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WHITE PAPER
DEFECT-FREE EV BATTERIES

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How Static Control Improves Performance, Safety, and Yield

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Every EV battery production line faces an invisible threat: static charge and fine particle contamination that can turn tiny defects into major failures. Left unchecked, these risks compromise yield, degrade performance, and create serious safety hazards, even in highly controlled environments.

Cleanrooms and dry rooms are designed to protect sensitive materials, but static buildup and fine particles can still breach material integrity, cause hidden defects, and spark thermal events. The challenge is even greater in ultra-dry production zones, where traditional cleaning methods often fall short.

This white paper explains the hidden challenges of static and contamination control in lithium-ion battery manufacturing. It also outlines how manufacturers can combine precision ionization, contact cleaning, and closed-loop control to keep surfaces cleaner, protect charge transfer, and build defect-free EV batteries at scale.

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The Stakes: Static and Contamination Risks in EV Battery Manufacturing

Modern EV battery lines are built for speed, precision, and high output. But these qualities create vulnerabilities to unseen threats like static charge and particulate contamination.

> *"Invisible risks like static charge and microscopic particles can turn tiny defects into major failures."*

Uncontrolled electrostatic discharge (ESD) can damage sensitive components or cause internal short circuits.

Metallic particles, often generated during slitting, calendaring, or roller abrasion, can pierce separator films, block ion transport, and create conductive pathways that trigger thermal runaway. [1]

Recent studies of commercial pouch cells found that conductive particles — including aluminum-magnesium and iron fragments up to 1.7 mm — can embed between cell layers, deform separators, and disrupt local ion flow. Even smaller particles (0.25-0.3 mm) create stress points that degrade performance or pose internal short circuit risks over time. [1]

Many of these defects can go undetected. While larger particles cause visible bumps on pouch film, deeper or smaller particles often escape inspection, especially in prismatic or cylindrical cells. The risk grows as internal cell pressure rises with aging and charge cycles and separator strength declines, creating conditions that heighten the chance of failure under high states of charge. [1]

Moisture is another major contaminant. Even trace water vapor in ultra-dry lithium-ion production can react with $LiPF_6$ salt to form hydrofluoric acid, a corrosive byproduct that damages internal structures and reduces battery life.

These risks make static and contamination control essential, not just at isolated steps but as part of an integrated production strategy. From material input to final assembly, prevention must be designed in, not added on.

Where It Happens: Risk Mapping Across the Battery Production Line

Electrostatic and contamination-related defects do not come from a single step. They can appear and build up throughout the entire battery manufacturing process, from slurry preparation to final assembly. [2] The risks increase in dry rooms where tight humidity control, sensitive materials, and charge accumulation intersect.

The following steps refer to the battery production flow in Figure 1 and examines, stage-by-stage, where these risks occur and how they affect yield, safety, and performance.

Step 1: Slurry Preparation

- **Risk**: Moisture intrusion and static buildup can cause poor electrode wetting and contaminate active material.
- **Impact**: Inconsistent energy density and weak adhesion between active layers and foils.

Step 2: Coating and Drying

- **Risk**: Attract sub-micron particles to sensitive surfaces, leading to defects that compromise battery performance, safety, and lifespan
- **Impact**: Degrade electrode surface quality, leading to reduced energy density, compromised fast-charging capability, and shortened battery lifespan

Step 3: Calendering

- Risk: High-speed rolling generates static charge. Particles can be embedded in compressed electrodes.
- **Impact**: Permanent structural defects limit ion mobility and reduce capacity over time.

Step 4: Slitting and Electrode Cutting

- **Risk**: Foil edges create metallic burrs. Slitting dust clings to charged surfaces.
- **Impact**: Higher risk of short circuits during stacking or winding and blocked separator pores.

Step 5: Cell Assembly (Z-Folding or Stacking)

- **Risk**: Static charge attracts contaminants to separator films and active layers.
- **Impact**: Latent faults, separator punctures, and reduced dielectric strength.

Step 6: Electrolyte Filling and Sealing

- **Risk**: Residual charges can disrupt electrolyte flow and cell formation.
- **Impact**: Uneven wetting, loss of charge capacity, or early self-discharge.

Step 7: Module Assembly

- Risk: Static can damage sensitive components, degrade cells, or even spark fires if not properly controlled.
- Impact: Electrical overstress, compromised battery safety, and catastrophic failure during end-use or transport.

Step 8: Final Testing and Quality Assurance

- **Risk**: Latent defects or static charge can disrupt sensitive test equipment.
- **Impact**: More rework, yield loss, or failures after the product reaches the customer.

FIGURE 1. MANUFACTURING STEPS OF LI-ION BATTERIES

At each stage, static charge and fine particles can introduce defects that are too small to see but costly to fix. These risks demand targeted controls at every critical point, not just a final check at the end of the line.

