Enabling Lithium Metal Anode Manufacturing at Giga-Scale

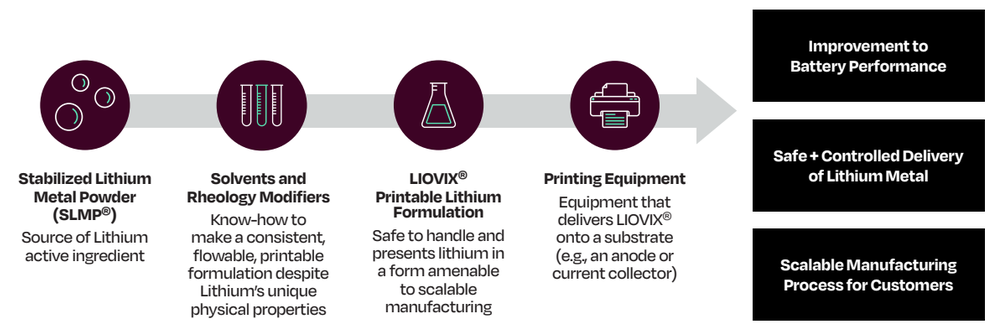
Introduction

The commercial success of rechargeable lithium batteries in electronic devices since the 1990s has been remarkable. Technologies in the field continue to develop to make batteries safer, longer lasting and more powerful. Emerging lithium battery technologies such as solid-state batteries utilize, for example, ultra-thin lithium metal foil due to lithium metal's high specific capacity[1,2] (3860 mA h g^{-1}). However, traditional thin lithium foil manufacturing methods have proven challenging at scale due to metal reactivity, poor foil tensile strength and safety concerns.[3] Additionally, lithium metal foil is needed in a variety of thicknesses and widths which are important for advancing lithium metal-based batteries. Fortunately, ultra thin, variable width lithium foil can be produced using industry standard technologies when using LIOVIX® Printable Lithium Technology, our proprietary printable formulation of lithium metal and other specialty materials.

The LIOVIX® formulation can be coated using slot die technology on roll-to-roll equipment. The formulation can be shipped, transferred to the production floor, mixed and delivered to the slot die head without exposing metallic lithium to air. This approach allows achieving uniform coating with thicknesses ranging from 5 µm to 50 µm at a variety of coating widths. The application of LIOVIX® is noteworthy for offering a strategic advantage in large scale manufacturing while maximizing the electrochemical performance.

What is LIOVIX®?

LIOVIX® Printable Lithium Technology, describes the collective set of Arcadium Lithium intellectual property that allows lithium to be deposited onto a substrate in a safe, controlled, scalable manner.



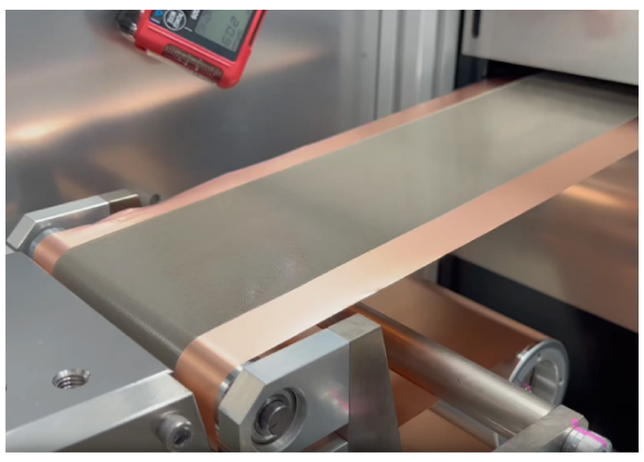
Proprietary technology uniquely positioned to enable next generation battery production through pre-lithiation and lithium metal anodes

