FROM PITCH TO POWER: HARNESSING DOMESTIC MESOPHASE PITCH FOR SYNTHETIC GRAPHITE ANODES IN LITHIUM-ION BATTERIES

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Agenda

- Background/Introduction
  - ACPT
  - Pitch 101
- Overview of Pitch to Power
  - Pitch processing
  - Anode processing
  - Battery manufacturing and testing
- Results
  - Anode research and development
  - Battery performance
- Q&A

Background

ACPT Background

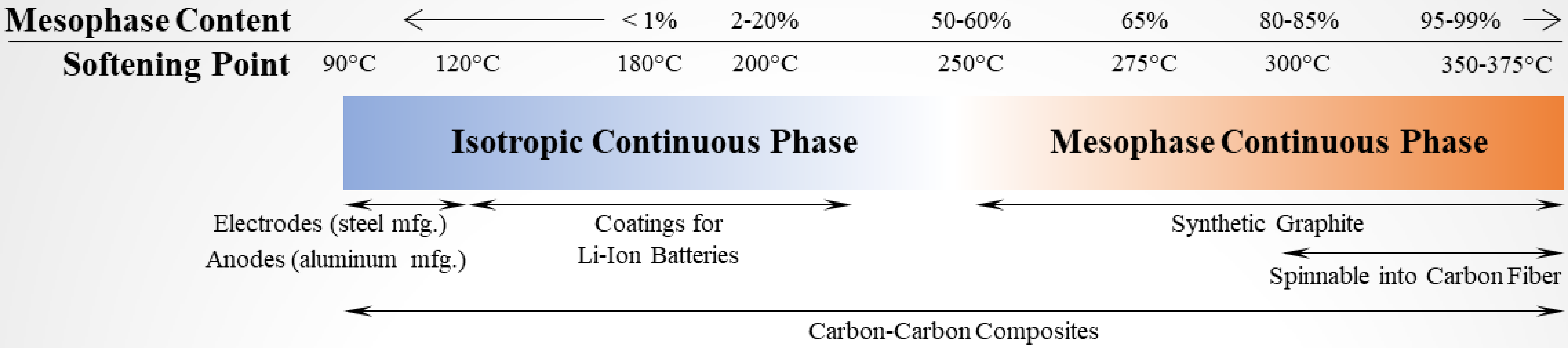
- ACP Technologies (ACPT) was founded in 2009
- Patented processes for converting low-cost petroleum feedstocks into high-value pitches
- Feedstocks are domestically sourced, low-cost decant oils
- Continuous process (cleaner / more efficient)
- Pilot plant in Kentucky
- Produce both **isotropic** and **mesophase** pitches

Isotropic Pitch

Mesophase Pitch

Pitch Background

- **Isotropic** pitch is composed of a variety of different randomly-oriented hydrocarbons
- **Mesophase** pitch is a liquid crystal composed of higher Mw hydrocarbons and is produced by further refining and polymerizing isotropic pitch.
- Pitch is desirable because it produces graphite and has a high char yield.



https://www.linkedin.com/pulse/advantages-electric-arc-furnace-steel-making-jean-
ee

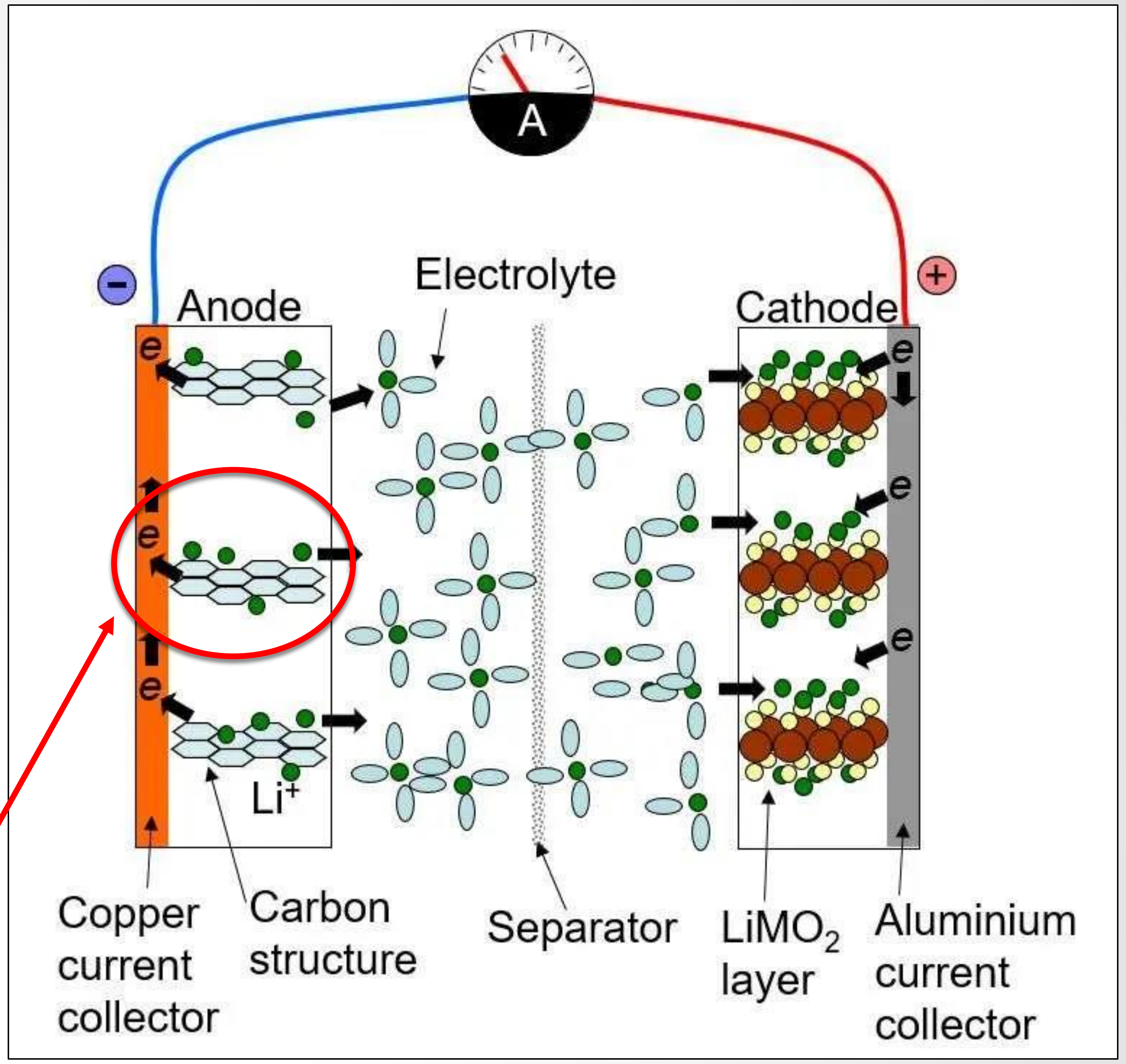
https://spacex.com/

https://airandspace.si.edu/

https://www.ornl.gov/facility/cftf

Li-Ion Battery Background

- Li-Ion batteries are rechargeable batteries that use the reversible intercalation of Li^+ ions into electrically conductive solids to store energy.
- They are composed of an anode, cathode, separator, electrolyte, and current collectors.
- Anodes are composed of either synthetic or natural graphite
- 25-30% of a Li-ion battery's weight is graphite
- 90% of the world's graphite supply comes from China
- This presentation focuses on anode materials only