The Dry-Room Problem: Why Traditional Cleaning Fails

Dry-room environments are essential for lithium-ion battery production. [3] These ultra-low-humidity areas maintain dew points as low as –70°C to protect electrolyte salts and keep cell chemistry stable. But while dry rooms remove moisture, they also create one of the biggest production hazards: extreme electrostatic charge buildup.

Traditional cleaning methods often fail in these conditions:

Air Knives and Blowers

- **Issue**: Use high-velocity air to dislodge particles.
- **Risk**: Air can introduce trace moisture into dry rooms and disturb airflow patterns, raising contamination risk.

Vacuum Systems

- **Issue**: Draw ambient air across surfaces to remove debris.
- **Risk**: Can carry particles or humidity to critical areas, making them unsuitable for sensitive, ultra-dry applications.

Brush Cleaners

- **Issue**: Use bristles to mechanically remove debris.
- **Risk**: Bristles can trap or spread particles and may damage delicate foils or electrode coatings.

Dry rooms magnify these limitations. Static charge attracts particles faster than traditional cleaning can remove them. Once contamination attaches, it often stays in the process flow, where it can trigger hidden defects and safety risks later. [4]

Why Contact Cleaning and Static Control Work Better

The most effective approach in dry environments combines cleanroom-ready surface cleaning with precise ionization.

- Specialized elastomer rollers gently lift particles from sensitive surfaces without causing abrasion.
- Integrated adhesive systems fully capture contaminants so they are removed from the process, not just moved around.
- Ionizing bars and blowers neutralize electrostatic charges, preventing particles from reattaching and helping maintain stable material handling.

These technologies remove metallic, oxide, and submicron particles without disrupting environmental controls, production speed, or product integrity.

"Small changes at the particle level protect every cell, every pack, and every vehicle on the road."

As EV battery production moves toward dry electrode coating and solid-state designs, the need for moisture-free, particle-free processing will continue to grow. A combined static control and contact cleaning strategy helps manufacturers protect material integrity, extend cell life, and support higher production yields in the cleanest possible conditions.

Precision Static Control for High-Yield EV Battery Lines

Simco-Ion, Technology Group delivers advanced, application-specific static control and contamination solutions for cleanroom and dry-room battery production. Unlike general-purpose ionizers or industrial web cleaners, these technologies are engineered from the ground up to match the demands of high precision, cleanliness, and throughput.

Application-Specific Engineering

Each step in lithium-ion battery production comes with unique static and contamination challenges, from electrode powder coating to electrolyte filling. Simco-Ion, Technology Group solutions are tailored to each need:

- Low-pressure ionizing blowers maintain coverage in coating, calendaring, and slitting zones without disturbing airflow.
- Ultra-clean ionizing bars neutralize static while complying with ISO 14644-1 Class 6-8 cleanroom standards.
- Closed-loop static monitoring adjusts ion output in real time to maintain process stability and prevent defects.

Cleanroom Compatibility

Simco-Ion, Technology Group's Room Ionization System and local-use Ionizers are built for:

- Dry-room production, where humidity and fine particle control are critical.
- Ultra-sensitive zones where minor contamination can damage battery performance and safety.
- High-speed, automated lines that need non-contact or in-line installation.

Every system uses materials and construction methods for controlled environments, including static-dissipative housing and particle-free airflow.

Scalable Integration Across the Battery Line

Simco-Ion, Technology Group's portfolio includes modular and fully integrated systems that align with key stages of battery production.

These cleanroom-ready platforms do more than eliminate static. They improve process consistency, reduce variation, and help unlock higher yields. By addressing the root causes of defects, Simco-Ion, Technology Group helps manufacturers protect performance, cut rework, and scale clean energy production with confidence.

