ADDIONICS

White Paper

Redefining Battery Architecture: How Smart 3D Current Collectors Unlock Scalable, High-Performance Energy Storage

Next-Generation Batteries by Smart 3D

Executive Summary

The world is rapidly moving toward electrification, a transformation that will reshape not only transportation but nearly every aspect of how we live, work, and interact. From EVs and mobile devices to defense, robotics, and energy storage, batteries are the foundation of this future. As applications multiply, so do the pressures on the battery industry. Performance, cost, scalability, and sustainability must all improve simultaneously to meet global demand.

Yet today's batteries often fall short. Manufacturers face rising costs, scaling bottlenecks, fragile supply chains, and growing pressure to improve efficiency, especially in automotive sectors where batteries must compete with the usability and economics of fuel-powered vehicles. Several high-profile gigafactories have already stalled or collapsed under the weight of outdated strategies and unsustainable unit economics.

For decades, most innovation in batteries has focused on chemistry such as new anodes, cathodes, and electrolytes. While these advances have delivered meaningful gains, progress is slowing, and the industry is approaching the limits of what chemistry alone can achieve.

One of the most overlooked yet powerful opportunities lies in structural innovation. Today's batteries are still built on flat, two-dimensional metal foils known as current collectors. These "inactive" components account for up to 15% of a battery's cost, yet contribute nothing to energy storage. Worse, they limit performance, increase production costs, and slow down manufacturing.

Addionics changes that with a breakthrough in battery architecture: Smart 3D Current Collectors. Our patent-pending, porous metal structure replaces traditional flat foils with a drop-in solution that works with any chemistry and integrates directly into existing manufacturing lines. It enhances all major battery performance metrics simultaneously without trade-offs:

- Higher capacity through increased active material loading
- Faster charging through lower resistance and better thermal regulation
- Longer cycle life enabled by improved adhesion and ionic transport
- Lower cost due to reduced metal use, fewer layers, dry coating compatibility, and faster production

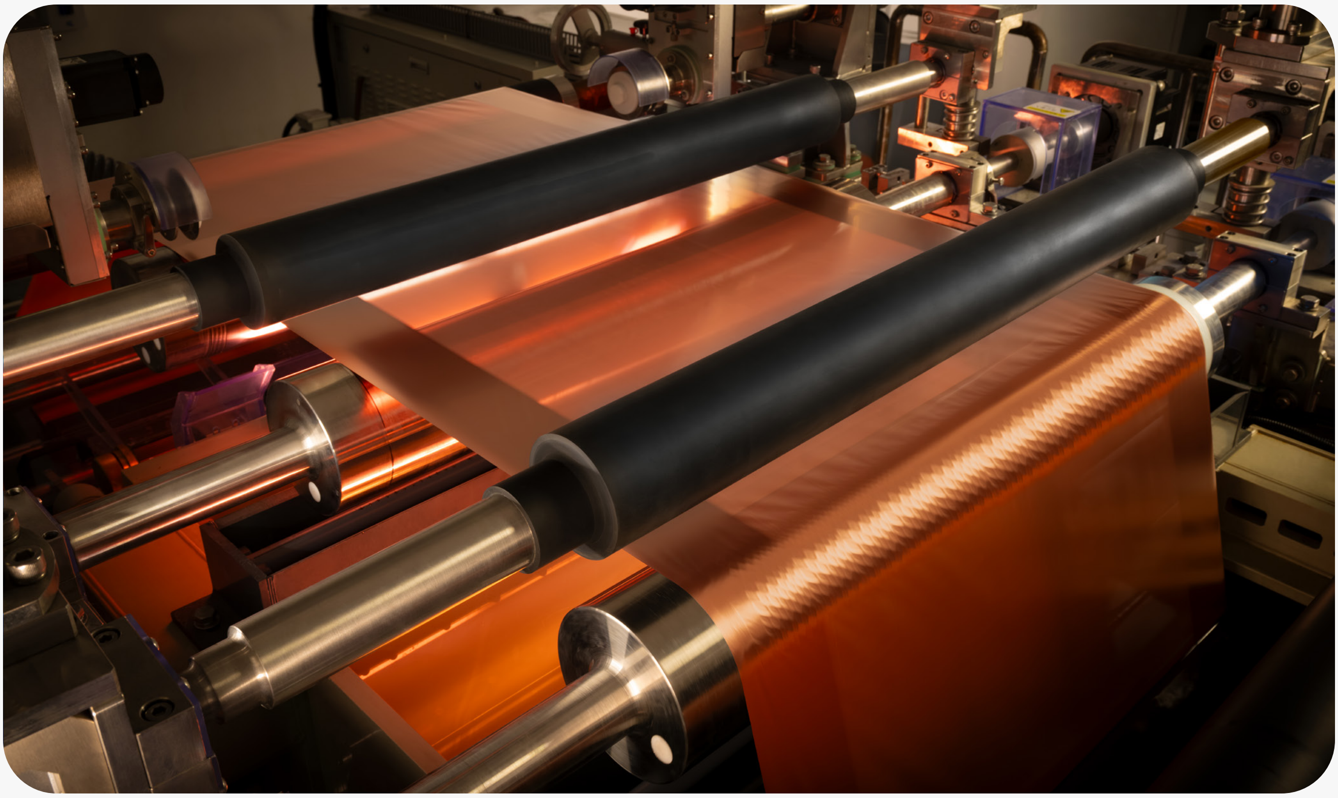
The impact goes beyond incremental gains. By replacing standard 2D metal current collectors with porous, ion-permeable architecture, Smart 3D Current Collectors transform any battery from a collection of independent layers into a unified electrochemical system.

Instead of each anode-cathode pair operating in isolation, the entire cell becomes interconnected, enabling faster ion transport, more uniform reactions, and fundamentally more stable performance. This shift redefines the foundation of lithium-ion batteries and opens the door to a new generation of cell designs.

Beyond performance, Smart 3D Current Collectors unlock new manufacturing possibilities, enabling greener, faster, and more efficient battery production. The technology supports dry coating by creating a mechanically stable structure that eliminates the need for primers, while also allowing faster drying and more efficient electrode wetting in standard wet-coating processes. Through our AI-powered optimization software, we design the ideal metal structure for each application, embedding intelligence directly into the manufacturing process.

This is not a theoretical concept. Addionics is already delivering at scale. Our technology is being produced at industrial volumes, integrated into operational battery assembly lines, and validated by major industry players across automotive, consumer, and defense sectors.

This paper outlines the need for structural innovation and presents Addionics' Smart 3D Current Collectors as a proven, scalable platform. With detailed data, visuals, and application-specific results, we demonstrate how structural upgrades can solve today's toughest battery challenges and unlock the next leap in industrial energy storage.



Scalable, Cost-effective Manufacturing Process

Production Process

While the advantages of 3D Current Collectors have long been recognized in academic research, no company had previously introduced a scalable and cost-effective manufacturing process to bring these benefits to market. This is the core innovation that Addionics has developed. Our primary IP and expertise center on the production process for Smart 3D Current Collectors, covering both copper for anodes and aluminum for cathodes. In other words, we have created the missing link that makes these advanced current collectors practical and accessible for industry-wide adoption.

By leveraging commodity-based and existing manufacturing techniques, Addionics became the first company to develop a highly scalable and cost-efficient production method for 3D Current Collectors in both copper and aluminum.

Addionics' facilities are already operating at a production capacity of 0.5 GWh, supplying partners worldwide. These partners are seamlessly integrating Smart 3D Current Collectors into their existing production lines, bringing this innovation to life at scale.