Overview of Pitch to Power

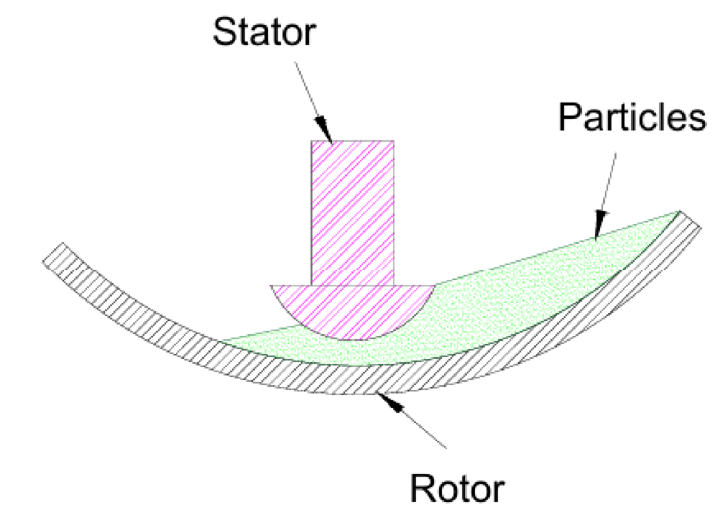
Synthetic Graphite Processing


https://blog.wika.us/knowhow/importance-dipleg-temperature-measurement-fcc-units/
Slurry Oil


Isotropic Pitch


Mesophase Pitch

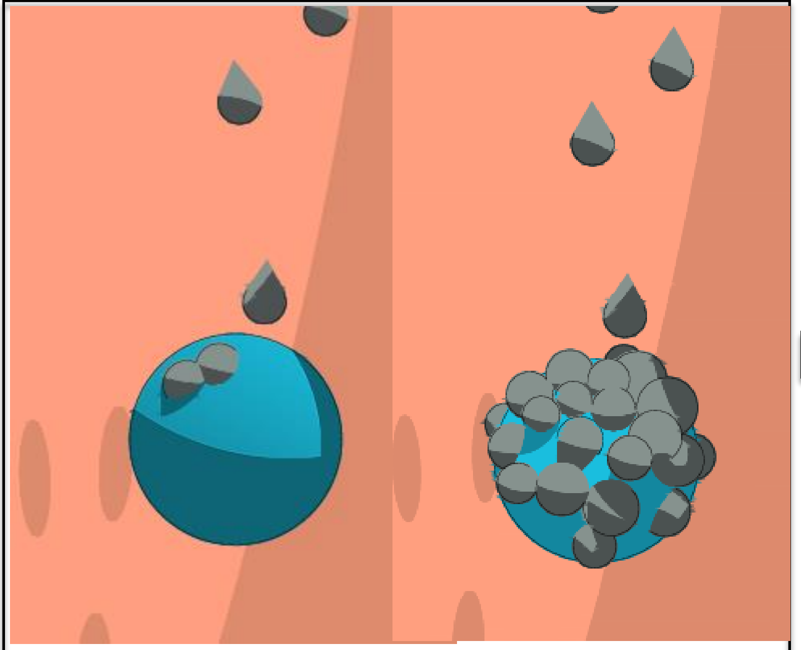

Coke

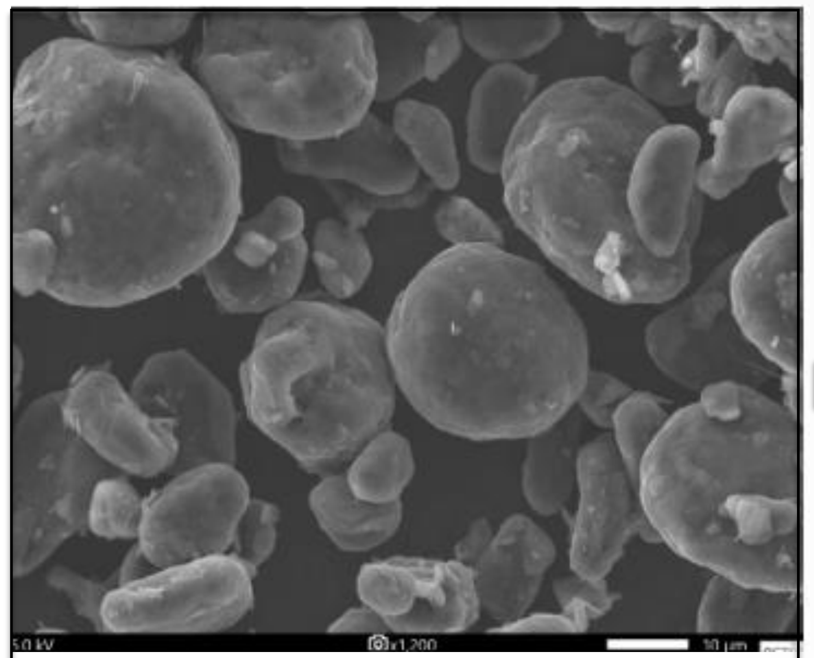


Milled


www.911metallurgist.com
Classified

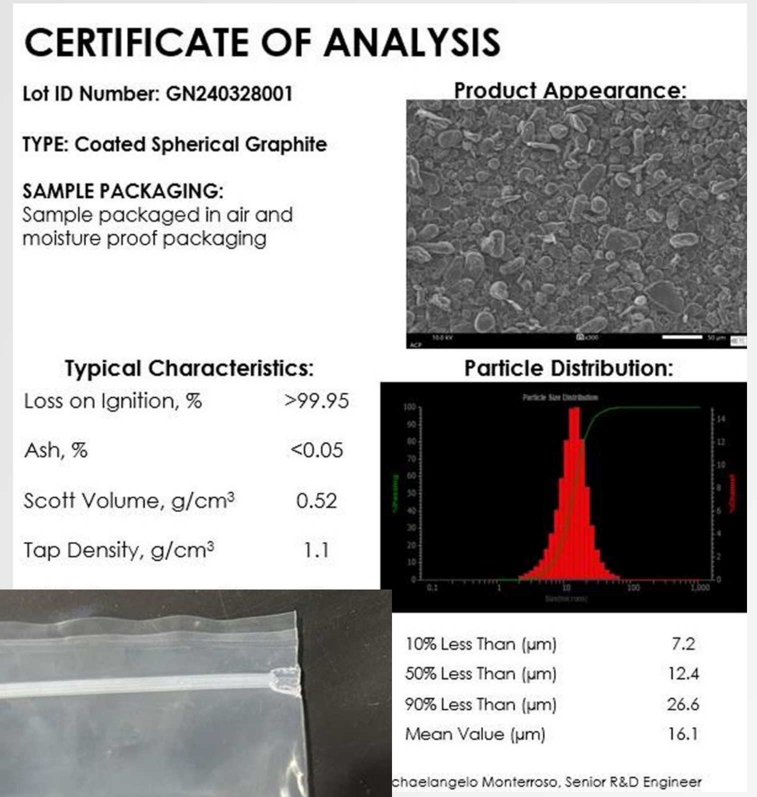

https://kindle-tech.com/products/graphitization-furnace
Graphitized


Coated


Calcined


https://www.metaltechnews.com/
~20 µm spheres of anode-grade synthetic graphite

Anode/Battery Manufacturing/Testing



CERTIFICATE OF ANALYSIS

Lot ID Number: GN240328001

TYPE: Coated Spherical Graphite

SAMPLE PACKAGING:
Sample packaged in air and moisture proof packaging

Product Appearance:

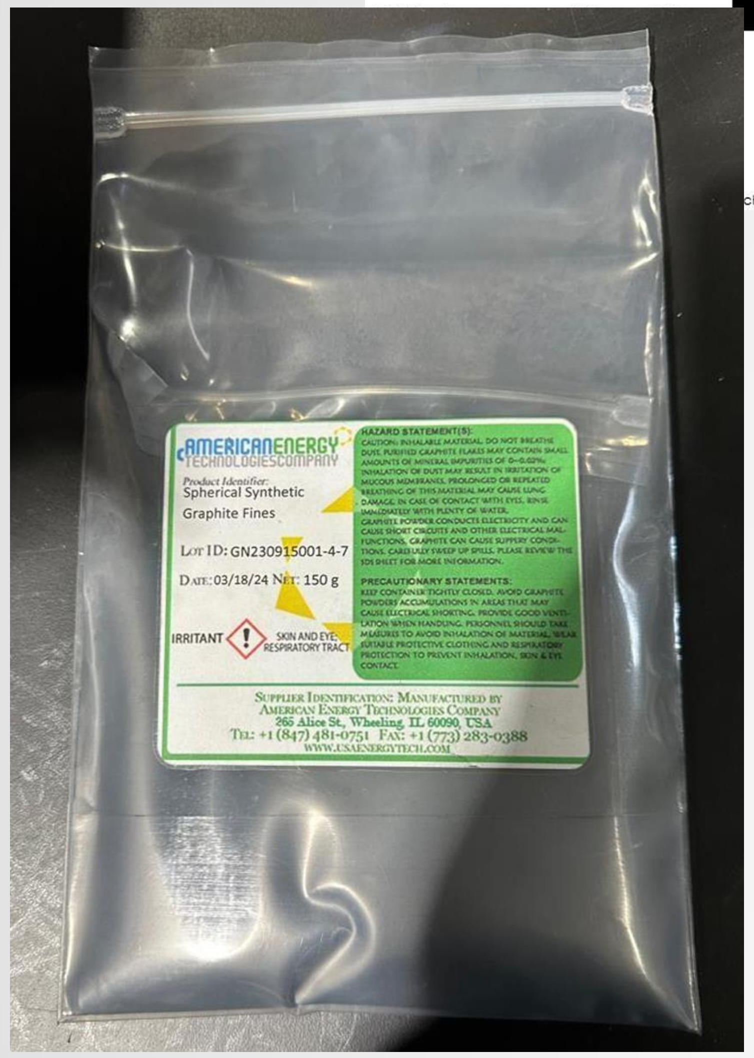
Typical Characteristics:

Loss on Ignition, %	>99.95
Ash, %	<0.05
Scott Volume, g/cm³	0.52
Tap Density, g/cm³	1.1

Particle Distribution:

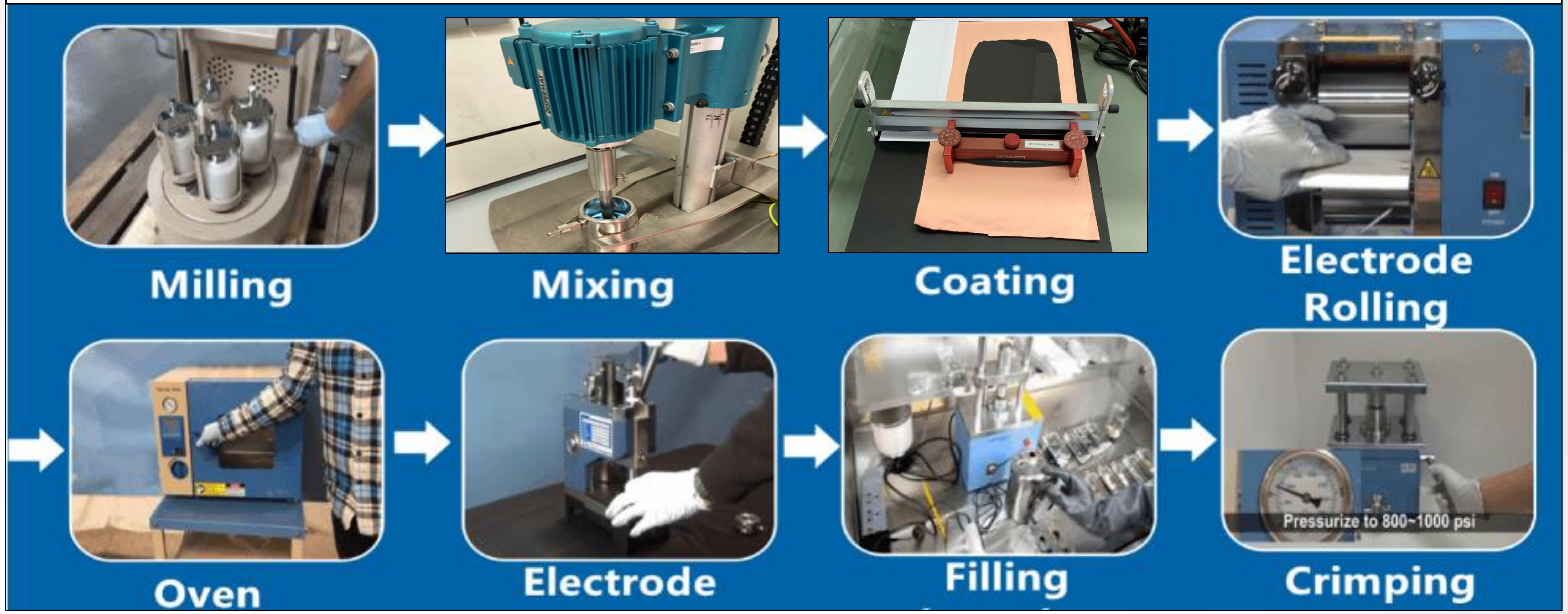
10% Less Than (µm)	7.2
50% Less Than (µm)	12.4
90% Less Than (µm)	26.6
Mean Value (µm)	16.1