Performance Proof Points: Yield, Safety, and Longevity Gains

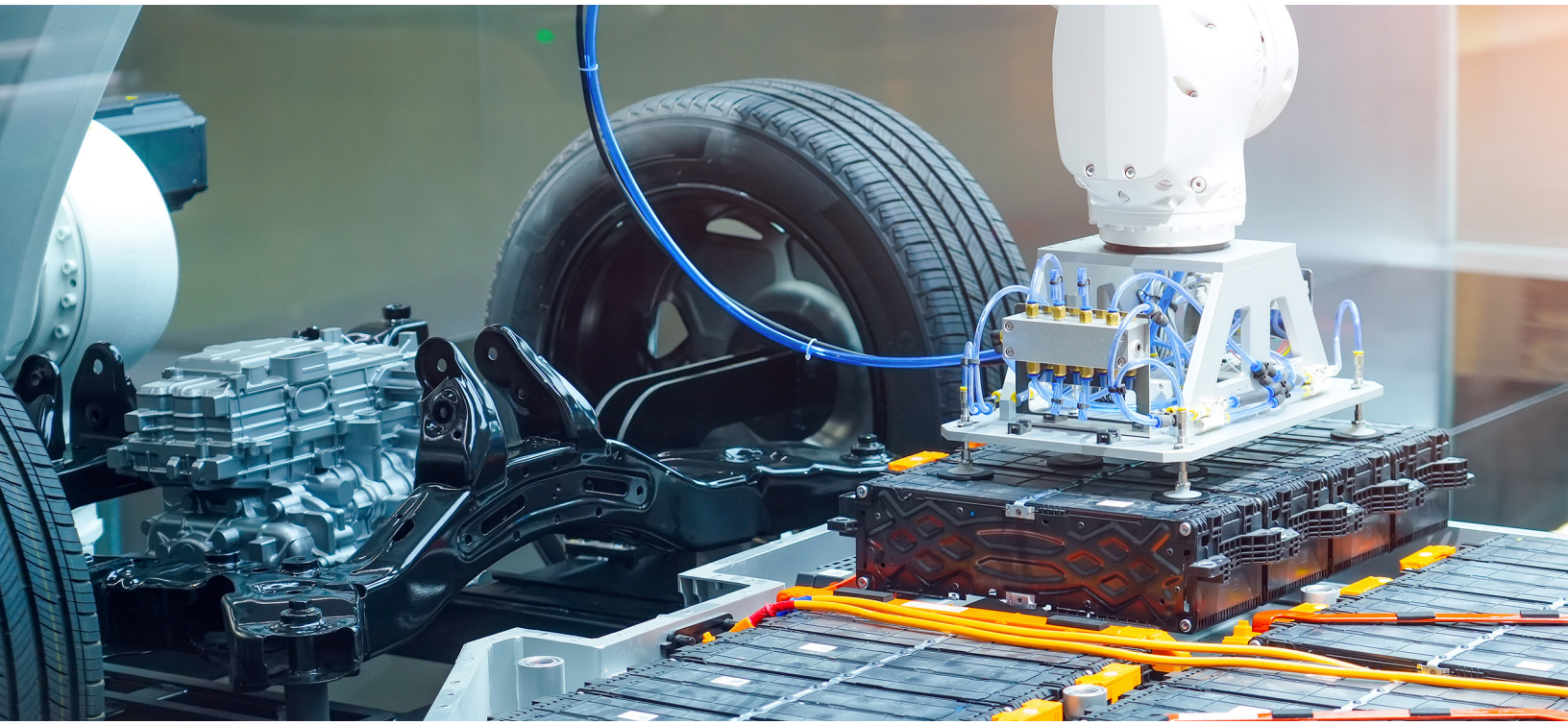
The value of advanced static control is not just in stopping defects. Every avoided defect turns into measurable gains in yield, safety, and product life.

> *"Every micron matters when your battery has to perform flawlessly for a thousand charge cycles."*

Improved Yield Through Defect Reduction

- **Problem**: Tiny particle-induced defects during calendaring, slitting, and stacking often lead to scrapped cells or costly rework.
- **Solution**: Neutralizing surface charge and removing submicron debris helps prevent misalignment, inclusions, and shorts.
- **Impact**: Higher first-pass yield, less downtime, and more predictable production runs.

Manufacturing Step	Static and Contamination Risk	Simco-Ion, Technology Group Solution
Slurry Preparation	Particle attraction and charge accumulation during mixing	5710 AeroBar or FPD Aerostat Blower
Coating and Drying	Particle attraction and charge accumulation during web handling and material transport	5710 AeroBar or FPD Aerostat Blower
Calendering	Embedded particles, triboelectric charge	5710 AeroBar or FPD Aerostat Blower
Slitting and Electrode Cutting	Burrs, metallic dust, edge contamination	5645 AeroBar or 5842 Overhead Blower
Cell Assembly (Z-Fold or Stacking)	Separator film charge, contamination between layers	5645 AeroBar or 5842 Overhead Blower
Electrolyte Filling and Formation	Disrupted wetting, latent charge	5645 AeroBar (non-air)
Module Assembly	Prevents ESD damage, maintains product reliability	FPD or 5842 Overhead Blower
Final Testing and Quality Assurance	Protects sensitive electronics, assure test result integrity	FPD or 5842 Overhead Blower



Better Safety by Reducing ESD Risk

- **Problem**: Electrostatic discharge can puncture separators, damage electrolytes, or cause thermal runaway, especially in high-voltage or tightly packed cells.
- **Solution**: Simco-Ion, Technology Group's ionizing systems remove local static fields and balance charge across critical areas.
- **Impact**: Fewer short-circuit risks and safer pack assembly, especially for dry electrode and solid-state designs.