Drop-In Solution

In the battery industry, any product that cannot integrate seamlessly into existing manufacturing lines faces a nearly impossible path to adoption. That is why, from day one, Addionics designed its solution to be truly drop-in, maintaining high battery-grade quality and allowing manufacturers to replace standard 2D foils with Smart 3D Current Collectors without any modifications.

Our products integrate directly into existing coating procedures, techniques, and machinery, ensuring a smooth transition and rapid adoption. No additional capital investment or operational changes are required.

When using Addionics' 3D Current Collectors in existing manufacturing lines, there is no disadvantage in coating, bleed-through, or efficiency, even though the metal structure is different. By optimizing our 3D porous metal design, we have created smarter, more sustainable, and more cost-effective collectors that improve production efficiency and reduce costs without altering existing processes.

Chemistry-Agnostic Solution

As global demand for improved battery performance and resilient supply chains accelerates, companies are exploring both new chemistries and ways to maximize existing ones. Traditionally, this involves lengthy development cycles of new materials or additives to improve battery behavior.

Addionics takes a different approach. Smart 3D Current Collectors are inherently chemistry-agnostic. They can pair with any battery chemistry, from today's dominant systems to tomorrow's breakthroughs, without requiring changes to the manufacturing line.

This flexibility allows manufacturers to innovate on the chemistry side without being constrained by the structure or performance limits of their current collectors. It also enables measurable improvements across all chemistries.

By focusing on the inactive materials and making the current collector smarter and more efficient, Addionics delivers universal benefits regardless of chemistry. It represents a fundamental shift with impact across the entire battery landscape.

It also means that Addionics unlocks measurable improvements across all battery chemistries. In NMC, it enables increased energy density by allowing higher loading of active material and supports faster charging by improving heat dissipation. In LFP cells, it improves cathode adhesion and contact resistance, eliminating the need for carbon priming. In silicon-based anodes, it improves lifetime by strengthening mechanical stability. In solid-state-lithium-metal batteries, enabling the use of thick cathodes helps unlocking the full potential of that chemistry. Focusing on the inactive materials - specifically, making the current collector smarter and more efficient - delivers universal benefits, regardless of chemistry. It's a fundamental shift with impact across the entire battery landscape.

Cost Reduction

In today's competitive battery market, lowering costs is not just an advantage, it is essential. Addionics delivers substantial cost savings across the entire battery lifecycle by improving both manufacturing efficiency and battery performance.

Smart 3D Current Collectors optimize how batteries are produced, how they perform, and how much they cost to manufacture and operate

Smarter Manufacturing

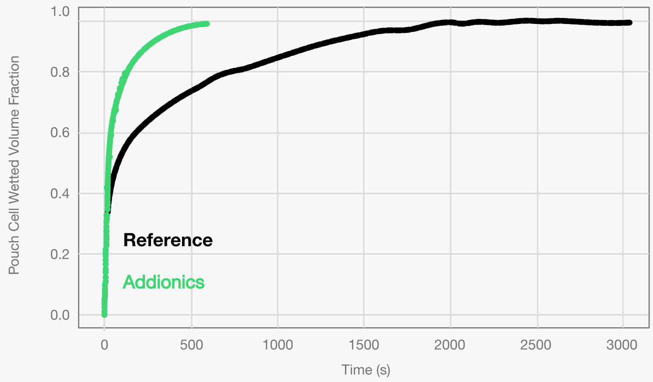


Figure 1: A model of pouch cell wetting time for cells made with Addionics current collectors vs. standard current collectors.

The porous structure enables a more efficient manufacturing process from the start. Improved airflow allows for faster drying cycles with less stringent temperature requirements, reducing total drying time and energy consumption.

Addionics current collectors also enable higher active material loading through improved adhesion and faster drying. This allows for fewer layers in each cell and can reduce the number of processing steps. Every layer requires coating, drying, calendaring, and slitting. By reducing the number of layers per cell, Addionics lowers the total number of process cycles, cutting both time and factory resource usage. This results in meaningful savings, especially at scale.

Enabling dry coating - Dry coating offers major cost and sustainability advantages but has long been limited by weak adhesion on flat foils. Addionics' 3D metal structure allows active material to interlock and adhere from both sides of the current collector, with no priming required, making large-scale dry coating practical and efficient. Manufacturers benefit from higher electrode quality, lower costs, and reduced energy and solvent use.

**Further information on dry coating benefits is provided in a dedicated section*

Enabling Fewer Cells via Better Performance

Addionics technology improves every aspect of battery performance, including energy density, charging speed, and thermal behavior. These gains directly translate into system-level cost savings:

- **Higher loading** results in fewer layers, which means higher energy density and lower cost.
- **Lighter packs** reduce vehicle and drone weight, improving efficiency and lowering energy consumption per mile or flight.
- **Better heat dissipation** allows for simpler and more affordable cooling systems.
- **Flexible structural design** enables space-efficient pack architectures and form factors.
- **Higher energy density** leads to fewer total cells, resulting in lower integration costs and faster pack assembly.

How 3D Porous Architecture Redefines Cell Behavior

The Problem with Conventional 2D Foils

At the core of every battery lies the current collector, a thin, flat metal layer, typically copper for the anode or aluminum for the cathode. While this design has been the industry standard for decades, it imposes significant limitations. Flat metal current collectors are solid and non-permeable to lithium ions, making electrochemical activity highly localized and sensitive to any non-uniformity.

The smooth surface of traditional current collectors also provides poor adhesion, limiting how much active material can be loaded onto the electrode and contributing to mechanical degradation over time. As batteries cycle, expansion and contraction stresses can cause delamination of the active material, leading to capacity loss and shorter lifespan. Standard current collectors further limit heat transfer, complicating thermal management during high-rate charging and discharging. Finally, their simple geometry does not accommodate emerging manufacturing methods such as dry electrode coating without additional primers or complex processing steps.

These structural drawbacks create a bottleneck that chemistry improvements alone cannot overcome. As manufacturers scale production and aim for higher performance, the inherent constraints of 2D current collectors increasingly stand in the way of cost reduction, faster processing, and longer-lasting, safer batteries.

A System-Level Transformation

Porous, ion-permeable current collectors reshape not only how a lithium-ion cell functions but also how it is manufactured. By creating through-plane pathways for lithium ions and electrolyte, they transform electrochemistry from a localized pair-by-pair process into a distributed, stack-wide activity. This shift flattens concentration gradients and enables higher charge and discharge rates.

The same three-dimensional transport topology also cascades into the manufacturing process, enabling two-sided drying, faster electrolyte wetting, and lower levels of residual solvents. At the same time, it boosts durability through mechanical interlocking that minimizes delamination and improves performance by promoting more uniform utilization of active material with fewer hot spots and reduced lithium plating. In short, porous current collectors do not simply fine-tune a single component; they introduce a system-level change that redefines the balance between process efficiency, reliability, and electrochemical performance.

Porous current collectors fundamentally alter ionic transport within the cell. Lithium ions and electrolyte can now traverse the collector itself, opening through-plane pathways that shorten diffusion distances. In conventional dense current collectors, which are impermeable to electrolyte, ionic cross-talk between adjacent layers is blocked and each anode and cathode pair operates largely as an isolated unit cell. Modeling and pouch-cell experiments demonstrate that porous current collectors significantly flatten concentration gradients and increase diffusion-limited rate capability, enabling faster charging and discharging without the usual trade-offs associated with thicker electrodes.

