

SHARP™ TECHNOLOGY FOR LITHIUM-ION BATTERY RECYCLING

NAATBatt

LITHIUM BATTERY RECYCLING WORKSHOP VII

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COHERENT AT A GLANCE



FROM A FOUNDATION OF MATERIALS AND IMAGINATION, WE ENABLE EXCITING MEGATRENDS

1971

Year Founded

COHR

NYSE

26,000+

Employees ⁽¹⁾

\$5.2 B

FY23
Revenue

2,400+

Research & Development ⁽¹⁾

\$64 B

Available
Market ⁽¹⁾

3,000+

Patents ⁽¹⁾

126

Locations

**VERTICAL
INTEGRATION**

Materials, Components,
Subsystems, Systems
and Service

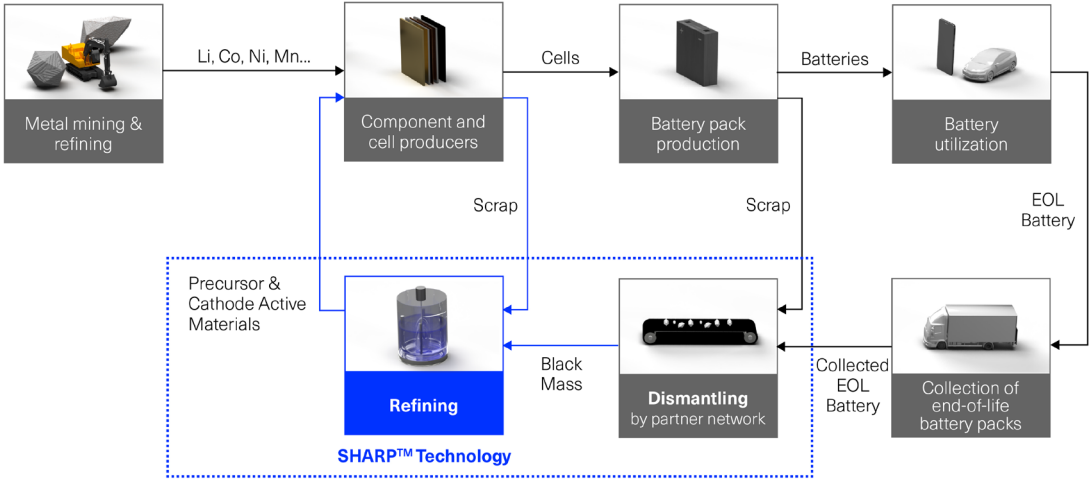
24

Countries

(1) As of June 20, 2023

SHARP™ TECHNOLOGY FOR LIB WASTE RECYCLING

Technology	SHARP™ - Streamlined Hydrometallurgical Advance Recycling Process
Challenge	Lack of economical and environmentally friendly processes for LiB recycling persists despite the critical need for them
Solution	A validated sustainable and economical closed-loop technology to recycle all critical metals and produce battery pCAM and battery-grade lithium compounds (multiple patent pending applications)
Advantages	<ul style="list-style-type: none"> ▪ >97% recovery of Li, Ni, Co, Mn ▪ Direct production of pCAM (currently no pCAM producer in North America) ▪ Process easily adaptable to convert NMC from legacy to next gen products (e.g., NMC 111 to NMC 811) ▪ Sustainable and robust



SHARP™ offers an industry leading sustainable solution for battery waste recycling:

- Low scale-up risk
- High profit margin

SHARP™ TECHNOLOGY

Novel Technology:

- A unique closed-loop process for direct production of precursor NMC Cathode Active Materials (pCAM) and battery grade Li compound
- Traditional recycling processes **lack Li recovery** through pyrometallurgy. Conventional hydrometallurgical methods allow for Li recovery. These processes involve **costly and intricate separation** and purification of Ni, Mn, and Co. SHARP™ offers **recovery of all critical metals, including Li, without the necessity for metal separation**. Robust impurity removal steps have been devised for purification of Ni, Mn, and Co solutions, enabling **direct pCAM production** followed by Li recovery.
- Multiple patent pending technology
- Focused on NMC: most common and highest value metals content

