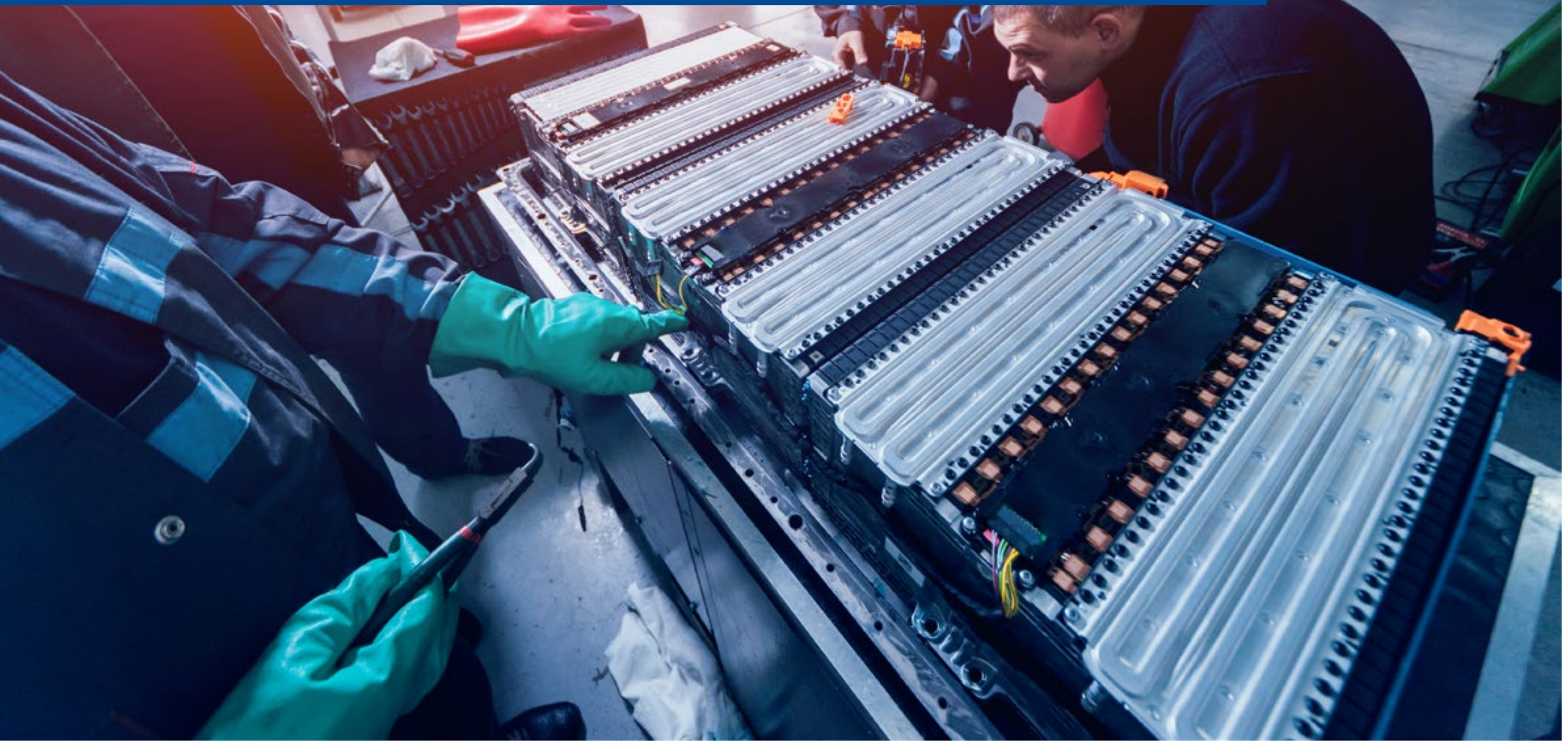
Energy

With the energy ratio of producing a storage cell around 50:1, high production yields are critical, especially with today's soaring energy prices.

Contamination removal and static control

While taking into consideration the need to maintain a contaminate-free environment, this must be achieved in the most efficient manner in order to maximise production output and profitability. Contamination can ultimately lead to production downtime, reduced output, product recalls, lack of consumer confidence and a waste of valuable raw materials.

