# PRIMER COATING

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# EXECUTIVE SUMMARY

## PRIMER COATING OF CURRENT COLLECTORS IN LITHIUM-ION BATTERY PRODUCTION

Lithium-ion battery manufacturing is undergoing rapid transformation as the industry pursues higher energy density, lower cost per kilowatt-hour, and more sustainable production routes. These pressures are driving electrodes toward lower binder content, thicker coatings, higher coating speeds, water-based chemistries, and emerging dry-coating technologies. While these developments improve cell-level performance and sustainability, they significantly narrow the process window at the interface between the electrode coating and the metallic current collector.

Primer coatings on copper and aluminum current collectors have emerged as a powerful, cost-effective lever to stabilize this interface. Properly engineered primers improve adhesion, reduce interfacial resistance, mitigate corrosion, enable aggressive calendering, and even support controlled delamination for recycling – benefits that cannot always be achieved by modifying the main electrode formulation alone.

This whitepaper reviews the electrochemical, mechanical, and manufacturing drivers for primer use and highlights **Matthews Engineering' coating solutions** – including **high-speed intermittent gravure coating, advanced foam-control chamber design, and optimized production architectures** – as industrially proven technologies for applying functional primer layers at scale.

## ENABLING HIGH-ENERGY, HIGH-SPEED, AND SUSTAINABLE MANUFACTURING WITH MATTHEWS ENGINEERING SOLUTIONS

# 1. BACKGROUND: LITHIUM-ION BATTERY STRUCTURE AND MATERIALS

## 1.1 CELL ARCHITECTURE

A typical lithium-ion cell consists of a porous anode and cathode separated by a porous polymer separator – often surface-coated to enhance thermal stability and safety (see Matthews Engineering whitepaper on separator film coating) – and infiltrated with a liquid electrolyte. The electrodes are composite coatings of active material, conductive carbon, and polymer binder deposited onto metallic current collectors (Figure 1.) – copper for the anode and aluminum for the cathode – and subsequently calendered to achieve the target porosity, thickness, and density [1,2].

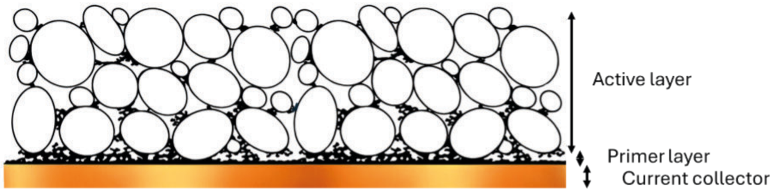

Figure 1. Structure of an electrode with the current collector coated with a primer layer, optimizing the required binder amount while ensuring the critical adhesion.The interface between the current collector and the electrode coating plays a critical role in electronic conductivity, mechanical integrity, and long-term durability. As electrode designs become more aggressive – featuring lower binder content, higher coating speeds, thicker layers, and alternative processing routes – this interface increasingly determines manufacturing yield, process robustness, and ultimately cell performance and lifetime.

## 1.2 CATHODE AND ANODE CHEMISTRIES

On the cathode side, layered oxides such as NMC ($LiNiMnCoO_2$-based) and olivine phosphates such as LFP ($LiFePO_4$) dominate. NMC offers higher energy density but requires stricter voltage control, while LFP provides superior thermal stability and cycle life [2–4]. On the anode side, graphite remains standard, with rising adoption of silicon-containing composites to increase capacity, at the cost of larger volume changes and higher mechanical stress [2–4].

## 1.3 BINDERS AND SOLVENTS

Binder selection is closely linked to solvent choice. PVDF binders dissolved in N-methyl-2-pyrrolidone (NMP) are common in NMC cathodes, while aqueous binders such as CMC/SBR, PAA, and acrylics dominate graphite anodes and are increasingly used for LFP cathodes [2–6]. The industry trend toward water-based processing is driven by environmental and cost pressures but introduces challenges such as aluminum corrosion, pH sensitivity, and adhesion loss.