Status:

- Successfully completed pilot operation – SGS – External Validation
- Recycled materials perform identically to pristine materials in battery cells – ANL– External Validation
- Ongoing engineering design – Worley – External Validation
- Extensive engagement with potential customers and suppliers
- Customer validation in progress

Patent Portfolio:

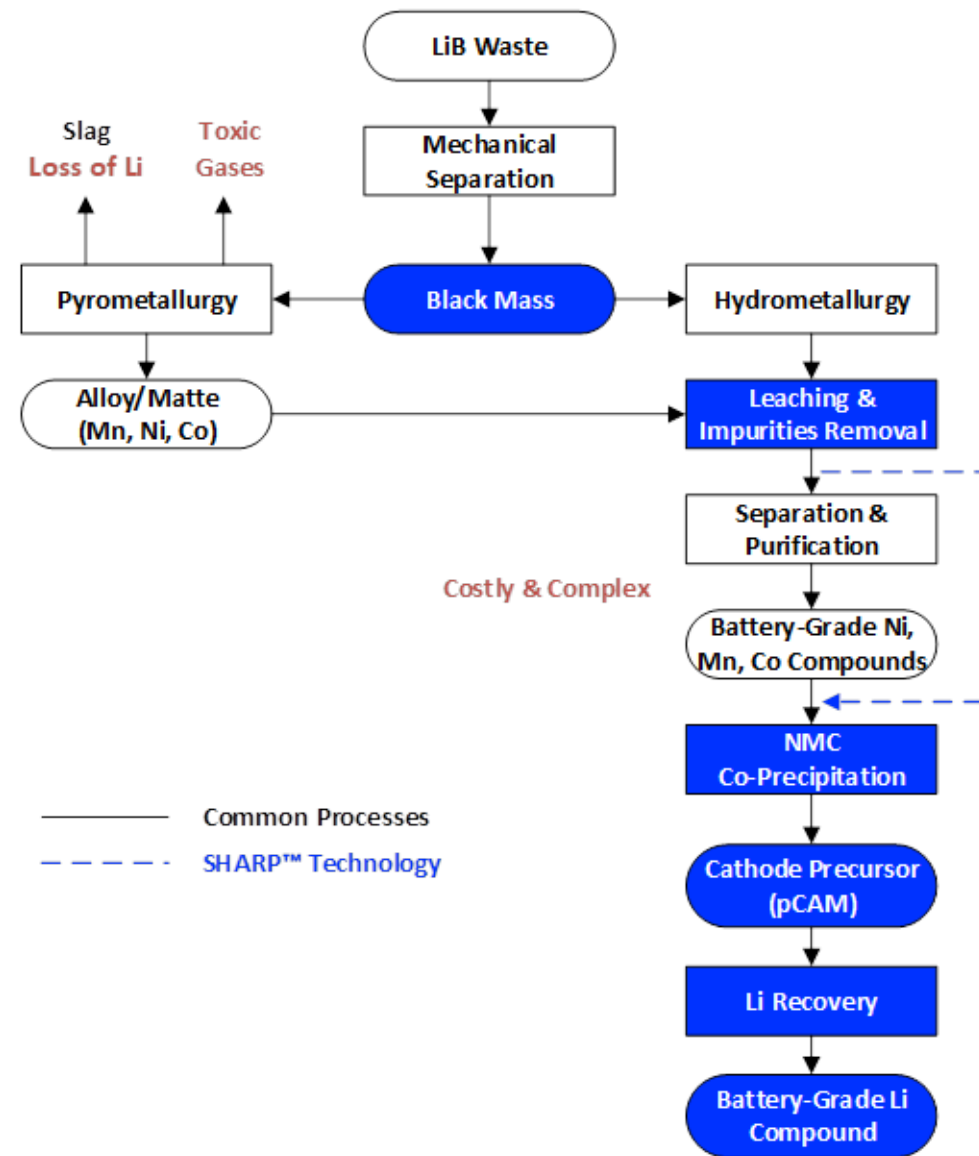
- G Nazari. G Abrenica (2023) Efficient and Sustainable CAM Synthesis: Streamlining Low-Cost, Low Environmental Impact Production. US Patent Application No 63/603,252.
- G Nazari. G Abrenica, E. Gluck, M Grimaldo, J Pagulayan, J Gerona (2023) Cadmium Removal in Lithium-ion Battery Recycling. US Patent Application No 18/496,481.
- G Nazari. G Abrenica (2023) Streamlined Lithium-ion Battery Waste Recycling. US Patent Application No 18/323,631.
- G Nazari. G Abrenica (2022) Hydrometallurgical Process for Lithium-ion Battery Recycling. US Patent Application No 17/804,337.