Dense current collectors not only block ion exchange but also restrict bulk electrolyte motion within each layer stack. Ion-permeable structures relax this constraint by adding through-stack channels that allow the electrolyte to redistribute evenly. This promotes uniform reaction distribution, reduces local overpotentials, and extends cycle life. It also accelerates electrolyte infiltration during manufacturing, lowering the time and energy required for wetting and formation.

Improved thermal homogeneity is another benefit, as more even current and reaction distributions minimize localized hot spots. Additionally, the mitigation of electrolyte motion-induced salt inhomogeneity (EMSI) becomes possible. This phenomenon, where salt concentration gradients develop due to electrolyte flow during cycling, has been identified as a new aging mechanism in large-format cells. Porous current collectors help alleviate this effect by facilitating more uniform through-plane electrolyte movement.

Beyond their electrochemical benefits, Addionics three-dimensional porous current collectors improve electrode adhesion through what can be described as “through-pore cohesion.” During double-sided coating, the slurry infiltrates the perforations of the current collector. After drying and calendaring, rivet-like structures of active material form, mechanically locking the coating to the collector from both sides. This interlocking increases real contact area, suppresses delamination under bending and cycling, and enhances electrode durability. The effect often exceeds the adhesion typically achieved by carbon-coated current collectors while also providing additional manufacturing advantages.

Manufacturing efficiency is another major benefit of porous current collectors. Their design allows two-sided, through-plane venting during drying, which means solvent vapors escape not only from the exposed surface of the coating but also through the current collector itself. This reduces the vapor pressure gradient that develops during the drying process, which is the main driver of binder migration and drying-induced cracking under conventional one-sided, high-flux drying conditions. By promoting more symmetric solvent removal, porous current collectors maintain a flatter binder profile, reduce the risk of mechanical defects, and deliver better adhesion at equivalent line speeds.

The advantages continue into the vacuum post-drying phase. The same through-plane escape paths allow residual solvents such as NMP and moisture to desorb and evacuate more efficiently. This results in lower residual levels, which is critical for meeting strict quality standards, especially in high-energy or high-voltage chemistries.

Electrolyte filling is also more efficient and faster with Addionics Smart 3D Current Collectors. In standard dense-metal designs, infiltration is limited to in-plane pathways, which are longer and less efficient. In contrast, porous architectures introduce trans-stack flow paths, allowing electrolyte to infiltrate directly through the shortest possible distance. Because infiltration time scales with the square of the path length, halving the path length can cut filling times by a factor of four. Testing confirms this acceleration in wetting, leading to faster and more uniform electrolyte distribution.

A further benefit is reduced gas evolution during formation. With fewer residual volatiles and more homogeneous wetting, there are fewer side reactions, less HF generation, and lower solvent decomposition during early cycles.

The effectiveness of three-dimensional porous current collectors depends critically on their design parameters. By tailoring hole size, pattern, and distribution to each chemistry and cell format, Addionics maximizes the performance and manufacturability of its current collectors. An optimized structure improves adhesion, ionic transport, and processing stability, while a poorly chosen design can increase resistance, disrupt ion pathways, or cause uneven calendaring.

At Addionics, we are committed to finding the right balance for every application. Our R&D team conducts systematic experiments, building and testing full cells with a wide variety of current collector designs to directly measure effects on rate capability, cycling stability, and manufacturability. In parallel, we employ a suite of multiphysics models that simulate mechanical, fluid, and electrochemical behavior. These tools help predict how geometry influences drying kinetics, electrolyte filling, adhesion, and reaction uniformity before scaling to production.

This combined approach, integrating modeling, theory, and experimental validation, enables Addionics to deliver optimized three-dimensional porous current collectors for every battery chemistry and format. Applications range from high-energy EV cells to long-life stationary storage and demanding aerospace environments where reliability and performance are critical. By precisely tuning each design, Addionics ensures that its current collectors serve as true system-level enablers for the next generation of batteries.

These system-level advantages extend all the way to the electrode interface, where the porous architecture directly enhances both adhesion and conductivity.

Enhancing material loading through better adhesion - The porous structure significantly improves the interface between the active material and the current collector. Unlike flat foils that depend on surface treatments or primers, the 3D design naturally enables active particles to embed within the pore network. This interlocking effect strengthens mechanical anchoring and enhances both handling and electrochemical performance. During cycling, active materials expand and contract, by about 10% for graphite and far more for silicon-based anodes. Loss of contact between the active layer and the current collector is a major source of degradation. Addionics current collectors improve adhesion, as confirmed in pouch cell testing, which shows longer cycle life compared to standard current collectors. Stronger adhesion also supports thicker electrode coatings, enabling higher active material loading without cracking or delamination. In peel-strength tests, Addionics collectors demonstrated up to four times stronger adhesion than conventional foils, directly translating into greater durability and reliability.

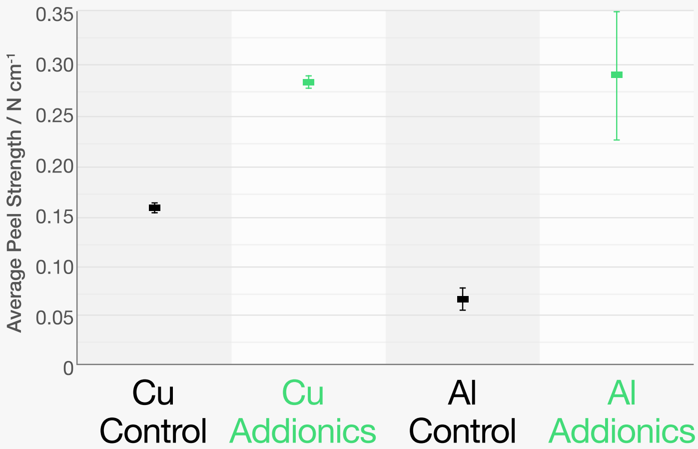
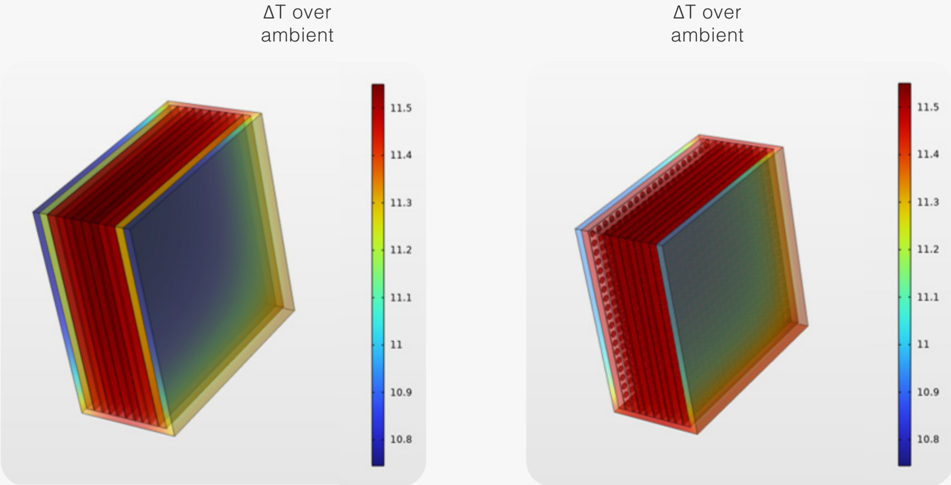


Figure 2: The peel strength of Addionics electrodes vs electrodes built with standard current collectors. Addionics current collectors show ~2X improvement in peel strength for copper and ~4x improvement for aluminum.