Longer Battery Life with Cleaner Production

- **Problem**: Metallic or ionic contamination can cause charge imbalance, electrode wear, and early capacity fade.
- **Solution**: Cleanroom-ready static control keeps particles off critical interfaces inside the cell.
- **Impact**: Longer cycle life, better energy retention, and more reliable performance in the field.

Small changes at the particle level deliver significant results at the pack level. Every micron counts when batteries must last for years.

From Equipment to Strategy: Embedding Static Control into Process Design

In a production environment as demanding as lithium-ion battery manufacturing, static control cannot stay an afterthought. Electrostatic discharge and contamination are not isolated risks. They need a system-wide approach built into the process from the start.

Integrated Solutions

Simco-Ion, Technology Group, helps manufacturers shift from single-point fixes to full-line integration.

- Ionization can be installed directly in coater heads, slitting modules, or Z-folding stations.
- Closed-loop monitoring connects with existing PLCs and MES systems.
- Cleanroom-ready hardware works with ISO airflow controls and room classifications.

This integration keeps static control aligned with production flow, rather than being added as a patch after problems appear.

More Stability with Predictive Control

Simco-Ion, Technology Group's monitoring platforms, like IonManager Pro for Room Ionization System and the closed-loop feedback control on designated ionizers with data logging by integrating with Novx monitoring system, give engineers real-time data on electrostatic conditions. With this visibility, teams can:

- Detect charge buildup before defects happen.
- Adjust the ionizer output automatically.
- Apply process controls to stay within tight thresholds.

This makes the line more stable and supports a data-driven manufacturing culture.

Scalable from Pilot to Gigafactory

Battery makers need systems that scale with them, from pilot lines to full gigafactories. Simco-Ion, Technology Group's global support and flexible design help manufacturers:

- Adapt systems for different chemistries, cell formats, and line speeds.
- Equip roll-to-roll lines and solid-state pilot plants.
- Expand across regions with local technical help.

Supports Digital Manufacturing and ESG Goals

As battery producers automate and tighten sustainability targets, static control becomes even more strategic:

- Fewer defects mean less scrap and fewer fire risks.
- Ionization and contamination data can be tracked as part of full-lifecycle quality records.
- Smart systems integrate with sensors and analytics to help teams build adaptive, defect-resistant lines.

Static control does more than fix hidden problems. It helps make battery production scalable, digital, and ready for the next generation of EVs.

Conclusion: Powering the Next Generation of Battery Manufacturing

As the global battery industry races to meet growing EV demand, manufacturers must scale faster, deliver better performance, and eliminate defects at every step. Static charge and contamination are not minor details. They are core threats to battery safety, reliability, and production yield.

Simco-Ion, Technology Group helps battery manufacturers tackle these challenges with cleanroom-ready ionization systems, advanced static elimination and monitoring, and cooperation with Teknek's contact cleaning, engineered for modern battery lines. From electrode coating to final assembly, these solutions reduce particle attraction, control electrostatic risks, and keep production stable in ultra-dry, high-speed environments.

By addressing static and contamination early, manufacturers can build more reliable batteries with fewer defects, less rework, and stronger safety in the field. Small changes in the process protect every cell, every pack, and every vehicle.

Let's power the future together!

To see how Simco-Ion, Technology Group can help you improve battery yield, safety, and quality, visit **www.simco-ion.com/technology or contact salesservices@simco-ion.com.**

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ABOUT SIMCO-ION, TECHNOLOGY GROUP

Simco-Ion, Technology Group is a global leader in advanced static control and contamination management for high-precision manufacturing. For more than 36 years, it has helped leading manufacturers boost yield, product safety, and process stability across industries, including electronics, batteries, and clean energy.

CITATIONS:

1. Grabow, J. et al., Particle Contamination in Commercial Lithium-Ion Cells—Risk Assessment with Focus on Internal Short Circuits, Batteries 2023, 9(1), 9. https://doi.org/10.3390/batteries9010009.
2. Li-Ion Battery Cell Production Process, PEM of RWTH Aachen University and VDMA, https://www.pem.rwth-aachen.de/global/show_document.asp?id=aaaaaaaaabdqbtk.
3. The 'Not-So-Dry' Topic of Battery Dry Rooms, https://volta.foundation/battery-bits/the-not-so-dry-topic-of-battery-dry-rooms.
4. Understand ESD and Lithium Battery Safety, Dr. Lee PAN, https://www.large-battery.com/blog/esd-and-lithium-battery-safety.
5. ANSI/ESD S20.20-2021: Protection of Electrical and Electronic Parts https://blog.ansi.org/ansi/ansi-esd-s20-20-2021-protection-electronic-parts.

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