



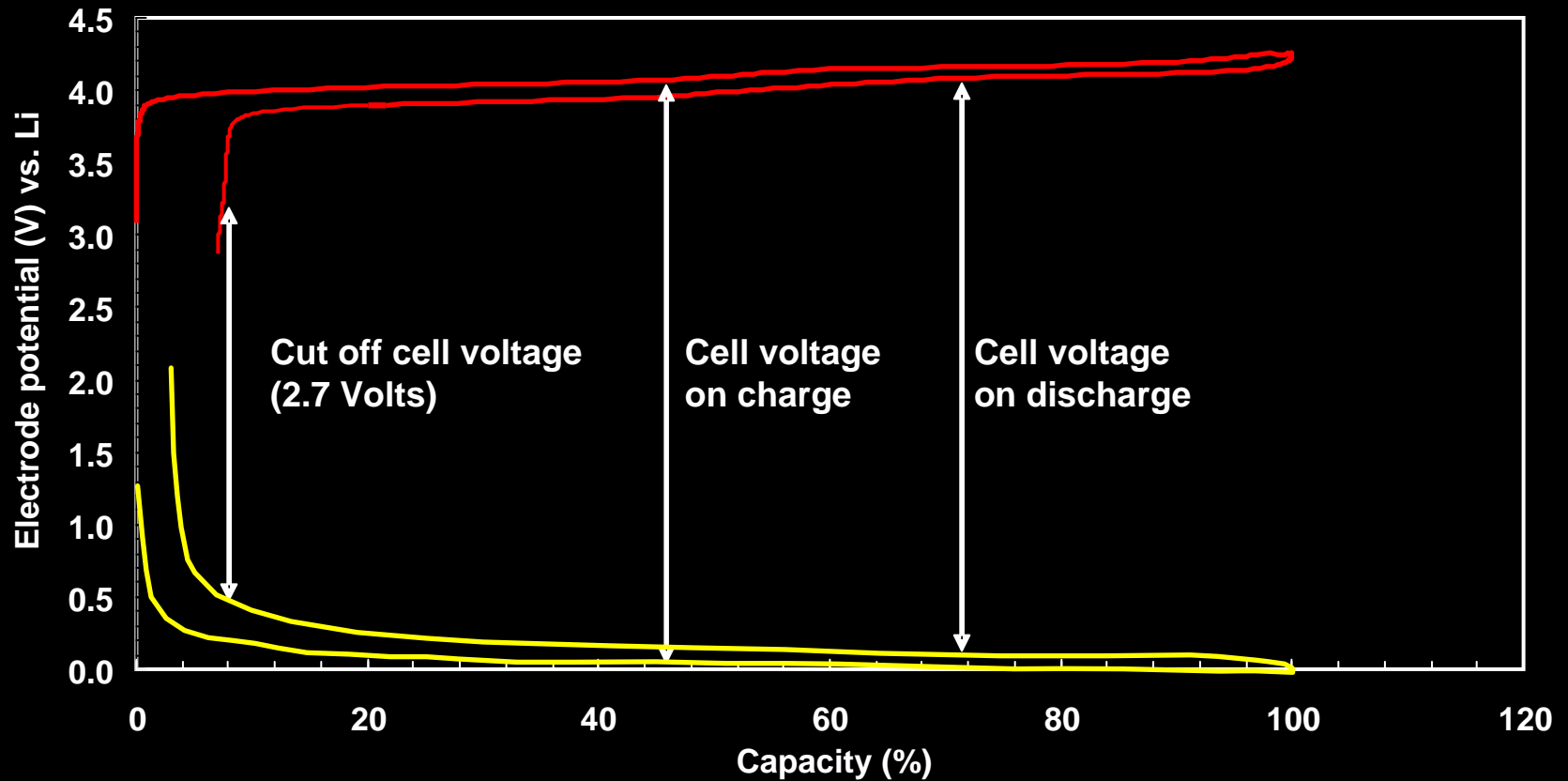
# Development of Manganese Spinel Compatible Graphite Anode Material