chaelangelo Monterroso, Senior R&D Engineer

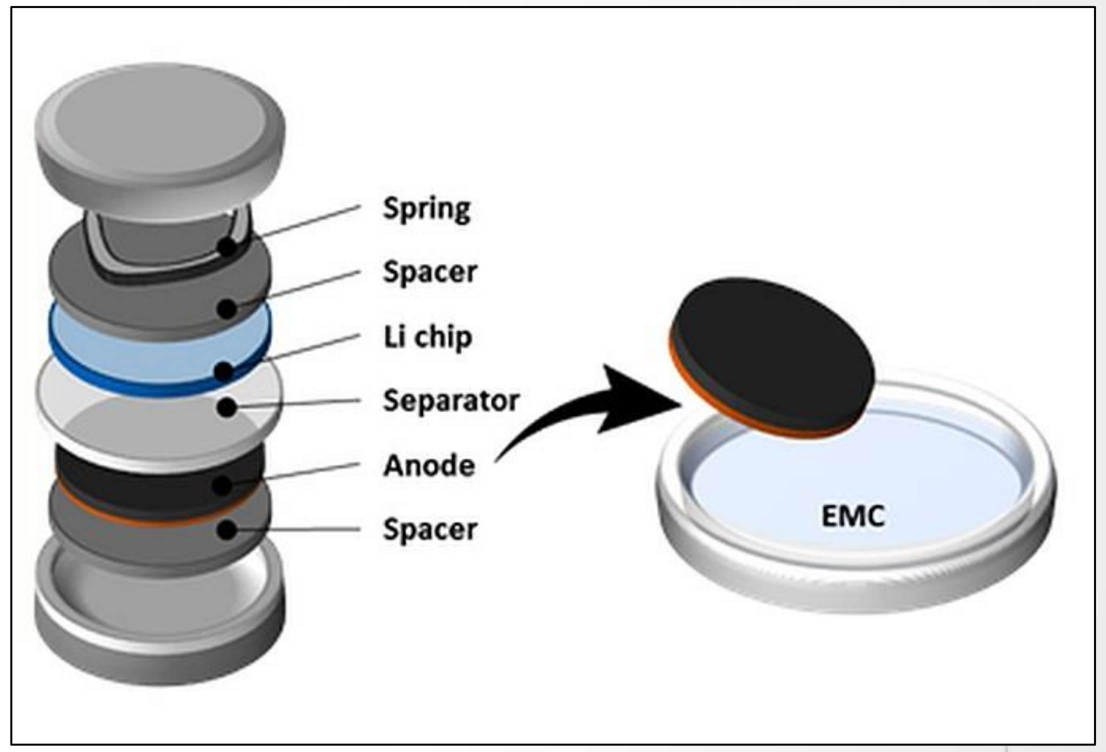


Synthetic Graphite Anode material

Coin Cell Assembly Process



Coin Cell Assembly



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Results

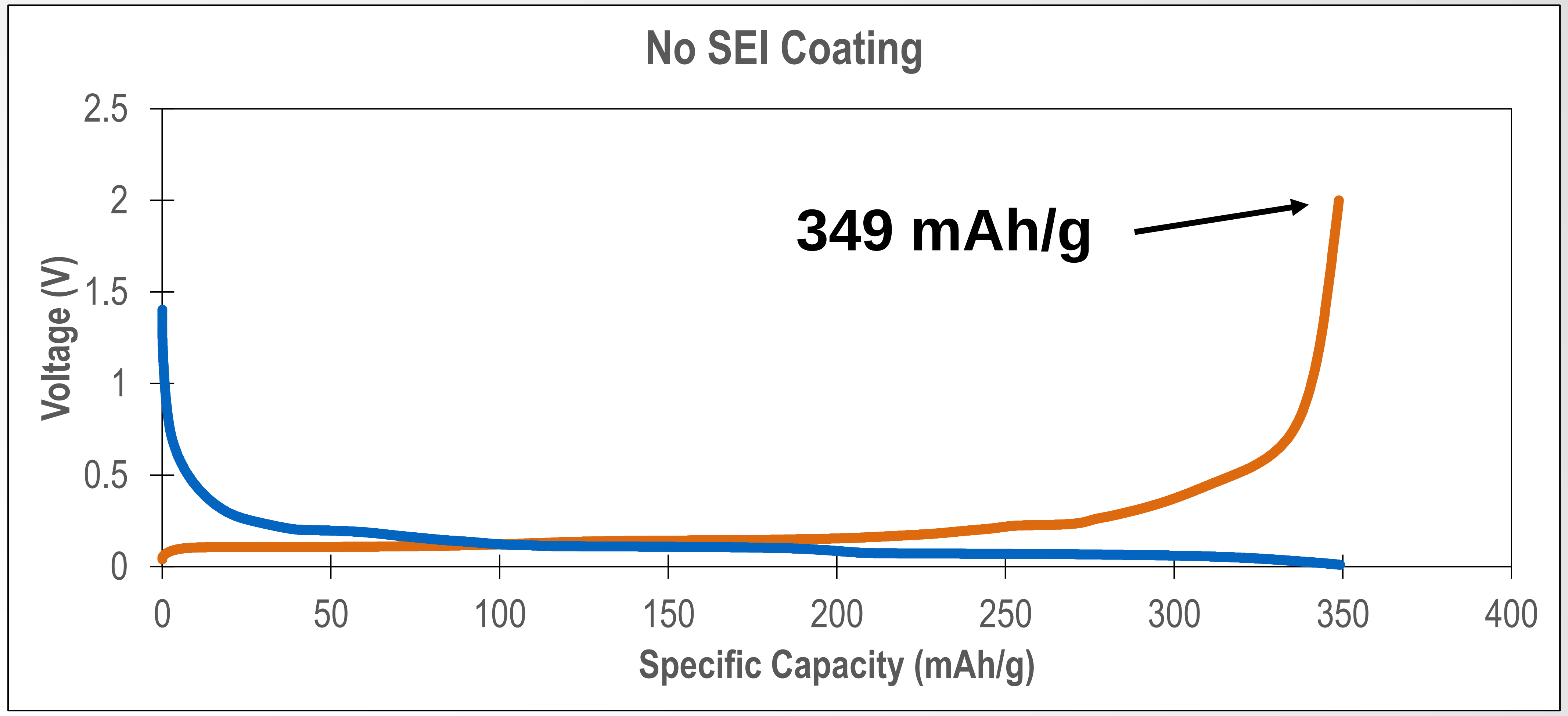
Effect of Isotropic Pitch SEI Layer

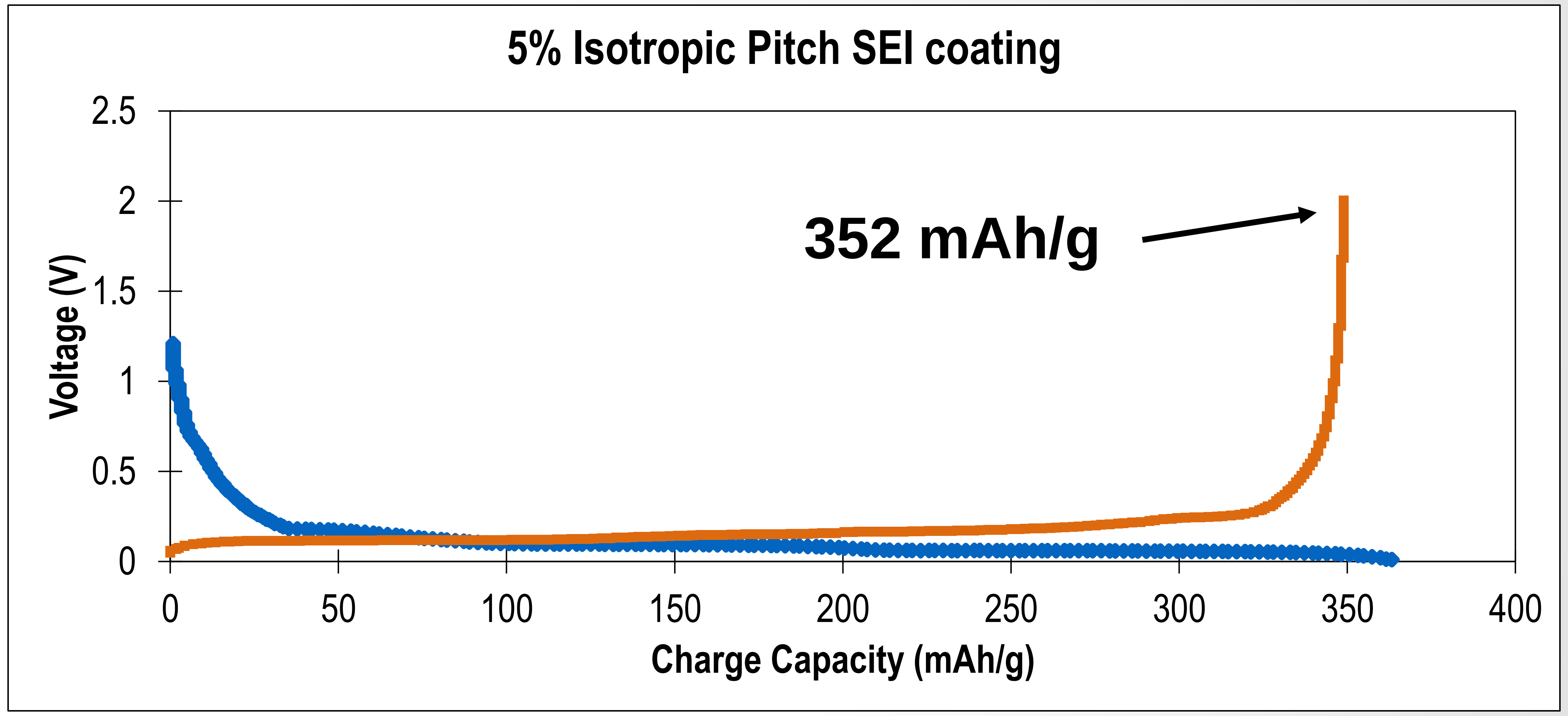
The Solid Electrolyte Interphase (SEI) layer is a protective layer that coats the anode materials. It prevents decomposition caused by the electrolyte. It is important for battery safety, rate capacity, and cyclability.