Critical manufacturing processes where contamination can occur



1. Pre-coating

The accuracy and quality of the coated web is essential to maintain a uniformed and efficient structure within the EV battery. Any contamination within the coating affects the performance within the structural layers and is carried forward into the final construction. Prior to the coating stage of the copper/aluminium web, a surface cleaning process is needed to remove contamination.

2. Coating roller cleaning

A further contamination risk area in the coating process is the roller itself. Essentially this roller provides an accurate position of the web to maintain a high tolerance coating layer. Contamination on the roller can therefore compromise the accuracy of the coating.

3. Pre-calendering

Calendering is the common compaction process for lithium-ion battery electrodes. It has a substantial effect on porosity and coating density, poor structure and therefore performance. During pre-calendering, the web and coating layers are compressed together to form the exact required thickness. Cleaning the web prior to this critical phase prevents loose particulates from the drying process being encapsulated into the surface, resulting in coating layer intolerance.

4. Post slitting

The slitting process can create significant volumes of debris of varying sizes from base and coating materials as well as toxic dust, presenting high contamination risks. Cleaning is therefore imperative to avoid the potential for future electrical shortages and expensive rejects. The use of a web cleaner at this stage ensures particles are removed and filtered from the operating environment, to avoid re-contamination. Depending on the process and materials, contamination can be bonded or un-bonded requiring careful analysis to select between contact or non-contact cleaning solutions.

5. Post cutting/stamping/laser cutting of electrodes

Similar to the post slitting stage, during electrode cutting, large amounts of particles and debris can contaminate the battery components. To minimise this, cleaning the surface of the substrate will help prevent contaminant build-up and ensure there are no electrical shortage risks.

6. Cleaning & static control on the separator film

The separator film is extremely sensitive to electro-static charges created by friction, winding and unwinding throughout the transfer process. Static charges generated on insulative materials such as the separator film attract ambient charged particles adding further to contamination risk problems. More significantly, charges generated can be high and if not carefully controlled, can lead to small sparks, which in turn results in small dendritic burns in the material. While not immediately obvious, these can lead to a loss of insulative properties and create shortages in the battery cell itself. In soak tests or in final vehicle use, these show up as a loss of capacity or even over-heating problems when later installed in a vehicle.

Throughout the separator film transfer process, ionisation bars should be located close to the film where charges can be carefully monitored and managed. To maximise static control and elimination, active ionisers can be tuned to match the material and application to ensure rapid decay times and minimal residual charges, coupled with voltage sensors to respond to varying application speeds or distances. For ultimate protection, the performance of the ionisers and sensors can be monitored in real time, so there is no loss of control on this critical material.

Conclusion

In today's dynamic and highly competitive world, EV manufacturers operate in a fiercely competitive market, where production and raw material costs are rising and margins are becoming tighter. In addition, given the instant-access to information, quality defects and product failings are quickly exposed and brands and reputations can be seriously damaged through loss of consumer confidence. Manufacturers are therefore constantly monitoring their own supply chains, to identify waste, eliminate poor practice, keep costs to a minimum while still maintaining the delivery of high quality products.

With the demand of EVs set to dominate the future of the automotive industry over the next few decades, it is now more important than ever that those in the industry engage and collaborate with the right specialised partners in areas of strategic importance to maximise production efficiencies, maintain competitive advantage and secure ongoing client/customer relationships.

This paper has identified the potentially catastrophic safety, performance and cost implications of particulate and ionic contamination in EV battery manufacturing. As a result, partnering with specialists in static elimination and both web cleaning and surface contaminant removal is vital to maintaining an optimum manufacturing environment for high yield, high performance output at lowest cost.

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About Meech International

Founded in 1907, Meech International is a specialist developer and manufacturer of both electro-static control and a wide range of contact and non-contact web cleaning solutions. They have been at the forefront of innovation in these areas earning a worldwide reputation for consistently designing and manufacturing solutions that offer unparalleled performance and technical superiority. The company's 'Zero Faults Forward' partnership with OEMs has resulted in tailored solutions to suit both pilot and scaled-up battery manufacturing environments where electro-static charge and particulate contamination causes serious manufacturing challenges. When coupled with live SMART monitoring systems, an assured level of control can not only be delivered but also logged for reassurance downstream in production.

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