Improving conductivity and thermal management - Beyond mechanical benefits, the 3D porous structure enhances both electrical and thermal performance. The interconnected metal network provides continuous conductive channels that lower internal resistance and distribute current evenly across the electrode. This structure also serves as a thermal pathway, spreading heat efficiently and minimizing localized hot spots. The result is improved ionic transport, higher power capability, faster charge cycles, and increased safety margins.



Regular cell

Cell containing Addionics CC

Figure 3: model heat dissipation in cells that are built with standard current collectors vs. Addionics current collectors show that Addionics current collectors reduce contact resistance which lowers heat generation. Addionics current collectors improve heat transport through the cell, reducing the Temperature differential between center and outer layers.

Improving Battery Performance with 3D Current Collectors

Battery Lifetime

Battery lifetime is one of the most important yet most underestimated factors in the success of electrified products. Whether in electric vehicles, mobile devices, or energy storage systems, longer battery life reduces total cost of ownership, improves sustainability, and strengthens OEM reliability. Addionics Smart 3D Current Collectors extend lifetime by addressing the core structural and thermal challenges inside the battery.

Traditional battery degradation is accelerated by heat buildup, mechanical stress, and unstable interfaces between layers. These issues become even more severe under high-rate operation, extreme temperatures, or when using advanced chemistries such as silicon or solid-state. Addionics addresses these challenges through architecture rather than additives, creating a more stable structure from the inside out.

How Addionics Improves Battery Lifetime:

- **Better heat distribution** - The 3D metal structure spreads heat more evenly across the electrode, avoiding thermal hot spots that accelerate aging. Improved thermal behavior helps cells maintain stability even under fast charging or high current loads.
- **Stronger mechanical integrity** - The porous current collector structure reinforces the electrode, reducing common failure modes such as cracking, delamination, or electrode separation. This is especially valuable for high-expansion materials like silicon or thick solid-state layers.
- **Improved volume change management** - Addionics current collectors are better at handling volume changes caused by electrochemical cycling. This minimizes mechanical fatigue that can occur during repeated charge and discharge cycles.
- **Slower chemical degradation** - Improved ionic pathways enable more uniform reactions within the electrode, reducing unwanted side reactions such as gas formation and lithium plating that shorten battery life.

In practical terms, Addionics-enabled batteries experience significantly less degradation over time. They retain more capacity over hundreds or even thousands of cycles, especially in demanding use cases such as electric vehicles or drones. The result is fewer replacements, longer warranties, and better performance retention, benefiting both manufacturers and end users.

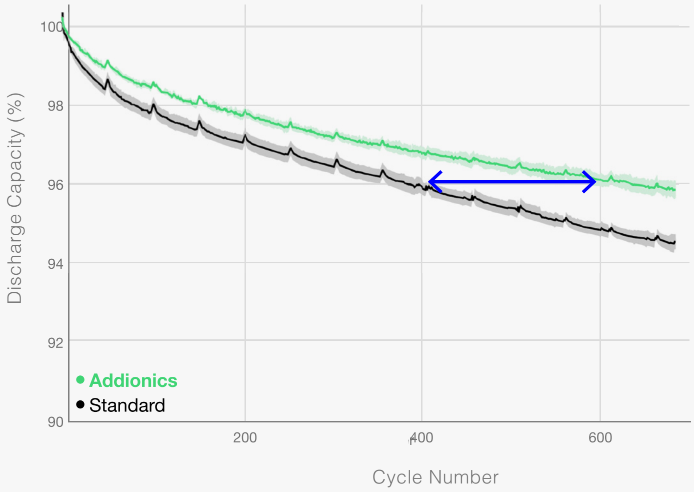


Figure 4: The % discharge capacity vs. cycle # of cells built with Addionics current collectors vs. standard current collectors. Addionics cells have improved capacity retention over cycles by 50% (~600 cycles vs. the ~400 cycles of the standard cells for the same capacity).

Higher Energy Density

Increasing battery capacity without increasing size or weight is one of the most critical challenges in energy storage. Addionics addresses this by enabling higher energy density at the cell level, not by changing chemistry but by improving how the battery is built. Smart 3D Current Collectors allow for greater active material loading and more efficient use of space within the cell, directly translating into higher capacity.

Traditional flat current collectors limit how much active material can be applied to the electrode. Beyond a certain thickness, internal resistance rises, mechanical integrity declines, and overall performance drops. Addionics 3D porous metal architecture changes that balance.

How Addionics Increases Battery Capacity:

- **Higher active material loading** - The 3D porous structure allows thicker electrode coatings to be applied without sacrificing conductivity or stability. This increases the total amount of lithium-storing material per layer.
- **Improved ion transport in thick electrodes** - In conventional cells, thicker electrodes slow down ion diffusion, creating bottlenecks. Addionics structure maintains open ionic pathways deep within the electrode, enabling high capacity with fast response.
- **Stronger structural support** - The 3D current collector acts as a mechanical

backbone for the electrode, preventing cracking, delamination, and warping even when higher volumes of active material are used.

- **Optimized electrode utilization** - The smart geometry distributes current and ions more evenly, ensuring efficient use of the full depth of the electrode, not just the surface layers.

The result is a meaningful increase in both gravimetric and volumetric energy density. Cells that use Addionics technology can achieve higher total capacity using the same or fewer layers, allowing manufacturers to either extend runtime or reduce battery size and weight without compromising performance.

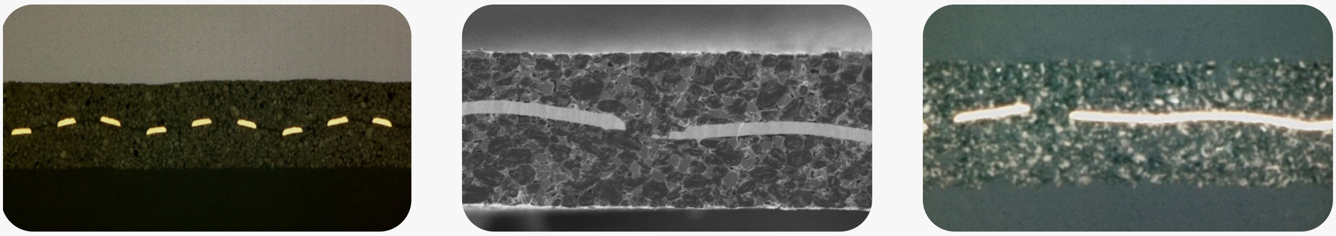


Figure 5: Cross section of electrodes made with Addionics current collectors are shown above.

Fast Charging

Fast charging is a key enabler for electric mobility and high-performance applications. It reduces wait time, improves user experience, and allows smaller batteries to meet demanding use cases. Achieving true fast charging, however, depends not only on how much power is supplied but also on what happens inside the cell. Addionics Smart 3D Current Collectors transform internal current and ion pathways, making high-rate charging safer, more stable, and more efficient.

Conventional batteries struggle with heat buildup, degradation, and uneven current distribution when operated at high C-rates. Addionics solves these issues by redesigning the current collector into a porous 3D structure that improves both ion and electron flow across the electrode.

How Addionics Enables Fast Charging:

- **Shorter ion pathways** - The 3D architecture reduces the distance lithium ions must travel during charging, allowing faster diffusion and improved charge acceptance at high rates.
- **Lower internal resistance** - Enhanced conductivity across both ionic and electronic channels minimizes ohmic losses and limits heat generation during high-rate operation.
- **High-rate cycling stability** - The structure naturally channels current through more efficient pathways under stress, allowing repeated fast charging without damaging the cell.