Typically formed during the first few charge/discharge cycles from additives in the electrolyte and typically ranges from 8-15% for commercial batteries.

Natural graphite was used as the benchmark for the isotropic pitch coating experiments.

- Depending on the softening point of the isotropic pitch and coating thickness, the ICL ranged from 2-6% and the surface area ranged from 2-3 m^2/g





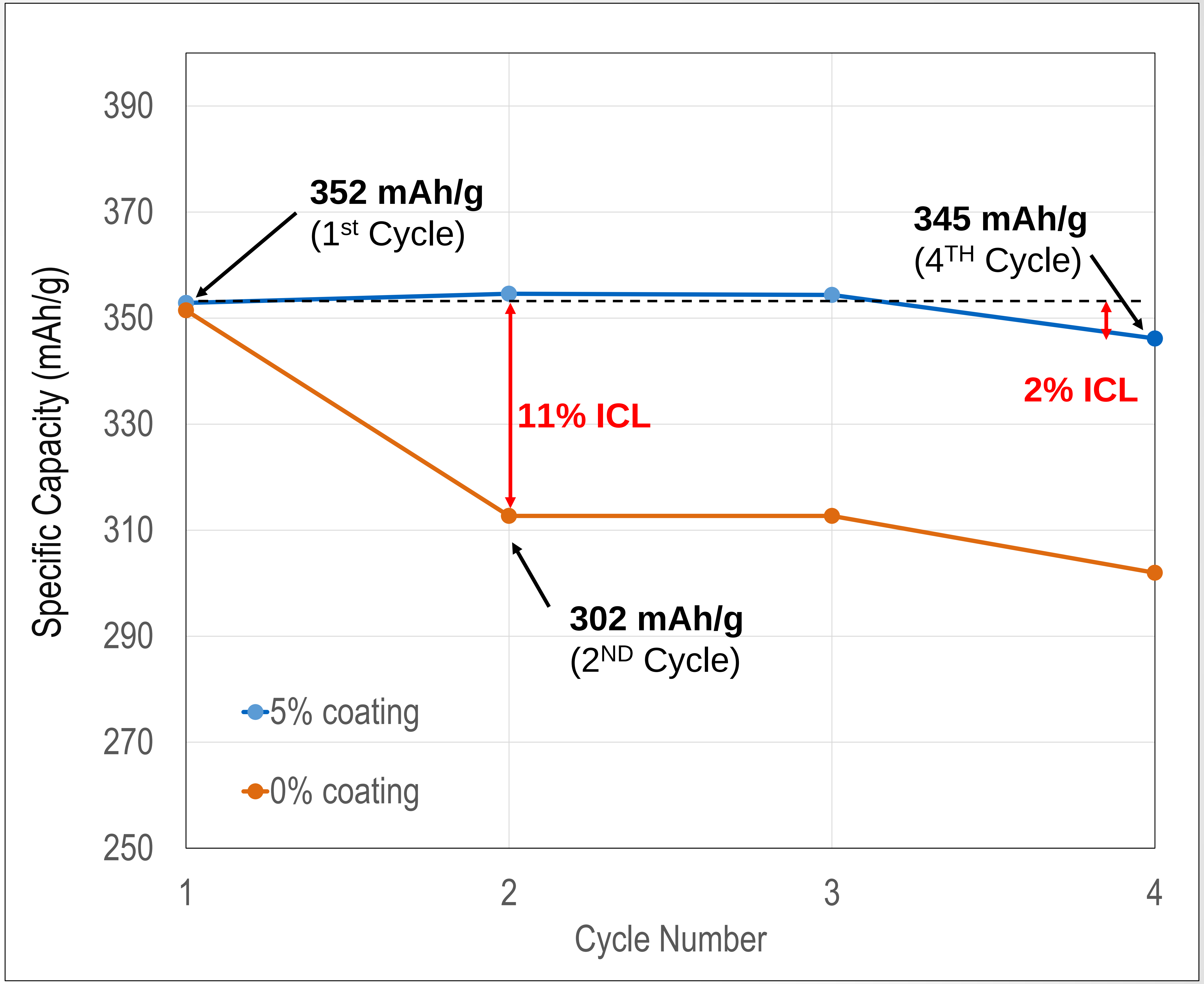
Effect of Isotropic Pitch SEI Layer

Anodes were made with 90% mesophase graphitic microspheres that were coated with 5 wt% isotropic pitch. This sample was subjected to electrochemical cycling:

- Specific Capacity = 352 mAh/g
- Irreversible Capacity Loss = 2%

Compared to the identical sample prepared without the isotropic pitch coating

- Specific Capacity = 352 mAh/g
- Irreversible Capacity Loss = 11%

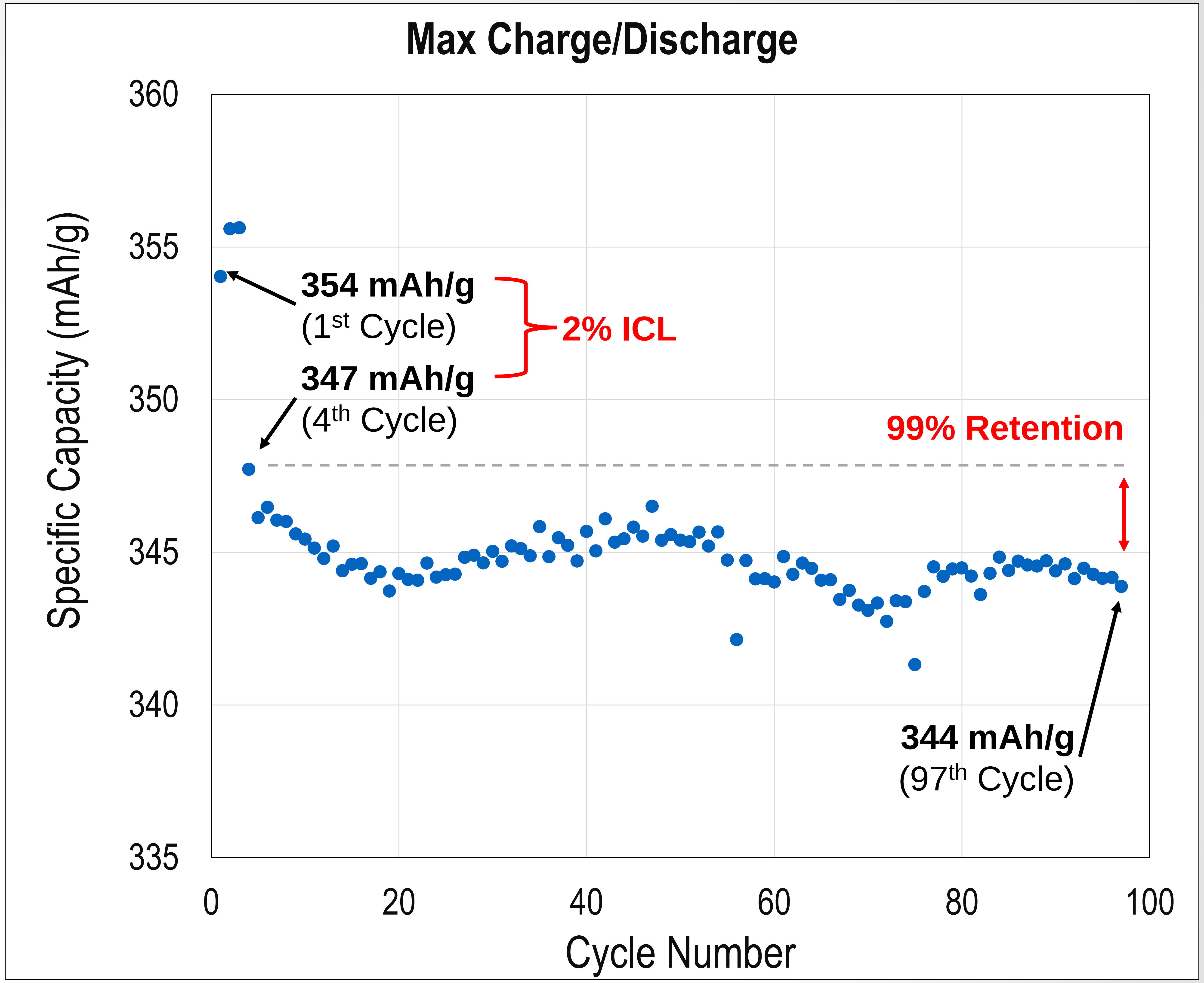


The isotropic pitch provides a significant improvement in the ICL (Industry standard is 8-15%)

Cycling Longevity

Coin cells were assembled using the methods previously discussed. ACP-Ts mesophase pitch-derived synthetic graphite was cycled against Li/Li+ reference electrode for nearly 100 cycles (rate = C/3) in order to establish its reversible capacity and stability over prolonged cycling.

- The electrochemical behavior of graphite is very stable. The initial reversible capacity was seen to be around 347 mAh/g once the steady state cycling was achieved (by approximately cycle #4).
- By cycle #97, cells reach a capacity of 344 mAh/g, which a degradation of a very low 1% from the initial capacity.

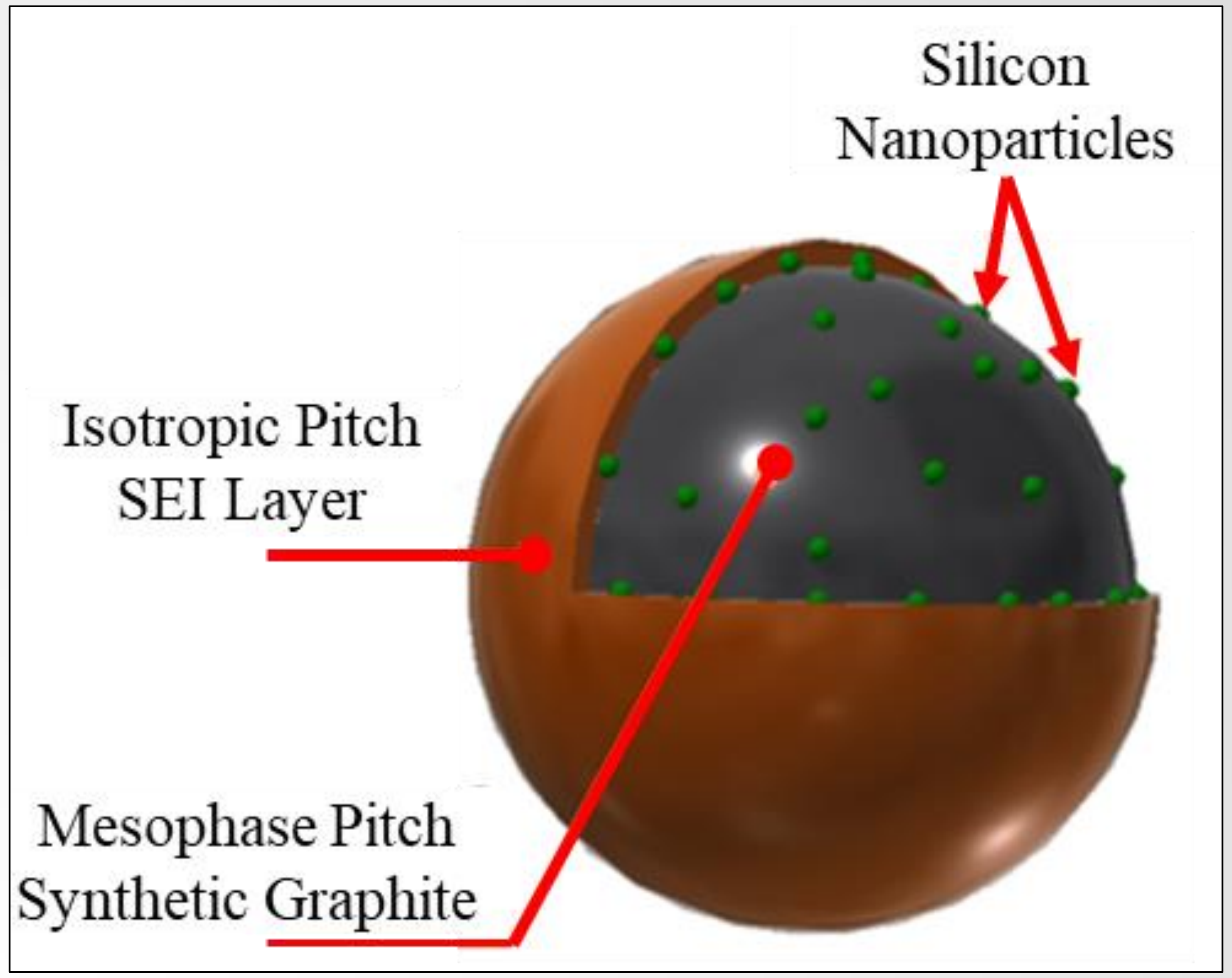


Synthetic graphite exhibits good capacity compared to commercial standards, and the cyclability is excellent. (Industry standard is 320-360 mAh/g)