Comparison of Alternative Thin Lithium Film Technologies

Pathway	Performance	Scalability	Economics	Safety
Thin Foil (<20micron)	Lot-to-lot variations	Throughput issues, width limitation, in-roll sticking	Requires special rolling and transfer equip., Li contaminated protected film disposal	Similar to commercial thicker foils
Lithium Vapor Deposition	Lot-to-lot variations	Thicker Li deposits are slow (results in low throughput)	Requires expensive equipment	Residual lithium in vacuum chamber requires special treatment to mitigate fires when exposed to air
Molten Lithium	Lot-to-lot variations	Low efficiency	Requires argon for safe operating conditions	Molten lithium is too dangerous to handle
Electro Chemical	Corrosion of the current collector might cause performance issues	Throughput is slow, thus low efficiency	Less expensive lithium salt, but complicated process (capex to wash, dry, gas capture)	Electrolysis generates vapors that need to be treated
LIOVIX®	Consistent lot-to-lot	Cell manufacturing throughput speeds	Standard industry equipment	Stabilized lithium contained in formulation

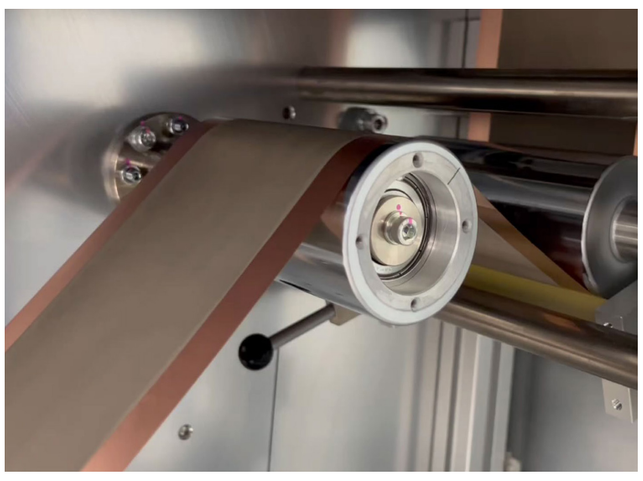
LIOVIX® Technology is a balanced and strong candidate for widespread adoption

LIOVIX® Thin Foil Manufacturing



- Common industrial coating techniques can be applied.
- Coating speed comparable to giga-scale manufacturing.

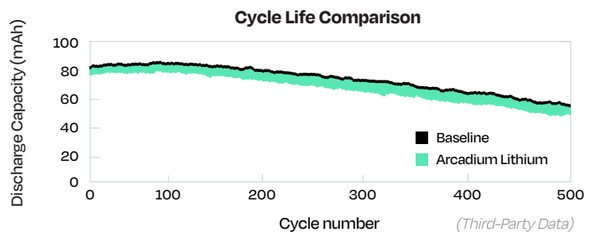
LIOVIX® Lithium Anode Roll-to-Roll Double-Side Coating



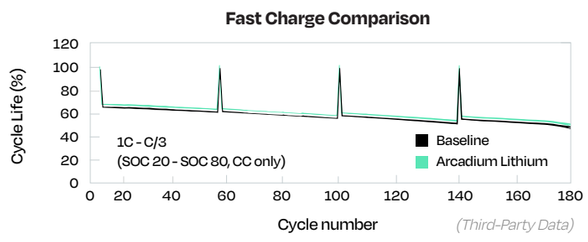
- Process for producing double sided electrode with controlled thickness and desired width has been demonstrated.

LIOVIX® Thin Foil Cell Performance

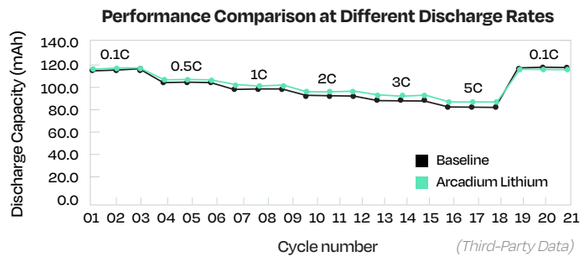
LIOVIX® 20µm vs. Commercial 20µm Thin Foil



- LIOVIX® composite electrode demonstrates similar performance to the commercial electrode.



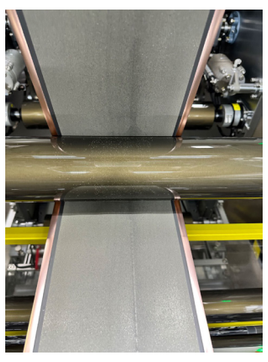
- LIOVIX® composite electrode demonstrates similar or better performance compared to the commercial electrode.