COMPARISON OF HYDROMETALLURGICAL RECYCLING TECHNOLOGIES VS. SHARP™

- Only hydrometallurgical processes allow for efficient Li recovery
 - Common hydro processes have not been commercialized outside of China yet
 - Direct recycling processes have not been commercialized anywhere in the world

Technology	SHARP™	Common Processes* (NMC Separation)
Feed Flexibility	High	Lowest
Process Effluent	Low	High
CAPEX	100%	220%
Reagents and Utilities	100%	260%
Plant Footprint	100%	180%
Carbon Footprint	100%	210%

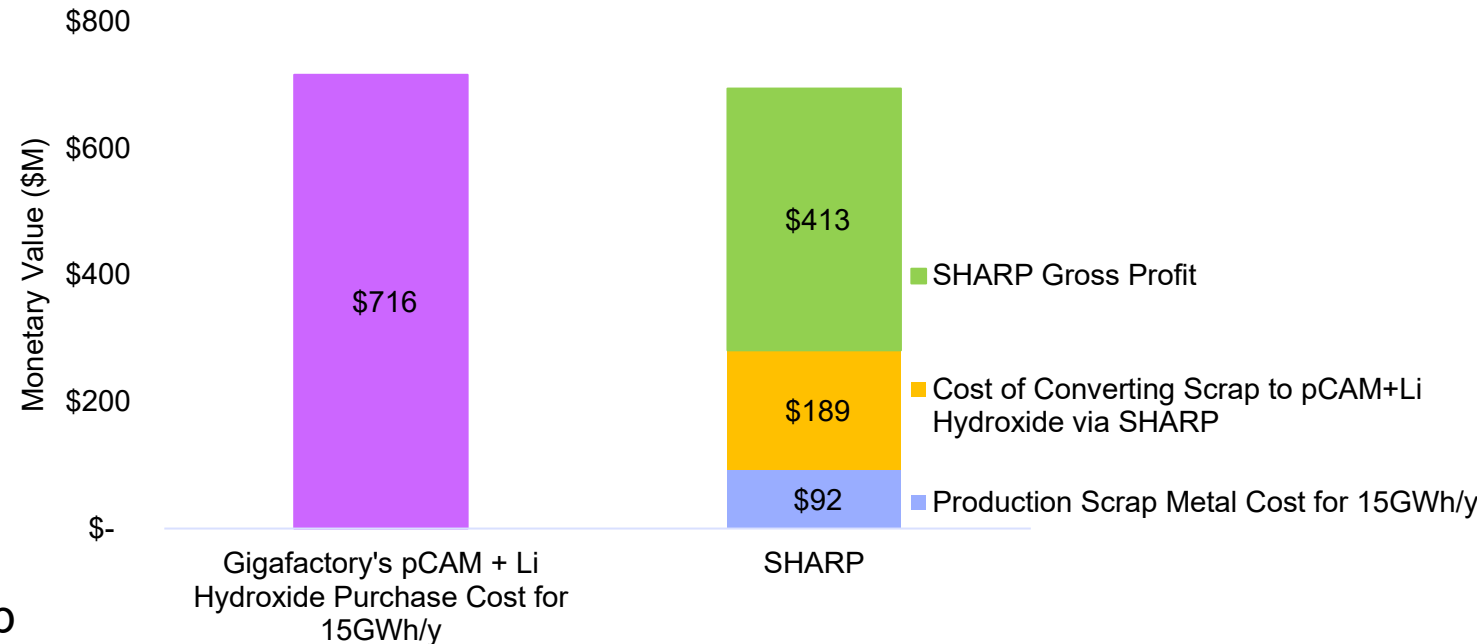
*Based on advanced process simulations and equivalent unit price assumptions for OPEX and CAPEX