# 2. PERFORMANCE, SAFETY, AND MANUFACTURING CONSTRAINTS

Electrodes must maintain mechanical integrity, low impedance, and adhesion over a wide temperature range and across extreme states of charge [1–3]. High-rate charging demands low interfacial resistance, while high-voltage operation (>4.3–4.6 V) exacerbates aluminum corrosion and electrolyte oxidation [2,3].

During cell assembly, electrodes absorb electrolyte and swell, altering thickness and stress distribution. Binder chemistry and porosity strongly influence this swelling behaviour, making interfacial robustness essential for dimensional stability and long-term cycling [1,2,4,7].

# 3. ELECTRODE MANUFACTORING: WET AND DRY TRENDS

## 3.1 WET COATING AND DRYING

Conventional electrode manufacturing relies on wet coating techniques such as slot-die, roll coating, and curtain coating, followed by convective drying [1,8]. While coating machinery can support web speeds of several hundred meters per minute, practical operation is typically limited to ca. 100 m $\text{min}^{-1}$, as higher speeds require longer drying sections and become economically unfavourable, in addition to narrowing the process window for rheology, drying uniformity, and defect control.

Drying is one of the largest contributors to energy consumption and line length, particularly for NMP-based cathodes requiring solvent recovery systems [1,2,5,8].

## 3.2 DRY COATING AND MECHANICAL CONSOLIDATION

Dry coating technologies eliminate most or all solvent by forming powder-based electrode layers that are bonded to the current collector via calendering or lamination [9,10]. While dry coating drastically reduces drying energy and footprint, it imposes higher mechanical loads at the electrode–collector interface, often necessitating primers or surface treatments to achieve sufficient adhesion [2,9,10].

# 4. WHEN AND WHY PRIMER COATINGS ARE JUSTIFIED

A primer coating on the current collector is justified when it unlocks performance, robustness, or sustainability that cannot be achieved economically through the main electrode formulation alone.

This is typically the case when:

- Binder content is reduced to maximize active-material fraction.
- Coating and drying speeds are increased, promoting binder migration and adhesion loss.
- Aggressive calendering or thick electrodes are required.
- Water-based or high-voltage operation increases corrosion risk.
- Recycling strategies demand controlled delamination.

## 4.1 LOW-BINDER, HIGH-ENERGY ELECTRODES

Experimental work has shown that thin primer layers can dramatically increase adhesion. Diehm et al. demonstrated that an aqueous CMC/SBR/carbon primer of ~0.3 g $m^{-2}$ increased graphite anode adhesion on copper by approximately fivefold, enabling low-binder, high-energy electrodes without sacrificing rate capability or aging performance. The minor mass penalty of the primer is outweighed by the energy-density gain from reduced binder content [9].

## 4.2 HIGH-SPEED INDUSTRIAL COATING

At industrial line speeds, primers stabilize the process window by providing a well-wetted, mechanically compliant interface that resists micro-delamination during drying and calendering. High-speed trials have demonstrated defect-free primer coating at web speeds exceeding 500 m $min^{-1}$, confirming scalability for gigafactory production.

## 4.3 DRY COATING AND MECHANICALLY DEMANDING DESIGNS

Dry-coated electrodes, thick cathodes, and high-silicon anodes impose severe mechanical stress at the interface. Primers act as conductive tie-layers that accommodate strain, reduce cracking, and maintain low contact resistance – critical for both manufacturability and cycle life [11].

## 4.4 HARSH ELECTROCHEMICAL ENVIRONMENTS

For high-Ni NMC cathodes at elevated voltages, carbon-rich primers protect aluminum from pitting corrosion and impedance growth. In water-based LFP or LMFP processing, primers act as both corrosion barriers and adhesion promoters, expanding the allowable pH and drying window.

## 4.5 DESIGN FOR RECYCLING

Recent studies show that primers can be engineered to enable controlled delamination during recycling, allowing nearly complete separation of active material from aluminum foil under electrical or thermal stimulus. Such designs support closed-loop manufacturing and compliance with emerging recycling regulations [10].