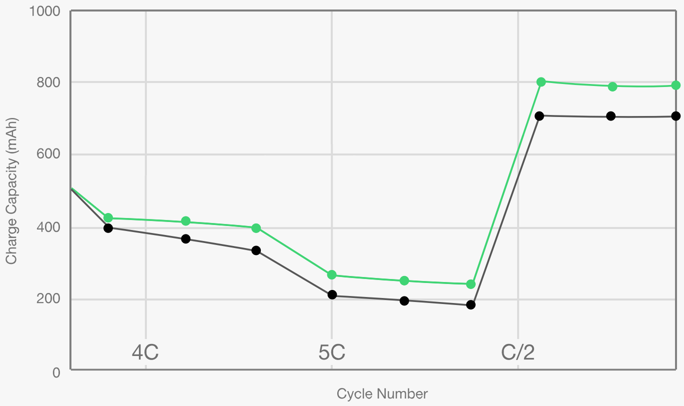
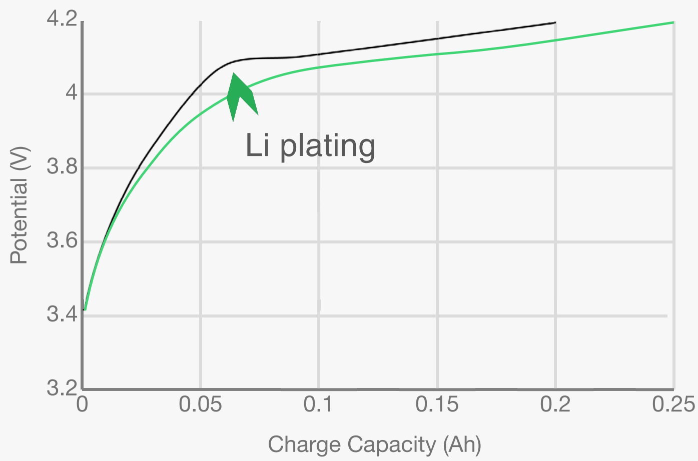


Figure 6: Charge rate capability in pouch cells made with standard current collectors (black) and Addionics current collectors (green). Addionics cells had improved charge rate capability at fast rates (4C, 5C) and had improved recovery after charge rate testing. This indicates that not only can Addionics cells improve high charge rate performance, but they also have less degradation at these high rates.

In real-world testing, Addionics-enabled batteries support sustained fast charging at rates up to 5C, charging a battery from 0 to 30% (approximately 150 km of EV range) in just three to four minutes. Unlike traditional cells that must reduce charge rates to control heat and degradation, Addionics cells maintain high-speed charging without compromising safety or lifetime.

Figure 7: A voltage curve of a cell with standard current collectors (black) and Addionics current collectors (green) at a very fast charge rate (5C). The voltage curve of the standard cell had a characteristic bump in it that is likely to be lithium plating whereas the voltage curve Addionics cell does not. This indicates that Addionics current collectors can promote higher charge rates without detrimental side reactions like lithium plating.



Cylindrical Cell Design Optimization

Today's cylindrical cell designs are inherently wasteful because they require excess anode material. To achieve the correct negative-to-positive (N/P) ratio in the outer layers of the cell, additional anode material must be applied to the inner layers, where it is never fully utilized.

The N/P ratio in cells is extremely important. If the ratio is too large, excessive SEI can form, and the active material is not fully utilized, which can reduce both cell lifetime and energy density. In cylindrical cells, maintaining a balanced N/P ratio is particularly challenging due to curvature and changes in jelly roll radius from the inner to the outer layers.

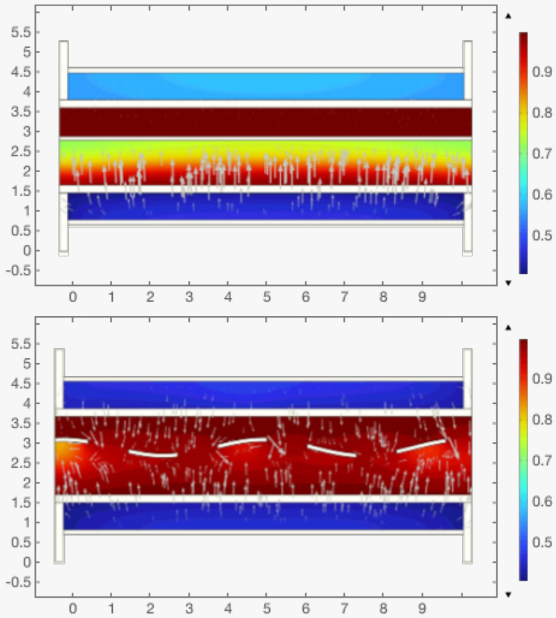


Figure 8: A model of a standard electrode (top) and Addionics electrode (bottom) showing ionic transport through Addionics current collector which leads to a more balanced ionic concentration.

In cylindrical cells the local N/P ratio can be calculated as:

N/Plocal= N/PAreal(1±2∂/r) [∂ - single sided stack pitch]

This variation in radius causes the N/P ratio to change from the outer radius to the inner radius. The resulting swing in N/P ratio reduces anode efficiency, since higher loading is required throughout the entire length of the roll. The effect becomes more severe when r < 2.5 mm. A simple mitigation is to increase the minimum radius of the jelly roll, but doing so also reduces energy density, especially in 18650 and 2170 cell formats.

Addionics 3D porous current collectors inherently balance the electrode because the structure is permeable to ions. The electrochemical boundary of the two-sided anode helps regulate the balance between the two adjacent cathodes. Just based on this simple design change with Addionics, anode material can be reduced by 5-6% with no change to performance.

Improved Safety

Safety is a non-negotiable requirement in battery development. Whether for electric vehicles, consumer electronics, aviation, or defense, the risk of thermal runaway, short circuits, or mechanical failure must be minimized by design, not left to chance. Addionics improves battery safety at the cell level by engineering a smarter, more stable foundation inside every electrode.

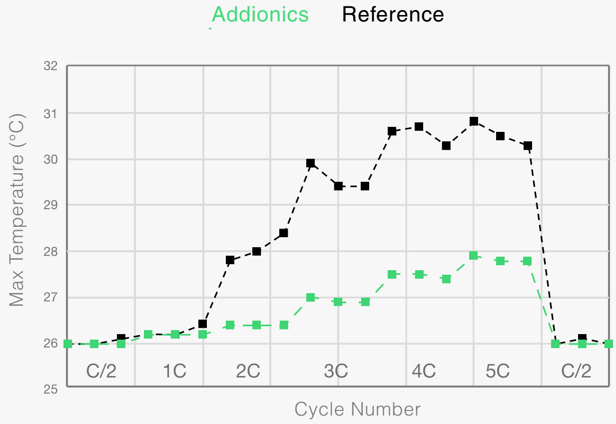


Figure 9: Temperature generated during charge rate is reduced for Addionics cells (green) vs. standard cells (black).

Instead of relying on external management systems to correct failure risks after they arise, Addionics' Smart 3D Current Collectors reduce the probability of failure at the source. Their porous structure improves temperature regulation, suppresses hot spots, and reinforces internal stability, resulting in safer batteries across all chemistries and applications.

How Addionics Enhances Battery Safety:

- **Better heat dissipation** - The 3D metal architecture spreads thermal energy more evenly across the electrode. This prevents local temperature spikes that could lead to thermal runaway, especially during fast charging or heavy load conditions.
- **Lower internal resistance** - Reduced resistance means less heat is generated during high-rate operation, helping to maintain a safe thermal profile even under demanding use.
- **Improved mechanical stability** - The porous structure acts as a mechanical buffer, reducing the risk of cracking, delamination, or short circuits caused by electrode deformation during cycling.
- **More stable interface** - Better contact between the current collector and active material leads to fewer stress points and more predictable electrochemical behavior over time.
- **Mitigates lithium plating** - The uniform current distribution helps prevent lithium metal buildup on the anode, a known cause of dendrite formation and internal short circuits.