VALUE PROPOSITION

- **Structure:** Purchase manufacturing scrap from Gigafactories → transform it into high value pCAM and lithium hydroxide → Sell products
- **Efficient Processing:** SHARP™ maximizes profit margins by reducing processing costs
- **Value Addition:** SHARP™ creates value-added products (pCAM) instead of individual metals
- **Substantial Savings:** For 100 GWh of battery production, SHARP™ offers a cost benefit of \$400M per year through its scrap recycling

Assumptions: Production scrap: 15% (the range is 5-40%); Gigafactory capacity: 100 GWh/y; Scrap selling price: 20% of Ni and Co and 10% of Li value; Recovery rate: 97%



LiOH.H₂O = \$30/kg; Ni = \$25/kg; Co = \$60/kg

2030 Forecast: S&P Global, Bloomberg NEF, Benchmark Mineral Intelligence

WHAT DIFFERENTIATES US

Hydrometallurgical Experience:

- More than 30 years of experience in operating rare metals refinery plants
- High purity Se production, 4N5: 15% of the world's demand
- High purity Te production, 4N5: 17% of the world's demand

Process Robustness:

- Capable of handling various impurities such as Al, Fe, Cu, and F that are expected in NMC LiB regardless of their concentration
- Low Scale-Up Risk: Required equipment has a proven track record of common and successful use in the hydrometallurgy industry

Technology Versatility and Flexibility:

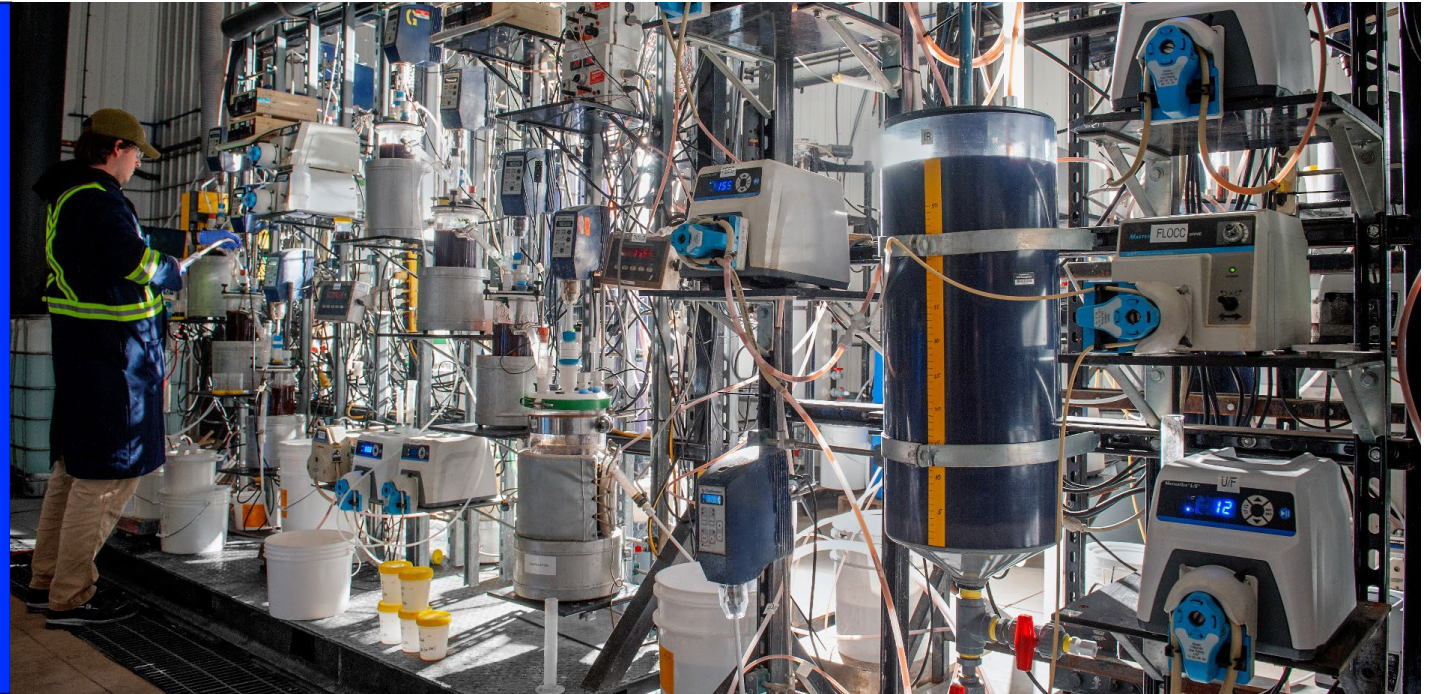
- In addition to manufacturing scrap, the process is capable of producing battery grade products from EoL black mass containing impurities such as Cd, Ca, Mg, Zn, W, Zr, etc.
- Black mass obtained from EoL batteries containing high levels of impurities was successfully utilized at our pilot plant