# 5. MATTHEWS ENGINEERING SOLUTIONS FOR PRIMER COATING

## 5.1 HIGH-SPEED INTERMITTENT GRAVURE COATING

Matthews Engineering provides intermittent ("skip") gravure coating solutions that enable precise primer patterning in the cross direction – capabilities that are not achievable with conventional single-cylinder gravure setups. By alternating two standard-dimension gravure cylinders in a controlled sequence, long repeat lengths (on the order of several meters) can be realized without resorting to impractically large gravure rollers (Figure 2., Figure 3A vs. 3B.). Implemented at industrial scale in 2020, this technology has since demonstrated robust scalability and repeatable coating quality.

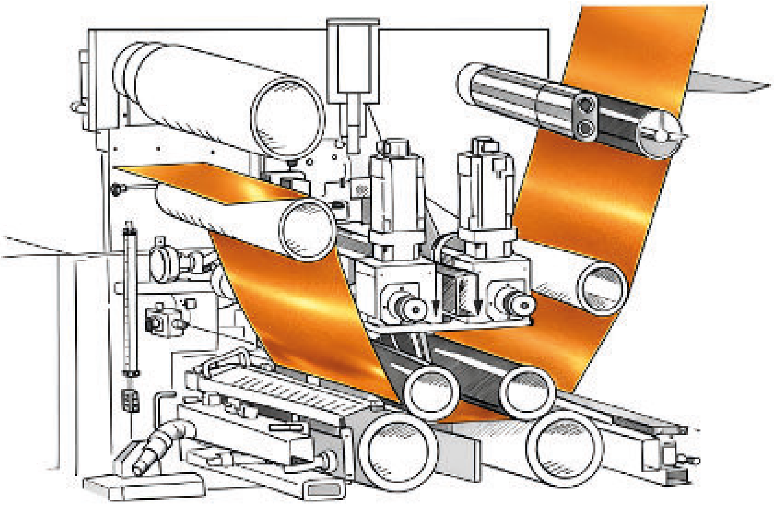

**Figure 2.** Schematic principle of the intermittent coater. Alternation of two standard-dimension gravure cylinders allow for selection of repeat length according to need without resorting to impractically large gravure cylinders.

**This architecture combines industrial robustness with exceptional flexibility:**

- Proven production speeds up to 300 m min$^{-1}$ for primer coating applications
- Typical operating speeds of approximately 250 m min$^{-1}$, depending on formulation
- Excellent edge definition and pattern control
- Compact system design, enabling factory space savings

# 5. MATTHEWS ENGINEERING SOLUTIONS FOR PRIMER COATING

A key advantage of the Matthews intermittent gravure concept is cell-size and format flexibility. The coated electrode length as well as the gap length, can be adjusted via software control, allowing rapid changes to the primer pattern length without mechanical modification (Figure 3.). These adjustments can be made on the fly while the coater is running, enabling fast changeovers and supporting mixed-format or evolving cell designs within the same production line. Adjustable electrode length and gap enable efficient material usage and reduce waste in battery electrode production. Primer patterning further allows selective tuning of adhesion strength toward the active layer. While its industrial validation has so far focused on primer applications, the intermittent concept may also benefit other technologies requiring patterned conductive base layers, such as flexible photovoltaic devices.