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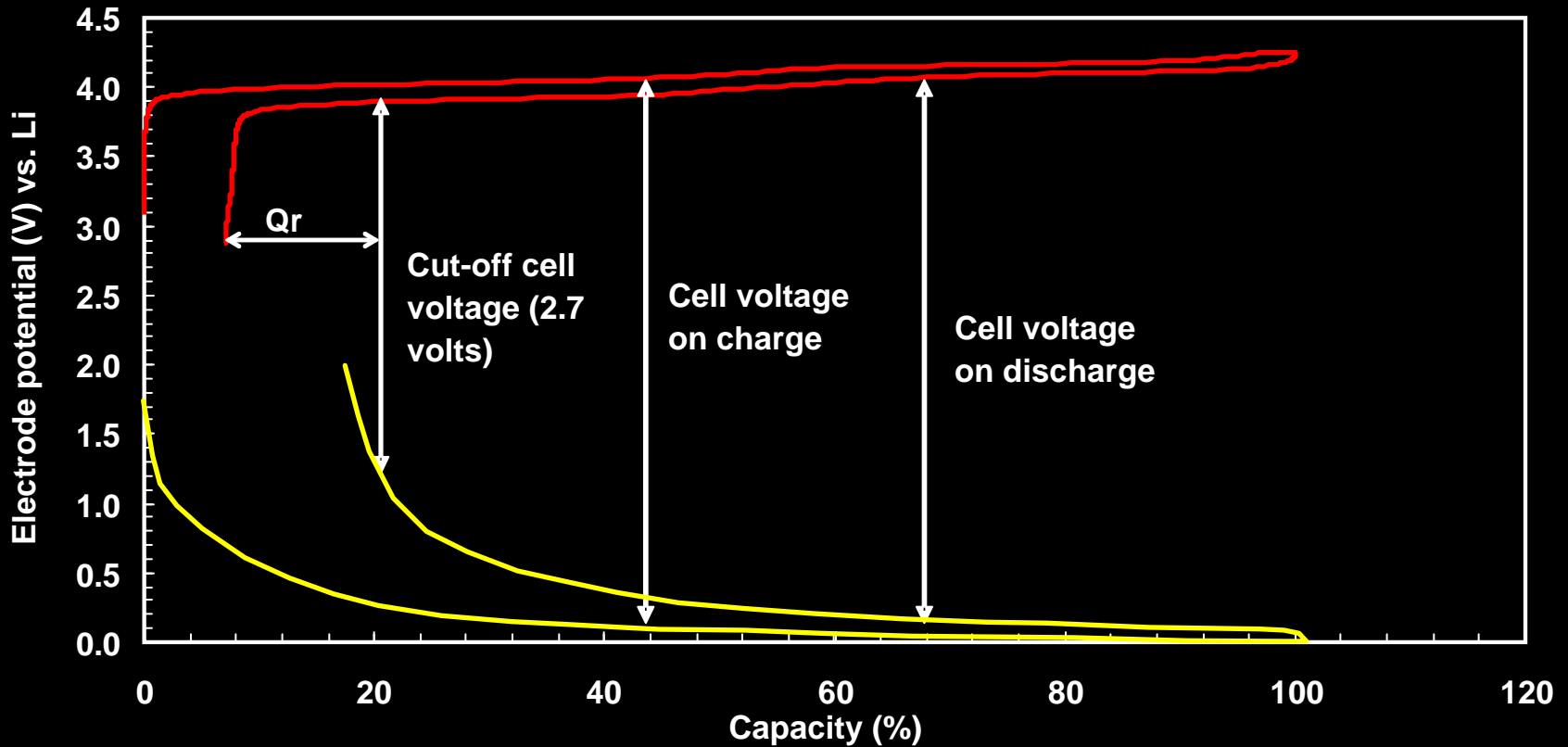
# Mn Spinel-Graphite Compatibility Issue