Access to NMC Battery Market

- Strategic contacts with majority of NMC battery manufacturers through Coherent's lasers being employed for battery manufacturing

SHARP™ PILOT OPERATION

- After lab scale development and verification, the process was scaled up
- SGS selected for pilot operation scale-up
- SGS is the world's leading testing, inspection and certification company

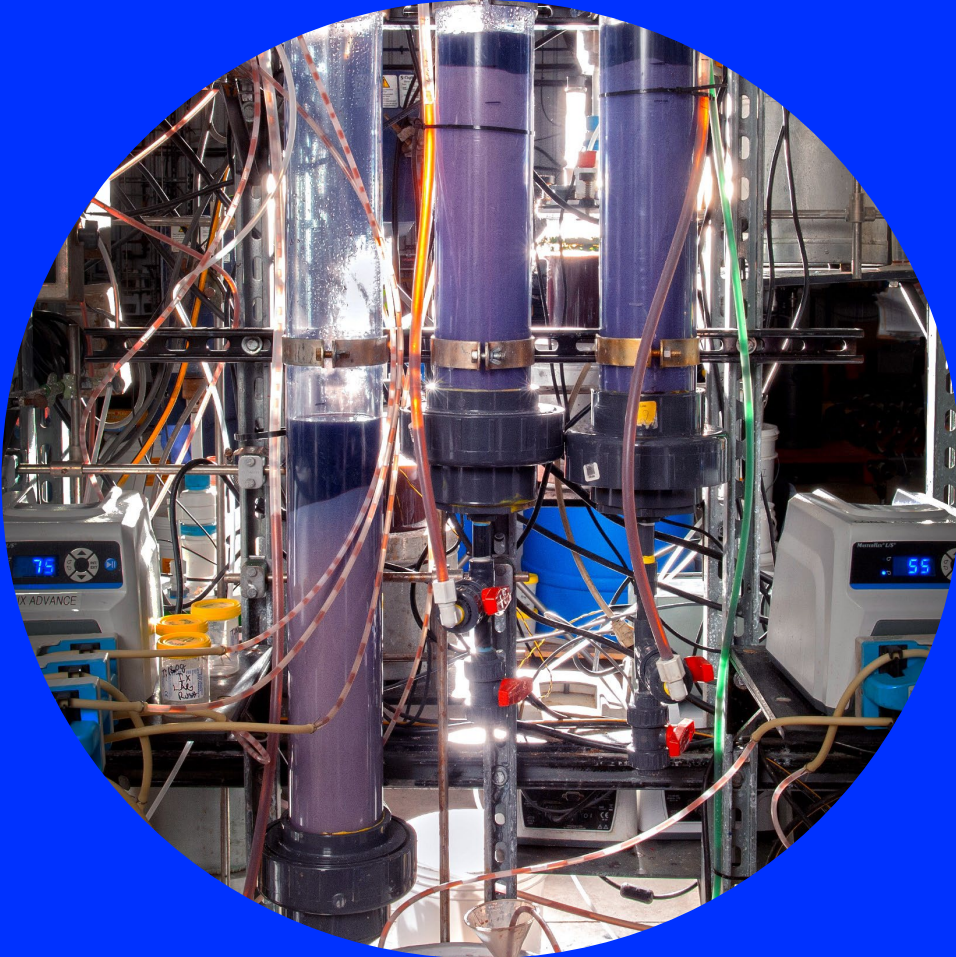


Objectives Achieved:

- Identified the technical, operational & design issues during scale-up