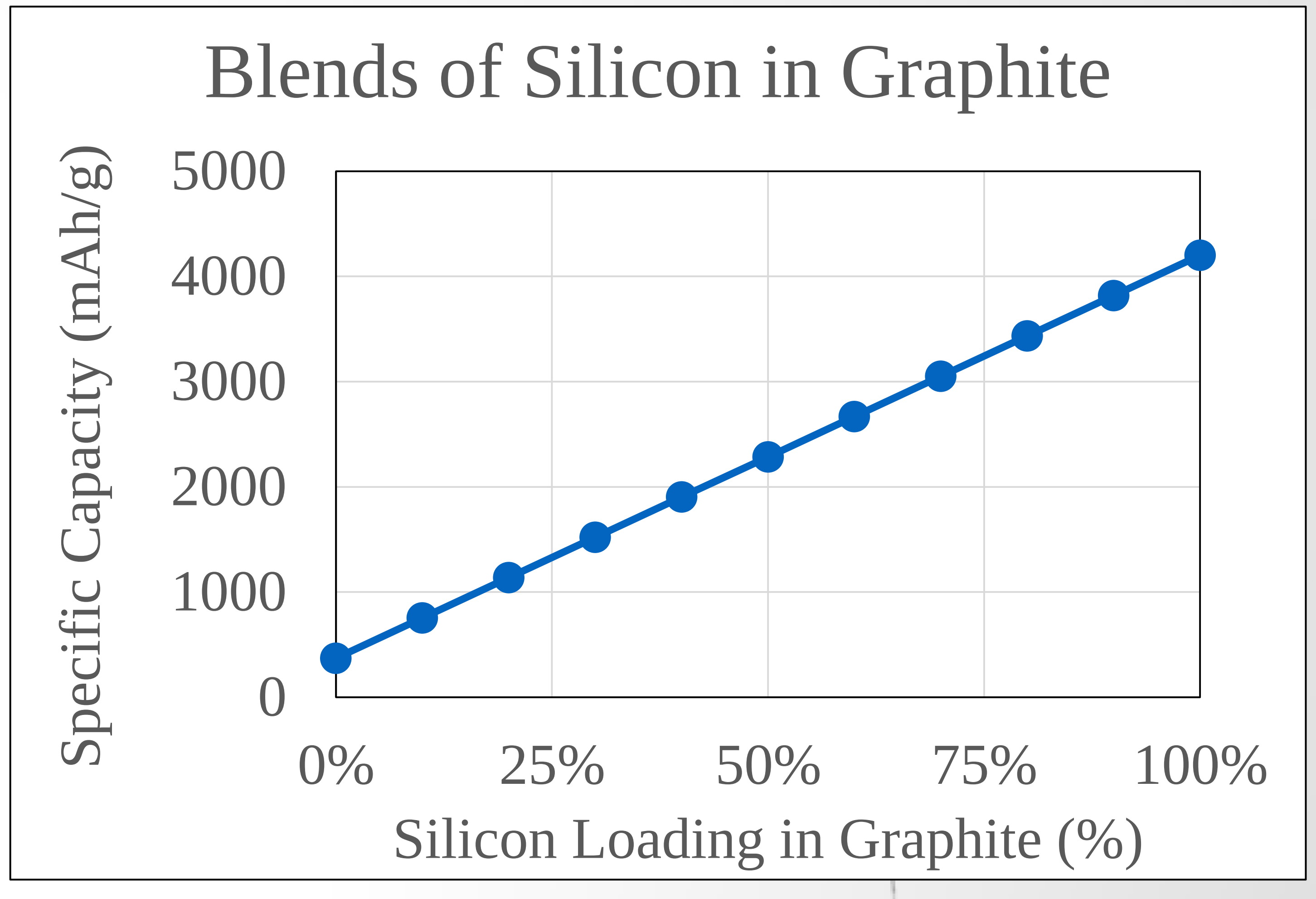
Silicon-Enhanced Synthetic Graphite

Material	Theoretical Specific Capacity (mAh/g)	Expansion During Lithiation (%)
Synthetic Graphite	372	10
Silicon	4200	300-400

This is the main issue with Silicon



Manufacturing Method:
Nano-sized silicon is added to the spherization milling step to impinge the silicon onto the surface of the synthetic graphite sphere. The composite is then coated with the SEI layer and calcined.