- Graphite has high efficiency and energy density
- Charge/Discharge profile of graphite can lead to Mn dissolution and reduction in cathode capacity during cycling
- Hard carbon and Li-titanates can address this, but energy densities with these anode materials are lower than graphite
- ConocoPhillips has developed CPreme® M-5 graphite material that retains many of the advantages of graphite but addresses the spinel stability issue
- This was accomplished by manipulating the charge discharge profile of the graphite by engineering the material with a proprietary technology

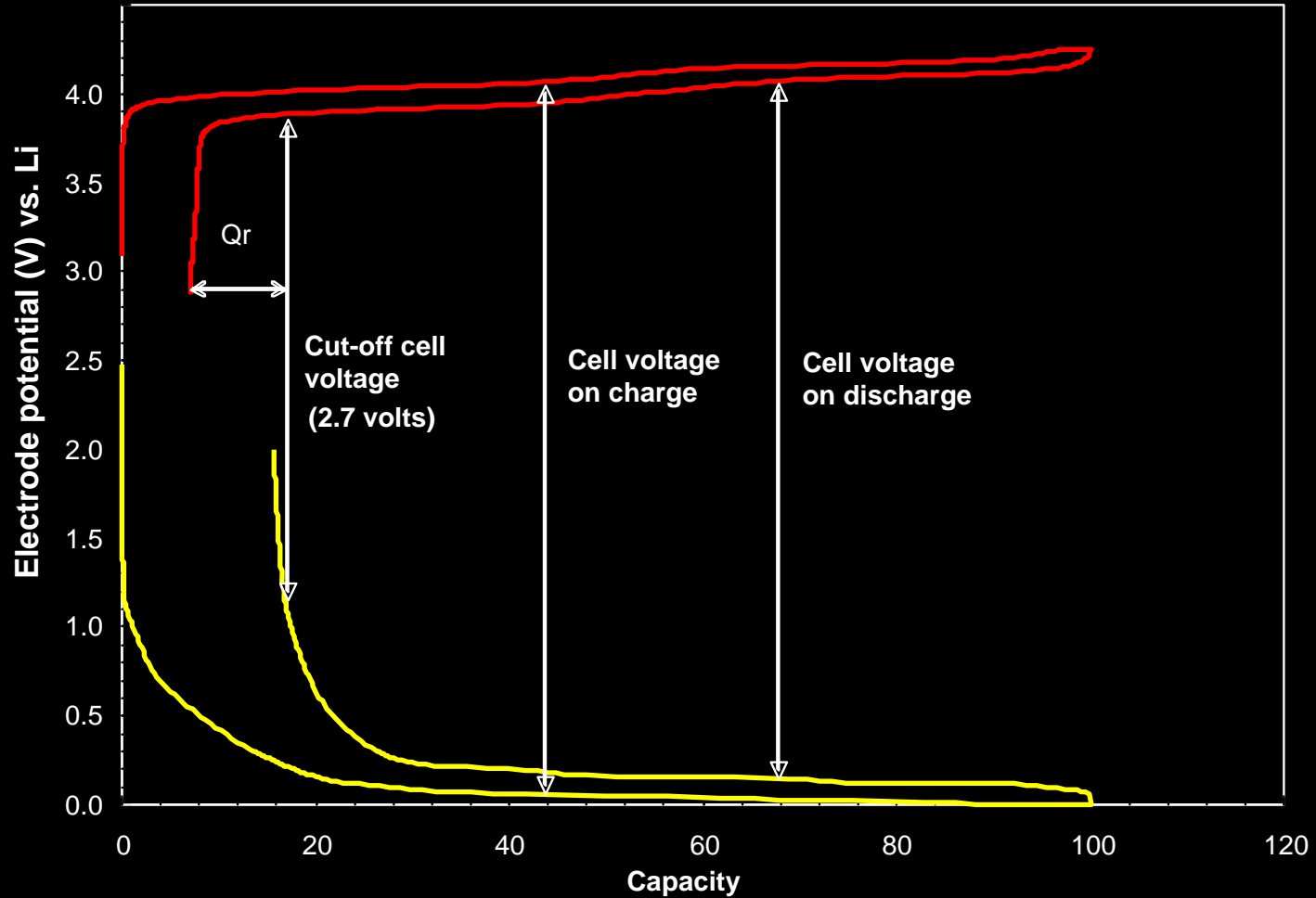
# LMO vs. Graphite



# LMO vs. Hard Carbon



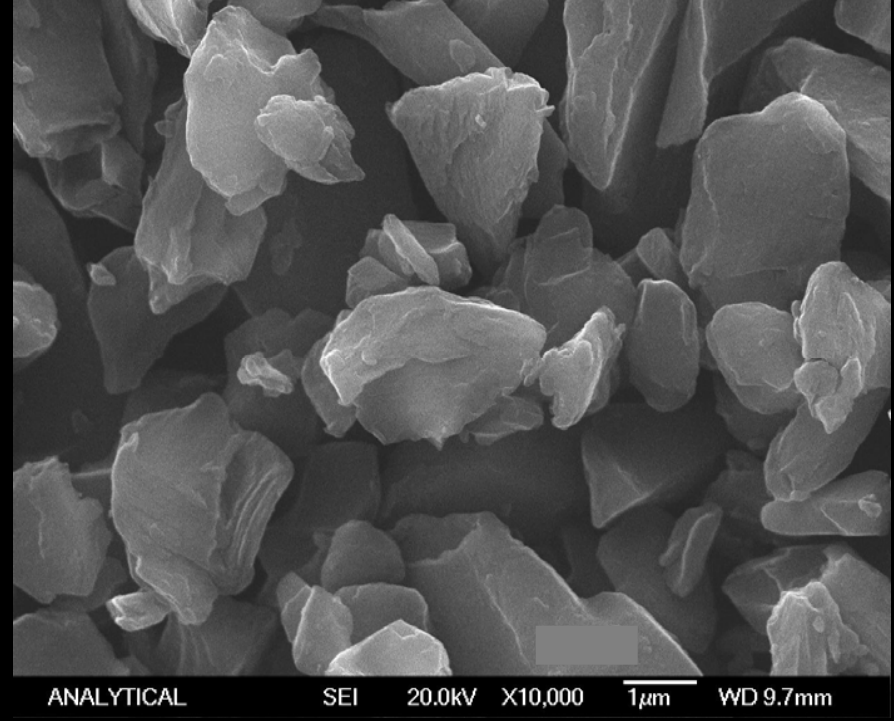
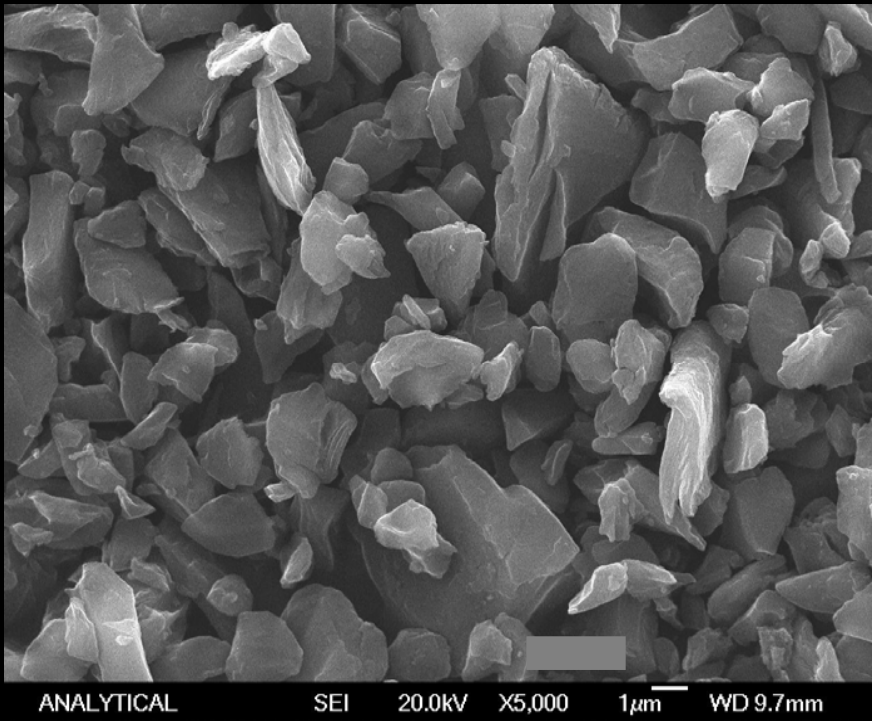
# LMO vs. CPreme® M5