- Provided an unbiased assessment of SHARP™ to our potential partners/customers
- Expedited the scale-up of the technology

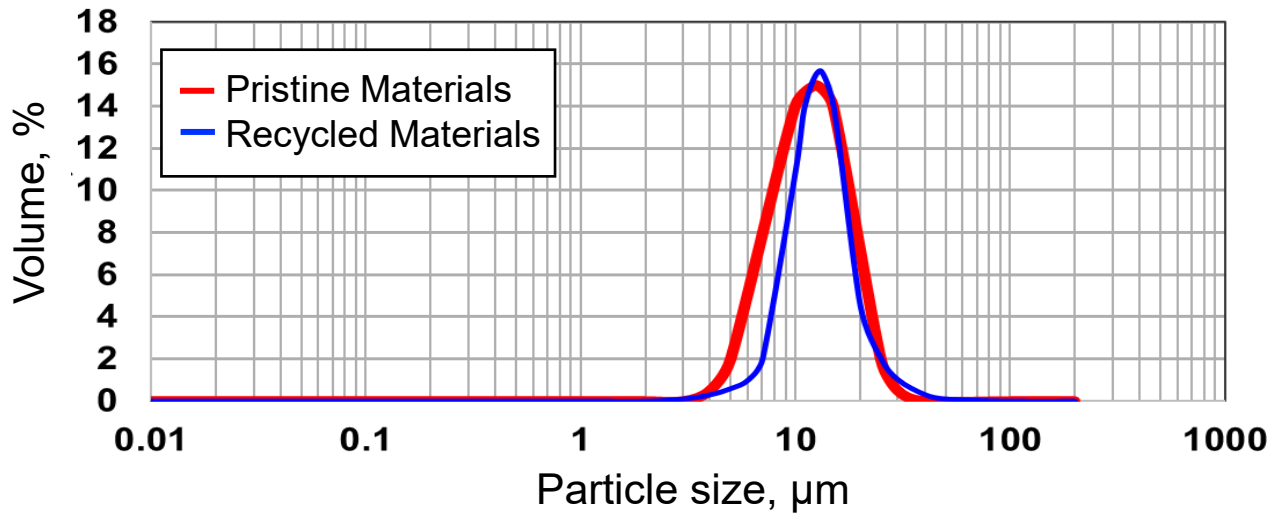
PILOT OPERATION RESULTS

- Started in Jan 2023 and completed in Feb 2024
- Pilot operation used black mass infeed containing high concentrations of impurities
- Results of pilot operation confirmed advantages of novel SHARP™ process including efficiency and robustness of process in relevant conditions
- Estimated Recovery:
 - Ni >97%
 - Co, Li, Mn >99%