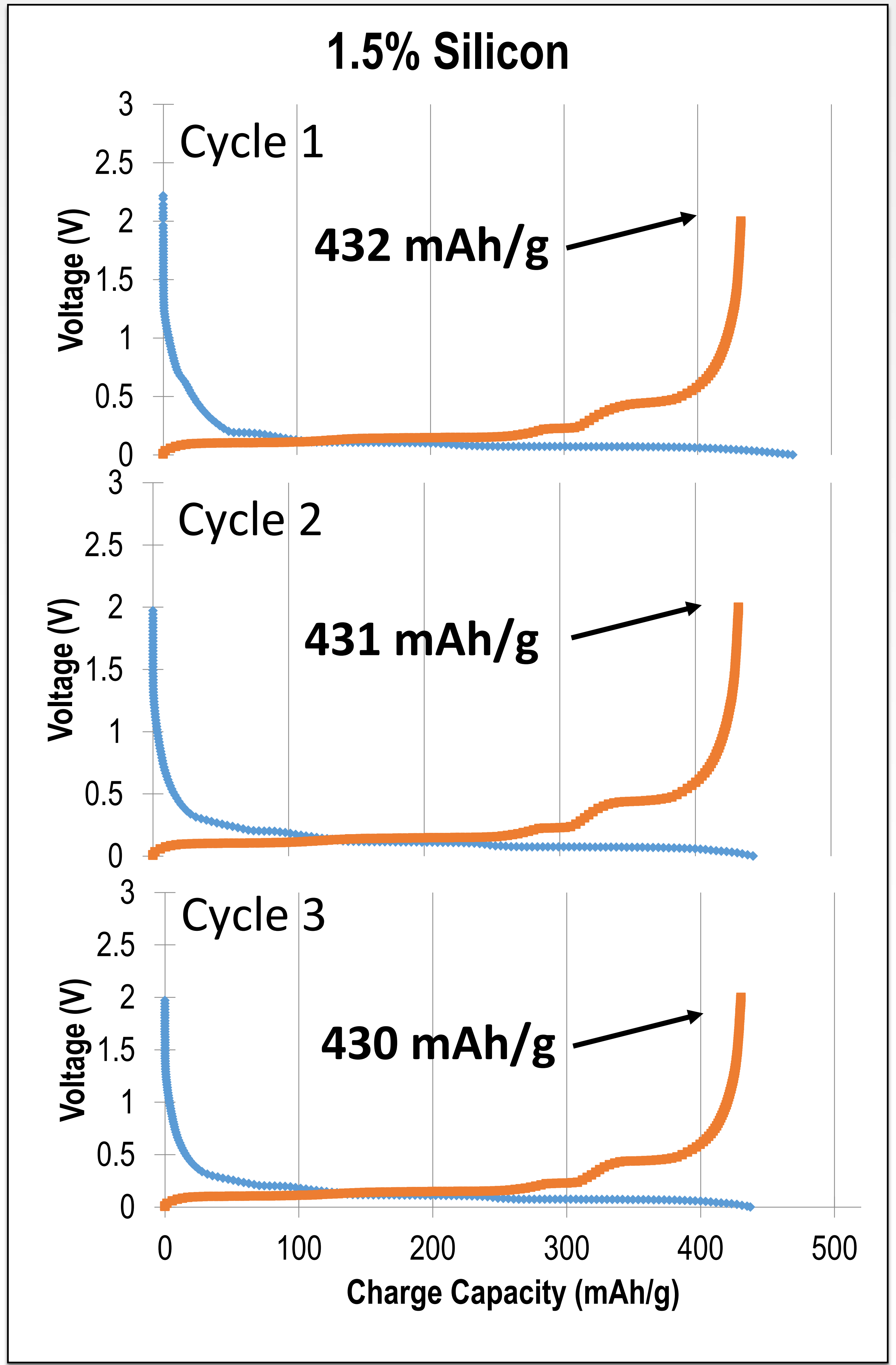
Silicon-Enhanced Synthetic Graphite

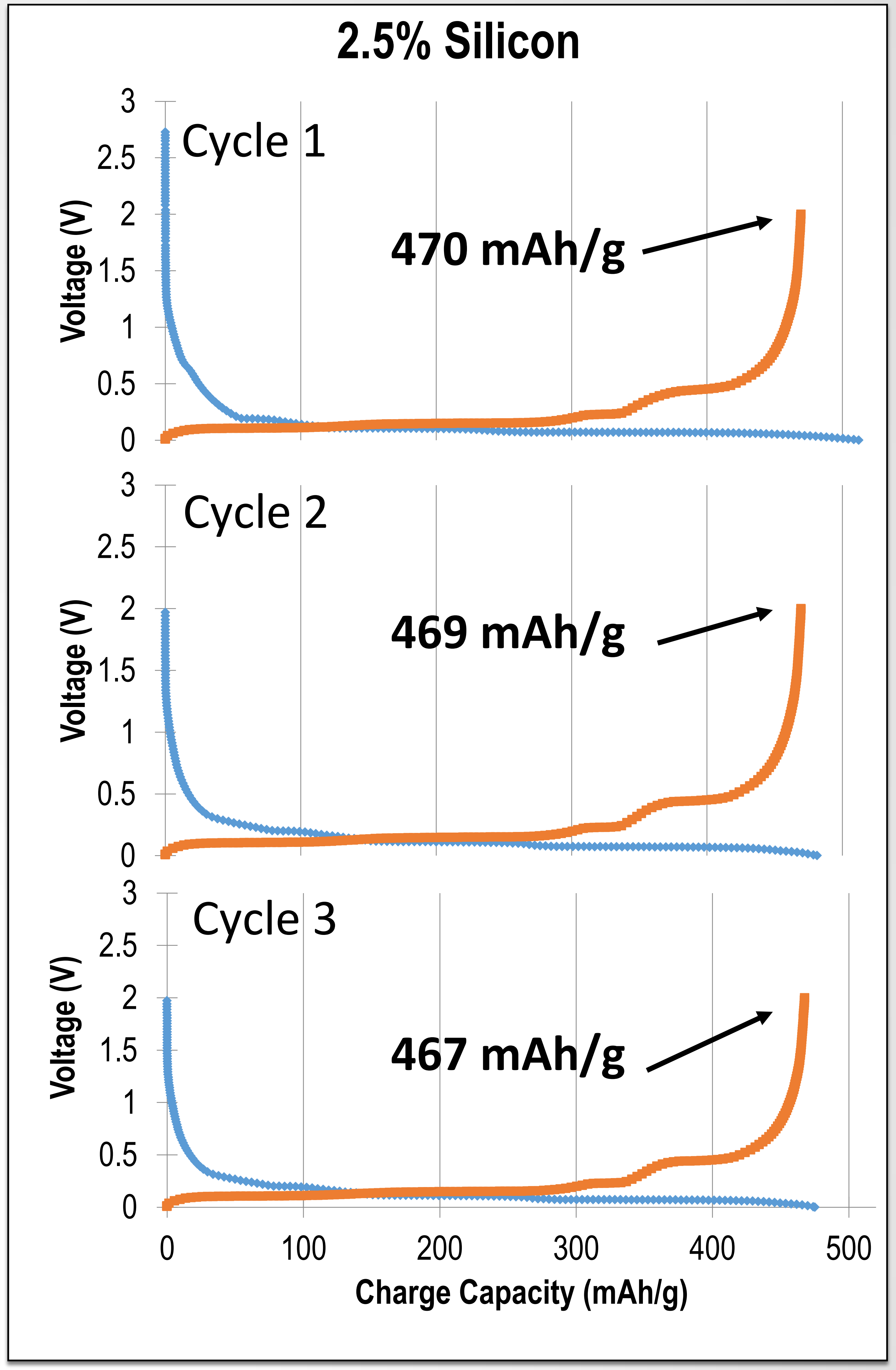
Coin cells were assembled using the methods previously discussed. ACP-T's Si-enhanced synthetic graphite was cycled 20 times (rate = C/3) to study capacity and stability.

- Initial Capacity
  - 0% = 352 mAh/g
  - 1.5% = 432 mAh/g
  - 2.5% = 470 mAh/g ← **33% higher capacity**

- Irreversible Capacity Loss
  - 0% = 2%
  - 1.5% = 1%
  - 2.5% = 1%

Adding Silicon can greatly boost capacity, but more work is required to improve cyclability





Summary

Key Take-Home messages:

- ACPT has a patented process for the continuous production of isotropic and mesophase pitch.
- Domestic feedstock (petroleum decant oil)
- Domestic production (Hitchens, KY)
- Wide range of softening points (isotropic pitches) and mesophase contents (mesophase pitches)
- Successfully tested batteries with:
  - High Specific Capacities
  - Low Irreversible Capacity Losses
  - Excellent cycling stability
  - Tunable surface area, tap density, SEI coating thickness, particle size, etc.
  - Silicon-enhanced batteries are also possible

Next Steps

- Optimize the use of isotropic pitch as the SEI coating
- Optimize manufacturing variables to further boost the specific capacity
- Continue with extended charge/discharge cycle testing
- Make and test pouch cell and higher capacity batteries
- Further explore the addition of silicon to enhance capacity
- Develop cathode materials from milling fines

Thank You

Questions?