# High Power Mn-Compatible Anode Properties (M5)

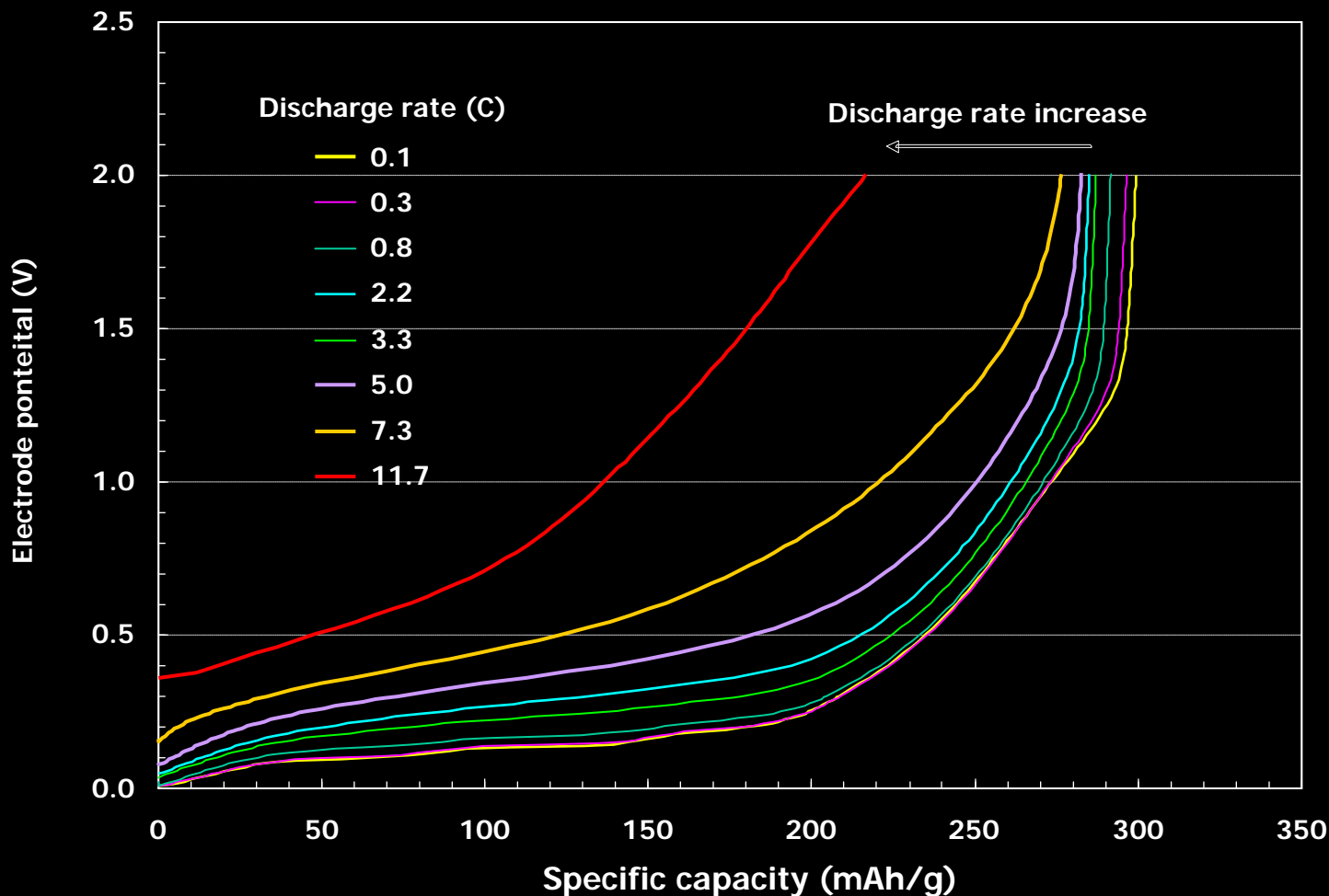
<b>Particle Size (D50, mm)</b>	<b>4 - 6</b>
<b>BET Area, m<sup>2</sup>/g</b>	<b>3 - 6</b>
<b>Tap Density, g/cc</b>	<b>0.4 – 0.7</b>
<b>Particle density, g/cc</b>	<b>1.9 – 2.1</b>
<b>Specific capacity, mAh/g</b>	<b>280 – 310</b>
<b>First Cycle Eff., %</b>	<b>80 - 90</b>