Together, these features reduce the likelihood of internal failure and extend the battery's safe operating window across a wide range of temperatures, C-rates, and use conditions. Instead of managing safety through layers of external controls, Addionics makes batteries inherently more robust by design.

Smarter Battery Manufacturing with Addionics

Shorter Drying Time

Energy consumption contributes approximately 5.5% of total cell cost on a $/kWh basis, making it a meaningful factor in overall battery production economics. Reducing electrode drying time directly lowers this energy cost, while also enabling shorter oven lengths and faster manufacturing throughput. Modeling shows that electrodes using Addionics porous current collectors dry up to 25% faster than standard current collectors at any given air speed, offering a clear efficiency advantage.

This improvement can be achieved as a drop-in solution within existing production lines, requiring no equipment modifications. By enabling drying at lower temperatures, manufacturers can maintain or even enhance performance while reducing operational expenses. The result is a significant reduction in production costs and a measurable increase in manufacturing efficiency, contributing to more sustainable and cost-effective cell production.

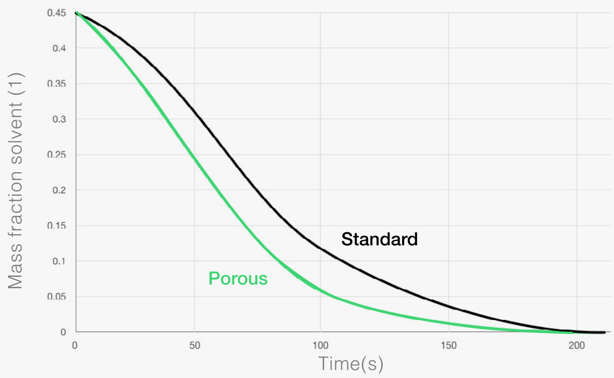


Figure 10: A model of drying time for electrodes made with Addionics current collectors vs. standard current collectors shows a 25% faster drying time.

Shorter and Better Electrolyte Soaking and Wetting

Electrolyte filling is one of the most time-consuming and costly stages in battery manufacturing, often taking up to 24 hours to complete. This step is critical because uniform soaking of the electrodes before formation directly affects battery performance, durability, and safety. Any inefficiency or inconsistency during electrolyte infiltration can lead to performance degradation, uneven formation, or reduced cycle life, making improvements in this process highly valuable for large-scale production.

Addionics porous current collector technology fundamentally changes electrolyte filling dynamics. In conventional solid current collectors, the electrolyte can only travel parallel to the collector layers, meaning wetting scales with electrode area. This limitation slows down the filling process, especially for large-format cells. In contrast, Addionics porous current collectors enable electrolyte transport both in-plane and through-plane, allowing it to move more freely throughout the electrode stack. This structural advancement means that electrolyte wetting now scales with stack thickness, not just area, facilitating faster and more uniform soaking throughout the cell.

As a result, Addionics materials achieve substantial improvements in wetting efficiency across multiple cell formats: up to ten times faster in 60 × 10 × 1 cm pouch cells, seven times faster in 2170 cells, and four times faster in 4680 cells. In addition to accelerating the filling process, the improved electrolyte distribution also reduces gas generation during formation, indicating fewer side reactions and a more stable electrochemical environment. Altogether, the enhanced electrolyte transport enabled by Addionics porous current collectors not only saves time and manufacturing costs but also contributes to superior cell quality, longevity, and performance.

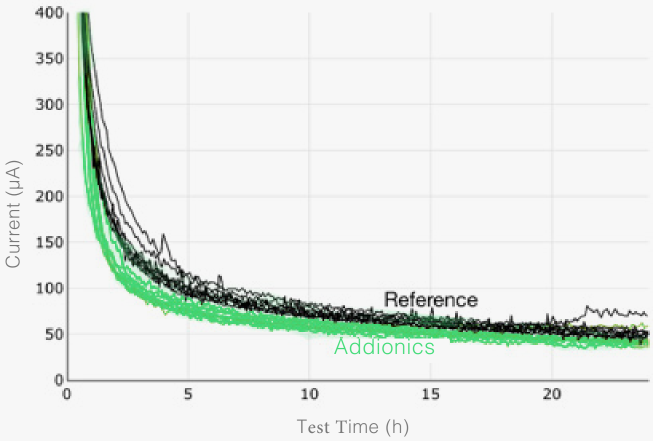


Figure 11: In 18650 cylindrical cells, Addionics cells had a faster current drop and lower overall capacity during the wetting step indicating faster and more efficient wetting.

Reducing Gas Formation with 3D Current Collectors

Gas formation during battery formation cycles poses a significant challenge to cell performance and production yield. As the electrolyte reacts with electrodes during early charging, it forms protective SEI and CEI layers but also generates unwanted gases like hydrogen and volatile organic compounds. While these gases can be removed in pouch cells, continuous gas generation can lead to swelling, capacity fade, and even internal damage if not properly managed.

Addionics Smart 3D Current Collectors address the root causes of gas generation by improving both the physical and electrochemical environment inside the cell. The more efficient drying enabled by Addionics current collectors creates a drier environment with less opportunity for gas-producing reactions to occur. There is more complete solvent and moisture removal than in flat foils, reducing the water content that would otherwise trigger hydrogen and HF formation.

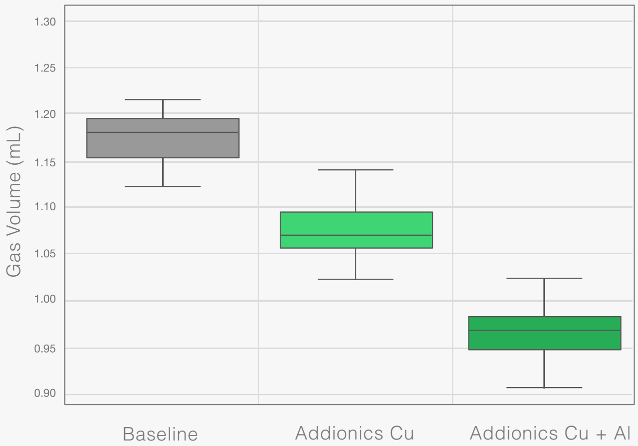


Figure 12: Gas volume removed after formation from 1Ah pouch cells built with standard current collectors and Addionics current collectors.

Beyond drying, the 3D structure ensures more uniform electrolyte wetting throughout the electrode. This prevents dry pockets and overpotentials that typically accelerate gas-producing side reactions. The result is a more controlled and even growth of SEI and CEI layers, minimizing excess gas and improving cycle stability.

The porous network also facilitates improved gas transport and release during formation. Gases diffuse more freely through the structure, avoiding pressure buildup that leads to interphase cracking and decomposition. The improved architecture supports more uniform current distribution and better ionic transport at the current collector interface, lowering overpotentials and reducing parasitic reactions.

In real-world testing, Addionics 3D Current Collectors reduced gas formation by up to 19% in NMC-based pouch cells and 23% in LFP cells during formation cycles. These results span both cathode and anode applications, confirming the cross-chemistry advantage of the approach.

By minimizing gas formation, Addionics helps manufacturers shorten degassing time, improve safety, increase formation yield, and lower operational costs, all while maintaining high-performance interphase integrity. It represents a cleaner, more reliable, and more efficient pathway to next-generation battery production.