- LIOVIX® composite electrode can be used for a variety of applications (e.g., EVs, EVTOLs, power tools, ESS).

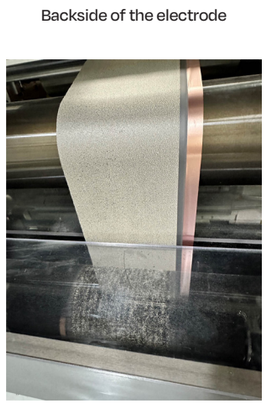
LIOVIX® Scalability

Third Party Roll-to-Roll Prelithiation Demonstration at Manufacturing Scale

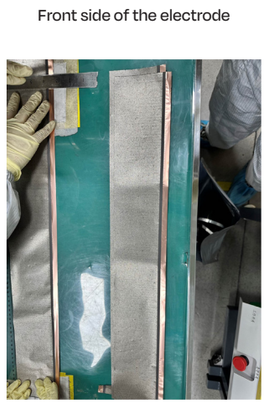


Backside of the electrode

Front side of the electrode



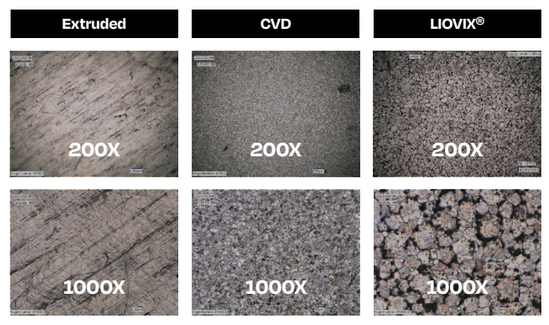
Electrode slitting



Finished electrode

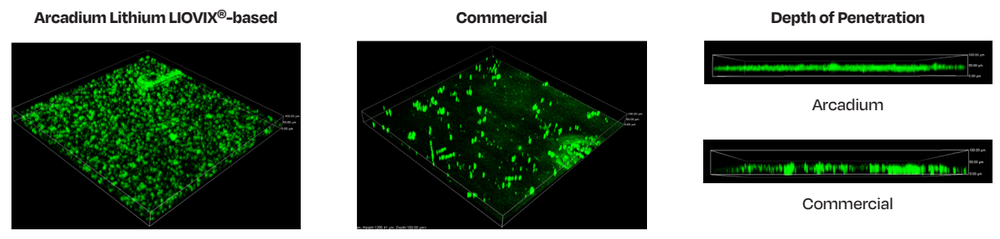
Unique Characteristics of LIOVIX® Thin Lithium Films

Morphology Comparison of Thin Lithium Films Produced Using Different Techniques



- LIOVIX®-based thin lithium foil has unique surface characteristics enabling fast battery charge and discharge and mitigating dendrite formation, thus improving battery safety.

Comparison of Electrolyte Distribution Uniformity on the Surface of Lithium Metal Electrode



- Fluorescent technique using laser scanning confocal microscopy was used to compare wetability and revealed uniform surface activity and shallow depth of penetration for the LIOVIX®-based thin lithium foil vs. commercial foil.
- This potentially signifies better utilization of lithium in the battery leading to longer cycle life.

Conclusion

- LIOVIX® is a proprietary printable formulation of lithium metal and other specialty materials that can improve the performance of lithium-ion batteries, reduce manufacturing costs and enable the next generation of battery technology, all while enhancing safety and sustainability.
- LIOVIX® allows for precision controlling of thin lithium foil thickness, width and delivers unique surface characteristics.
- LIOVIX® enables similar or better performance compared to commercial thin lithium foil as demonstrated by our customers.
- LIOVIX® has superior surface wetting properties, which enable more homogenous lithium utilization.

References

1. D. Lin, Y. Liu, and Y. Cui, *Nature Nanotechnology,* 12, 194–206 (2017) http://dx.doi.org/10.1038/nnano.2017.16.
2. Q, Hu, Y. Matulevich and Y, Tang, Solidenergy Systems, US Patent No. 16/308,023, June 08th, 2016.
3. O. Mashtalir, M. Nguyen, E. Bodoin, L. Swonger, and S. P. O'Brien, *ACS Omega,* 3, 181–187 (2018).

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