# M Grade Morphology



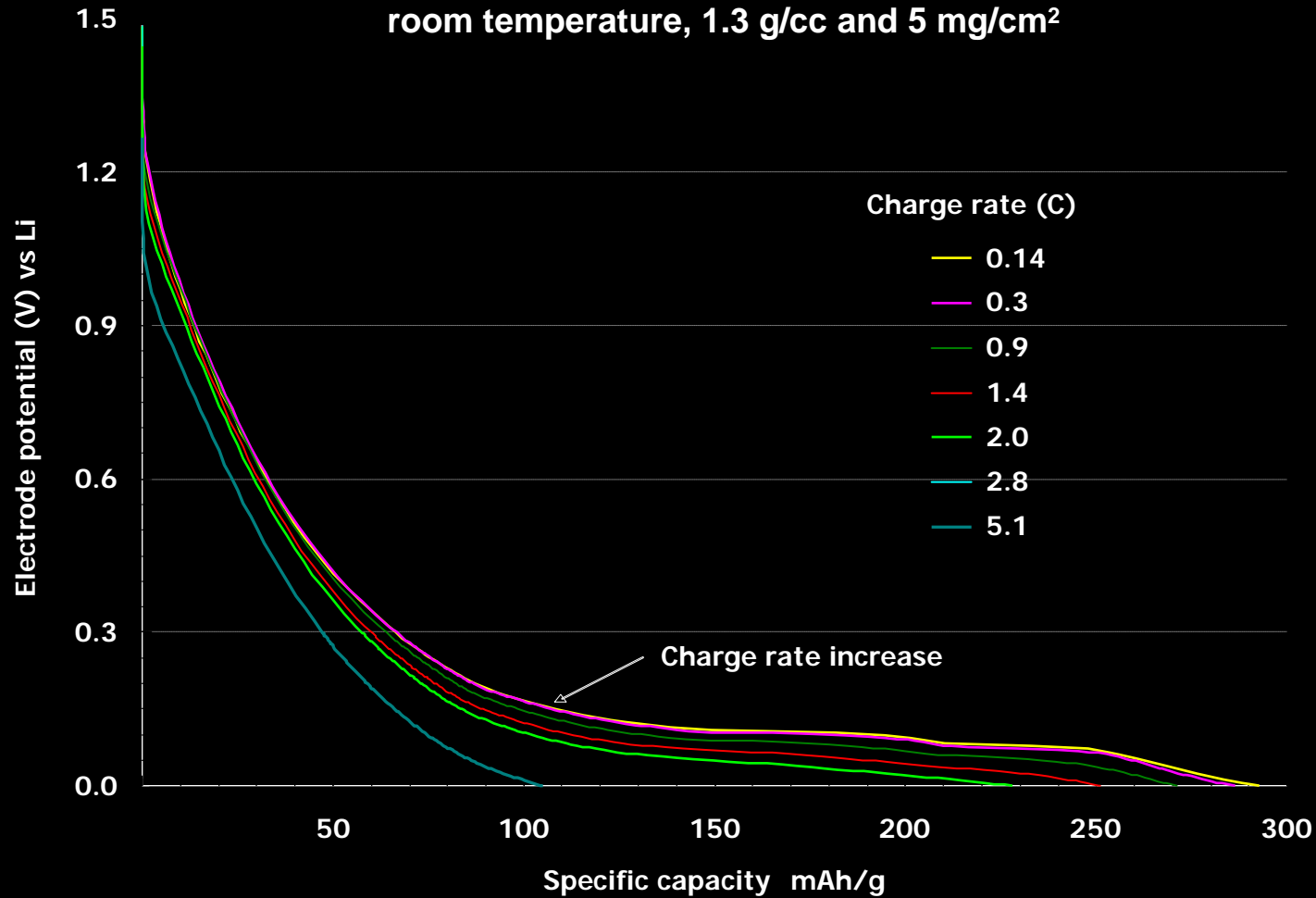
# Discharge Profile of M5

Cycle condition: 3-electrode cell