Enabling Dry Coating Through 3D Porous Current Collectors

Dry coating is one of the most promising advances in battery manufacturing. It eliminates solvents, shortens processing time, cuts energy use, and reduces environmental impact. However, despite growing interest, most dry coating efforts have struggled to scale.

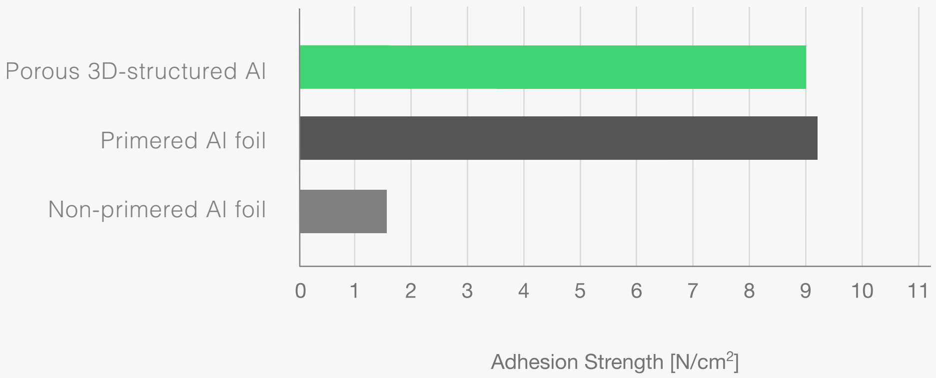


Figure 13: Cathode peel strength of dry coating on Addionics current collector, primed aluminum foil, and standard aluminum foil. Addionics current collector has similar peel strength to primed aluminum foil and significantly higher peel strength than standard aluminum foil.

A key challenge lies in adhesion. Dry electrode materials do not naturally bond well to flat, solid metal current collectors, resulting in weak contact, delamination, and yield loss. To overcome this, many manufacturers use primed current collectors. Yet priming is a wet process that adds cost and complexity to the entire coating stage.

Addionics solves this challenge with a fundamentally different structure. The 3D Porous Current Collector features a precisely engineered network of holes that allows dry-coated active materials to physically engage from both sides. Rather than sitting on top of a smooth surface, the particles partially embed within the porous framework of the current collector, interlocking through the holes and creating a mechanically anchored bond.

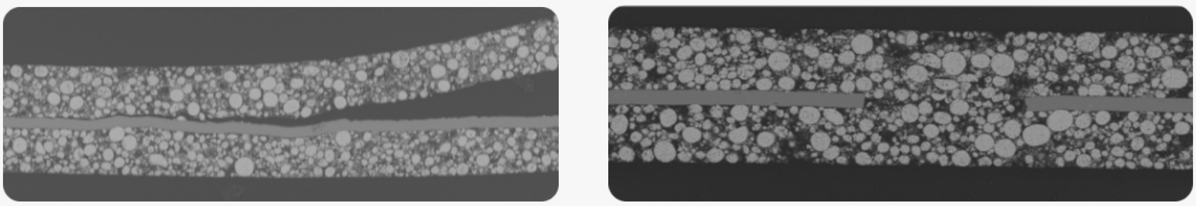
This through-pore architecture strengthens the connection between the electrode and the current collector while forming a more uniform, cohesive layer across the entire surface. Adhesion is achieved through geometry rather than chemistry, eliminating the need for primers or additives and supporting higher active material loading. The result is a stable, high-strength interface that remains compatible with high-throughput dry coating processes.

This mechanical interlocking mechanism is what makes dry coating scalable. It stabilizes the electrode by design, maintaining structural integrity throughout high-speed manufacturing and repeated cycling.

Alongside this core advantage, Addionics' 3D structure provides several benefits:

- **No primer required.** Primer is typically needed to improve adhesion on flat foils, but with Addionics it becomes unnecessary. Removing this step significantly simplifies production and cuts material costs.
- **Better process compatibility.** The structure is ideal for dry coating methods that require physical compression rather than wet slurry spreading. It supports stable, uniform electrodes even in thin layers.
- **Faster and greener production.** Without solvents or primer drying, the manufacturing process becomes faster, cleaner, and less energy-intensive.
- **Line-ready design.** The 3D current collectors work with existing and future dry coating equipment, enabling seamless adoption in advanced battery factories.

By unlocking mechanical adhesion through structure rather than chemistry, Addionics makes dry coating practical and scalable. Manufacturers can reduce factory footprint, speed up throughput, and eliminate costly materials, all while improving battery performance and sustainability.



Reference Standard foil

Addionics porous Al Current Collector

Figure 14: SEM images of electrode cross sections of dry coated standard aluminum foil (left) and Addionics aluminum current collector (right). Addionics current collector enables improved adhesion of the dry coating over the standard aluminum foil.

Addionics AI Platform for Current Collector Design Optimization

Battery innovation has historically focused on chemistry, but Addionics is proving that structure matters just as much, and is using artificial intelligence to design it smarter than ever before.

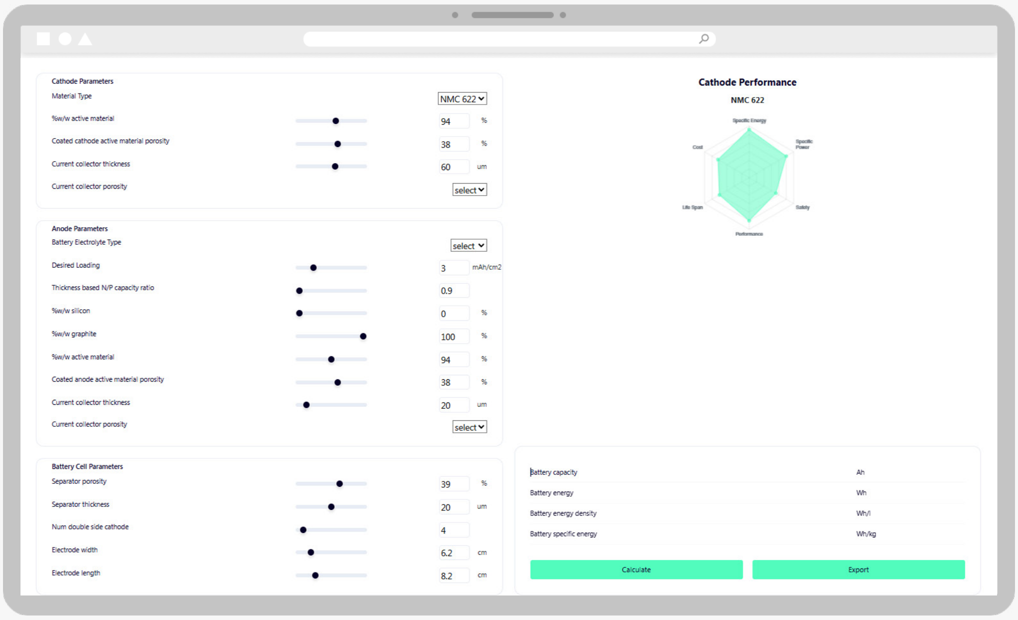


Figure 15: Addionics AI model.

Addionics has developed a patent-pending AI-based optimization platform that integrates directly into the battery development process. This platform uses advanced structural modeling and machine learning to determine the ideal 3D current collector structure for any given application. By simulating and predicting how different structures will influence battery performance, the software can identify the optimal geometry, tailored to chemistry, use case, and system-level requirement.

In addition to traditional battery modeling tools, which focus primarily on energy distribution or pack-level thermal management, Addionics platform operates at the cell and electrode level. It analyzes structure-property relationships inside the battery and designs the architecture accordingly. This enables a new level of precision in performance tuning, material efficiency, and application-specific optimization.