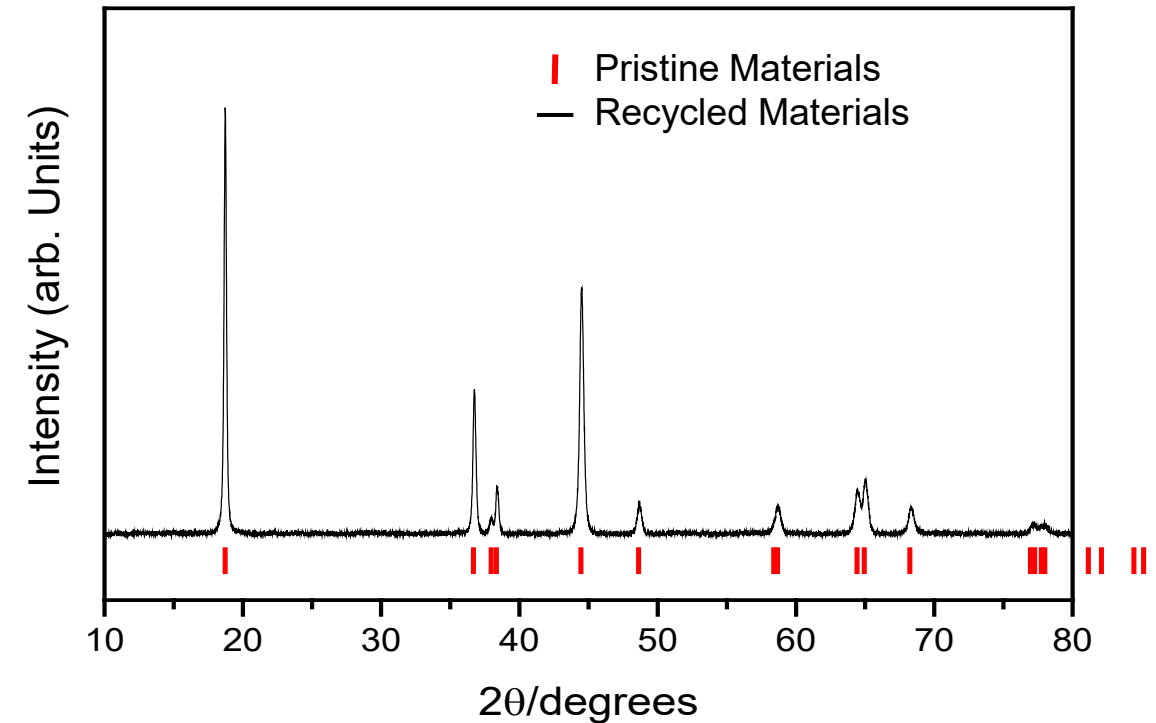


CATHODE ACTIVE MATERIAL (CAM) EVALUATION – NMC 622

- pCAM products from recycling was converted to CAM.
- Tap density, particle size distribution, XRD patterns are all comparable with those produced from pristine materials.