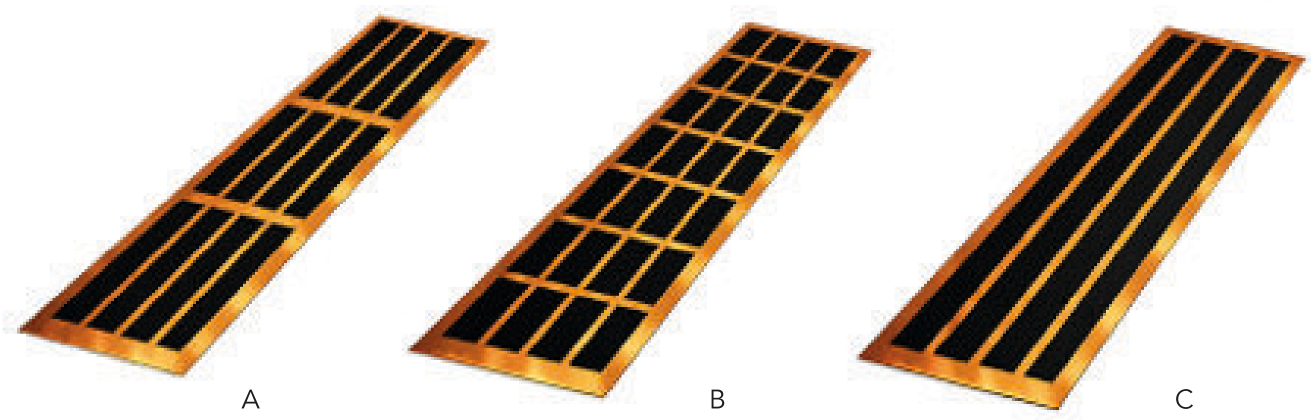

**Figure 3.** The intermittent coater allows for adjustment of the electrode and gap lengths according to need.

- A: Coated electrodes with a large aspect ratio utilizing multiple rotations of one standard size gravure cylinder.
- B: Coated electrodes with a short aspect ratio limited by one rotation of a similar size gravure cylinder.
- C: Continuous electrodes without gap, coated with direct gravure or for maximized throughput with indirect gravure.

For applications that prioritize maximum throughput over patterned deposition, Matthews Engineering also offers indirect gravure coating solutions. This technology is optimized for continuous coating and enables even higher web speeds for both anode and cathode primer layers, providing a robust and scalable pathway for ultra-high-volume production environments (Figure 3C.).

# 5. MATTHEWS ENGINEERING SOLUTIONS FOR PRIMER COATING

## 5.2 ADVANCED FOAM-CONTROL CHAMBER DESIGN

Foaming is a critical limitation in water-based roll and gravure coating, especially at high speeds. Matthews Engineering has developed a mechanically simple, pressurized single-chamber gravure system with integrated cell pre-filling, specifically designed to minimize air entrainment at the gravure-to-chamber interface.

Key benefits include:

- Strong reduction of foam formation at the source
- Stable coating windows at higher line speeds
- Reduced reliance on complex circulation loops and degassing systems

This design is particularly advantageous for aqueous primer formulations containing surfactants and polymer binders, where conventional chambers become the bottleneck.

## 5.3 OPTIMIZED PRODUCTION ARCHITECTURES

Matthews Engineering supports production optimization, for example by deploying one high-speed wet primer coating line to supply multiple downstream dry-coating lines. This architecture maximizes asset utilization, minimizes solvent-handling infrastructure, and accelerates scale-up of dry electrode technologies.

# 6. IMPACT ON THROUGHPUT, ENERGY, AND SUSTAINABILITY

**Primer coating adds only a thin, lightweight layer but enables:**

- Higher coating speeds and yields
- Reduced binder content and higher energy density
- Expanded use of water-based and dry processes
- Lower drying energy and shorter line length
- Improved recyclability and material recovery

When integrated with Matthews Engineering' coating and chamber solutions, primer application becomes a high-value, low-complexity step that supports both performance leadership and sustainability goals.

# 7. CONCLUSIONS

As lithium-ion battery manufacturing pushes toward higher energy density, faster throughput, and lower environmental impact, the electrode–current collector interface has become a critical limiting factor. Primer coatings provide a practical means to improve adhesion and stabilize high-throughput coating and calendering.

**Matthews Engineering solutions** – combining high-speed intermittent gravure coating, advanced foam-control chamber design, and optimized production architectures – provide battery manufacturers with industrially proven tools to apply functional primer layers reliably, efficiently, and at scale. Matthews Engineering enables wider process windows, higher yields, and future-ready manufacturing strategies.

# REFERENCES

1. Chemistry Europe, Electrochemical Science Advances, 2023.
2. National Center for Biotechnology Information (NCBI), Lithium-ion battery manufacturing review, 2024.
3. Cell Reports Physical Science, 2025.
4. NCBI, Binder and electrode swelling studies, 2024.
5. Daikin Chemicals, Lithium-ion battery binders and solvents.
6. Ossila, Battery binder systems overview.
7. Electrochimica Acta, 2017.
8. NCBI, Advanced coating and drying processes, 2024.
9. Energy Technology, Wiley, 2020.
10. Waste Management, Elsevier, 2025.
11. German National Library Dissertation, Dry electrode processing, 2021.