In short, Addionics AI platform transforms battery design from a slow, experimental process into an intelligent, data-driven development cycle that delivers performance, cost, and time advantages across the entire value chain.

Unlocking the Full Potential of Every Battery Chemistry

Battery performance today is limited not just by chemistry but by structure. The conventional 2D current collector has become a bottleneck across all major battery types, restricting energy density, cycle life, and manufacturability. Addionics Smart 3D Current Collectors offer a universal structural upgrade that delivers significant performance and cost advantages across every major chemistry, from today's lithium-ion systems to tomorrow's solid-state and silicon-dominant batteries.

LFP (Lithium Iron Phosphate)

LFP is gaining momentum across energy storage and electric vehicles applications due to its exceptional safety, thermal stability, and affordability. However, its low energy density and poor electronic conductivity have traditionally limited its use in high-performance systems.

Addionics' 3D Current Collectors directly address these limitations. The porous structure significantly increases the interface between the metal and active material, enhancing conductivity and enabling higher active material loading. This results in greater energy density, less reliance on conductive additives, and lower overall costs per kilowatt-hour.

The 3D design also enables the use of thicker electrodes, reducing the number of layers required and improving manufacturing efficiency. This makes LFP not only a safe and low-cost option but also a viable high-performance solution for mainstream EV and storage applications. Addionics architecture supports fast charging and compact pack designs, helping LFP reach its full potential in a broad range of use cases.

NMC (Nickel Manganese Cobalt)

NMC remains the chemistry of choice for premium electric vehicles, offering high energy density and strong power performance. However, increasing cost pressures and evolving performance expectations have exposed limitations in charging speed, mechanical stability, and production efficiency.

Addionics 3D structure improves NMC performance on multiple fronts. It enables higher active material loading for longer driving range without increasing battery size. At the same time, it reduces internal resistance, improving both charge and discharge rates. The porous framework also enhances mechanical integrity, minimizing cracking, delamination, and other degradation over time. These benefits apply across NMC variants, including 622, 811, and future high-nickel formulations.

Solid-State Batteries

Solid-state batteries are widely considered the next frontier in energy storage, offering higher energy density and improved safety by replacing flammable liquid electrolytes with solid materials. However, scaling these batteries remains challenging due to manufacturing complexity and structural limitations, particularly around cathode thickness.

Addionics 3D Current Collectors provide a scalable solution by supporting thicker cathodes without compromising mechanical or thermal stability. The porous design improves ion transport, reduces the risk of delamination, and ensures even heat distribution, allowing manufacturers to extract more capacity without sacrificing safety or lifetime.

Silicon-Based Anodes

Silicon anodes can deliver up to ten times the capacity of traditional graphite, promising a major leap in battery energy density. Yet silicon expands and contracts significantly during cycling, which leads to mechanical degradation and reduced battery life.

Addionics 3D structure acts as a flexible metallic scaffold that absorbs silicon expansion, maintaining structural integrity and extending cycle life. This makes higher silicon content feasible, whether in hybrid blends or pure-silicon formats, without the trade-offs that have limited commercial adoption. Addionics technology supports both near-term silicon integration and long-term transition pathways toward next-generation energy performance.

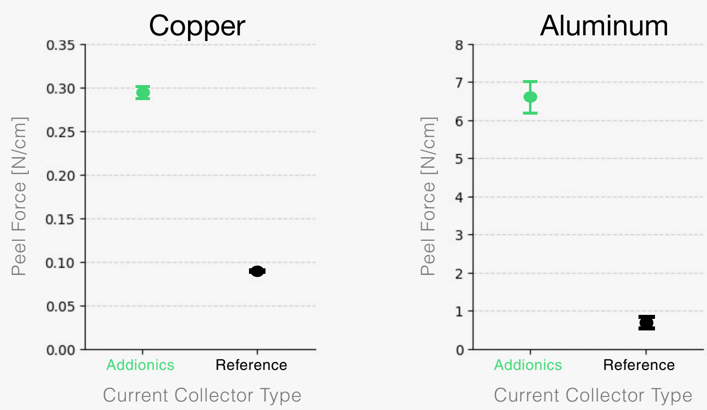


Figure 16: LFP Peel strength tests for copper (left) and aluminum (right) current collectors. Addionics current collectors show at least a x3 improvement in peel strength compared to standard current collectors.

Chemistry-Agnostic Platform

Addionics Smart 3D Current Collectors provide a universal structural upgrade that enhances performance across all battery chemistries, from those widely used today to next-generation systems that are still emerging. The same design principle applies to every chemistry: by rethinking the fundamental architecture of the current collector, Addionics improves how any cell stores, transports, and delivers energy.

The examples highlighted in this paper represent several key chemistries currently shaping the market and those expected to enter large-scale production in the coming years. The technology is designed to integrate seamlessly with diverse battery architectures and chemistries, delivering meaningful gains in energy density, lifetime, cost efficiency, and manufacturability without requiring changes to chemistry or production lines.

This chemistry-agnostic approach makes Addionics 3D architecture a truly foundational solution for the battery industry, empowering manufacturers to optimize current technologies while seamlessly preparing for the next generation of energy storage.

The Green Impact of the Technology

Addionics chemistry-agnostic approach allows the company to adapt to environmentally friendly materials and evolving regulations, enabling battery manufacturers to adopt new chemistries that rely on fewer scarce resources. Beyond its performance advantages, Addionics proprietary manufacturing process is inherently more sustainable than conventional methods.

The company's AI-driven optimization and energy-efficient drying process improve manufacturing efficiency and reduce embodied emissions across the production chain. The Smart 3D architecture allows higher active material loading and fewer layers per cell, reducing raw material usage and waste. The technology is fully compatible with recycled copper and aluminum, supporting circular economy principles and minimizing the environmental footprint of each battery. Addionics uses 100% recycled copper to produce its advanced 3D anode current collectors, strengthening both sustainability and supply chain resilience.

The same structural advantages that improve performance also extend battery lifetime, reducing the need for replacements and minimizing lifecycle waste. Addionics innovation enhances electric vehicle efficiency by improving range, charging speed, and durability, while lowering emissions across multiple chemistries.

Addionics leadership in sustainable innovation has been widely recognized. In April 2022, the company received the BloombergNEF Pioneer Award, honoring breakthrough technologies driving global decarbonization. Addionics was also featured in Bridges' Annual Impact Report 2021, which highlighted that its 3D architecture enhances the performance of multiple battery chemistries and significantly reduces CO^2 emissions per battery pack. Additional recognition includes first place in the Movin'On Michelin Startup Challenge in the Preserving Resources category, as well as a €2.3 million EU Horizon 2020 grant for environmental impact, describing the technology as disruptive and potentially a game changer in the energy storage market.

Addionics: From Innovation to Industrial Transformation

Every major leap in battery technology has come from rethinking what is possible. Chemistry brought the industry this far; structure will take it further.

Addionics Smart 3D Current Collectors represent a fundamental shift in how batteries are designed, built, and scaled. By embedding intelligence and functionality directly into the metal architecture, Addionics transforms the current collector from an inert layer into an active enabler of higher performance, faster manufacturing, and more sustainable production.

This is not just the next chapter in battery evolution; it is the foundation for a new one, a world where faster charging, longer lifetime, and lower cost are achieved not through trade-offs but through better design.

With 3D Current Collectors already produced at scale and integrated into commercial production lines, structural innovation has moved beyond theory. It is now shaping the batteries that power vehicles, devices, and industries worldwide.

The future of energy storage is three-dimensional, and it has already begun.