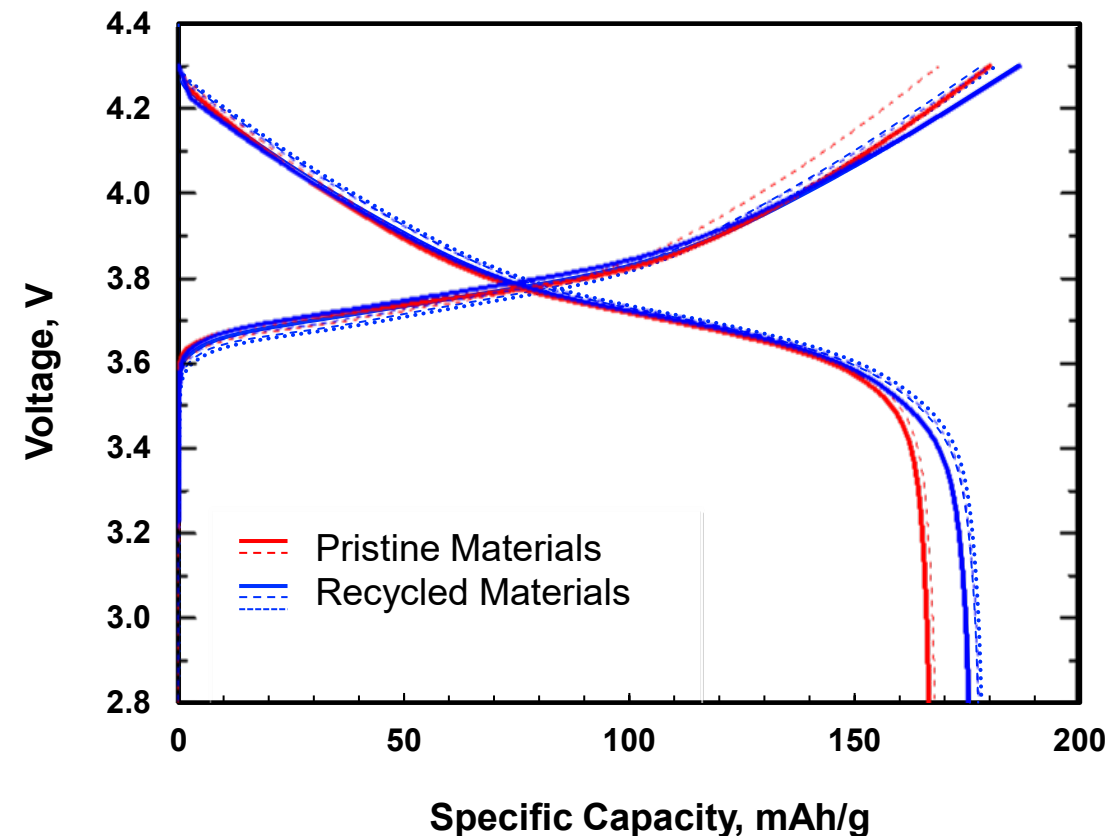


μm	Standard	Typical	Recycled
D10	≥5	10.8	8.3
D50	11.5 ± 1.5	11.6	12.7
D90	≤25	19.6	21.2



PRODUCT VALIDATION

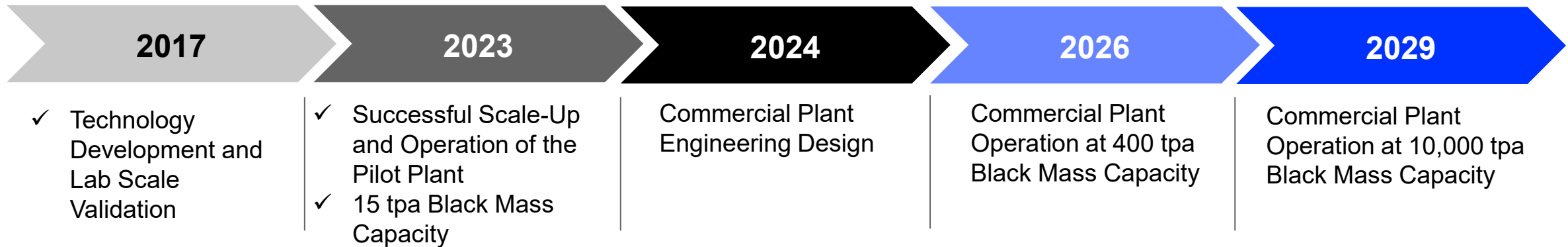
- **Equivalent cell performance to pristine materials**
- Electrochemical testing consisted of assembling the CAM material into cells followed by multiple charge and discharge cycles while measuring specific capacity (mAh/g)
- Tests confirmed that SHARP's pCAM performed as well as pCAM manufactured from pristine materials
- Discharge capacities of ~180 mAh/g over multiple charge and discharge cycles at upper cut-off voltage of 4.3 V were observed
- Cathode synthesis and coin cell evaluations were done in collaboration with Argonne National Laboratory at the Materials Engineering Research Facility (MERF)



Half Coin Cell Conditions	
Voltage window	2.8 -4.3 V
C-rate	0.1C
1C	200 mA/g
Temperature	30 °C

COMMERCIALIZATION PATH

- **SHARP™ offers:**
 - Simplicity in operation, low cost with positive environmental impact
 - Flexibility in throughput, various LiB types as manufacturing scrap or EOL
- **Investment Opportunity:** Investment vehicle is being established to expedite the advancement of SHARP™ to commercialization. This effort supports the development of our streamlined, environmentally friendly recycling technology.



THANK YOU

For More Information

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