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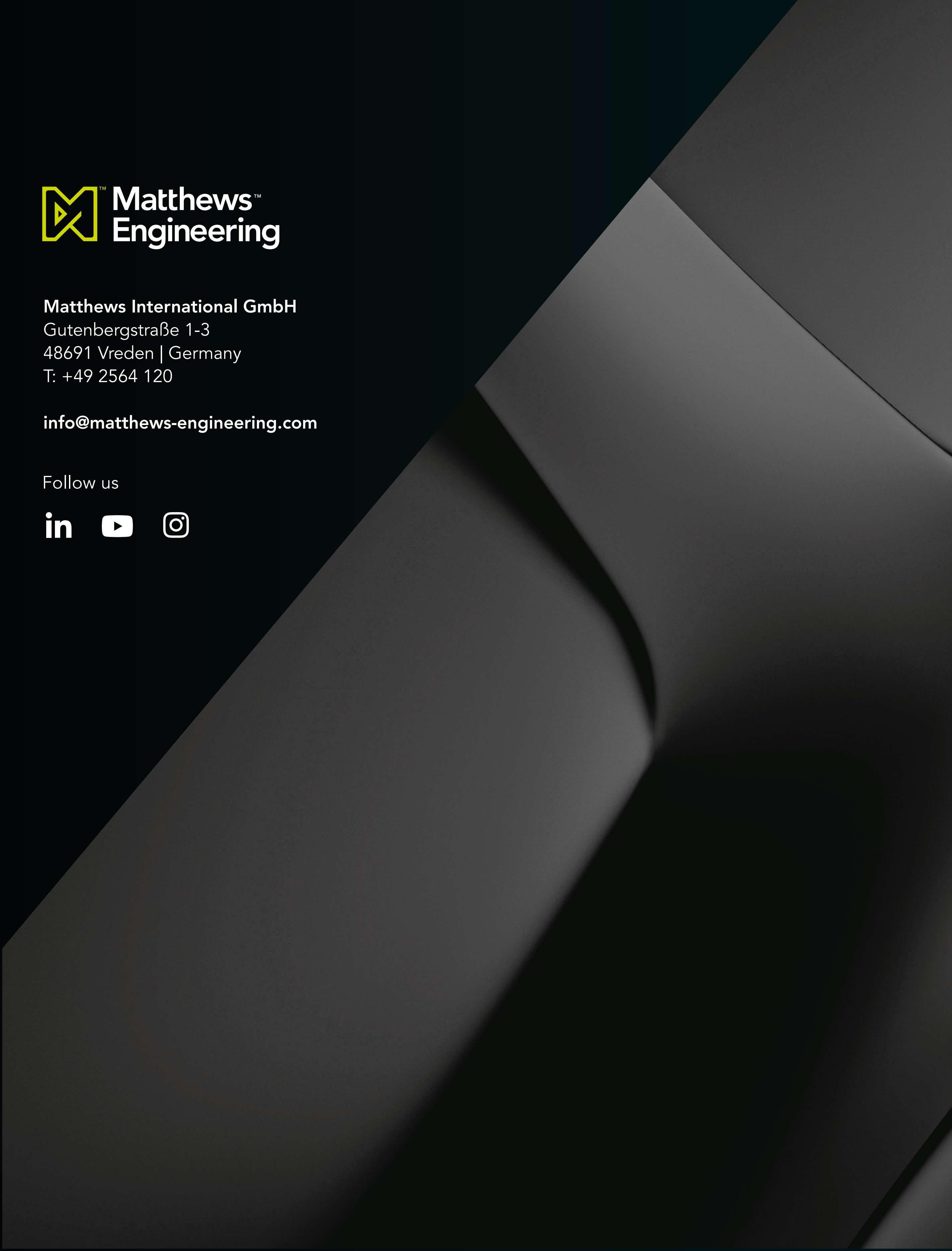

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