at room temperature, 1.3 g/cc and 5 mg/cm<sup>2</sup>

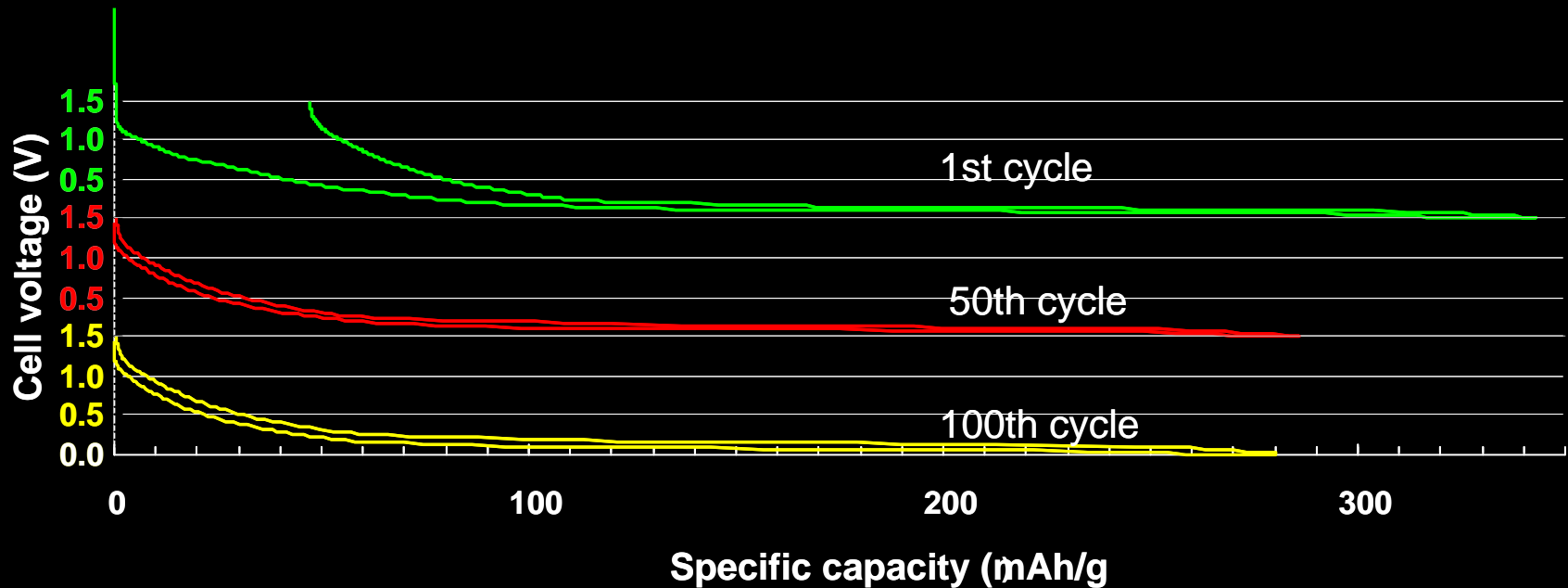


# Charge Profile of M5

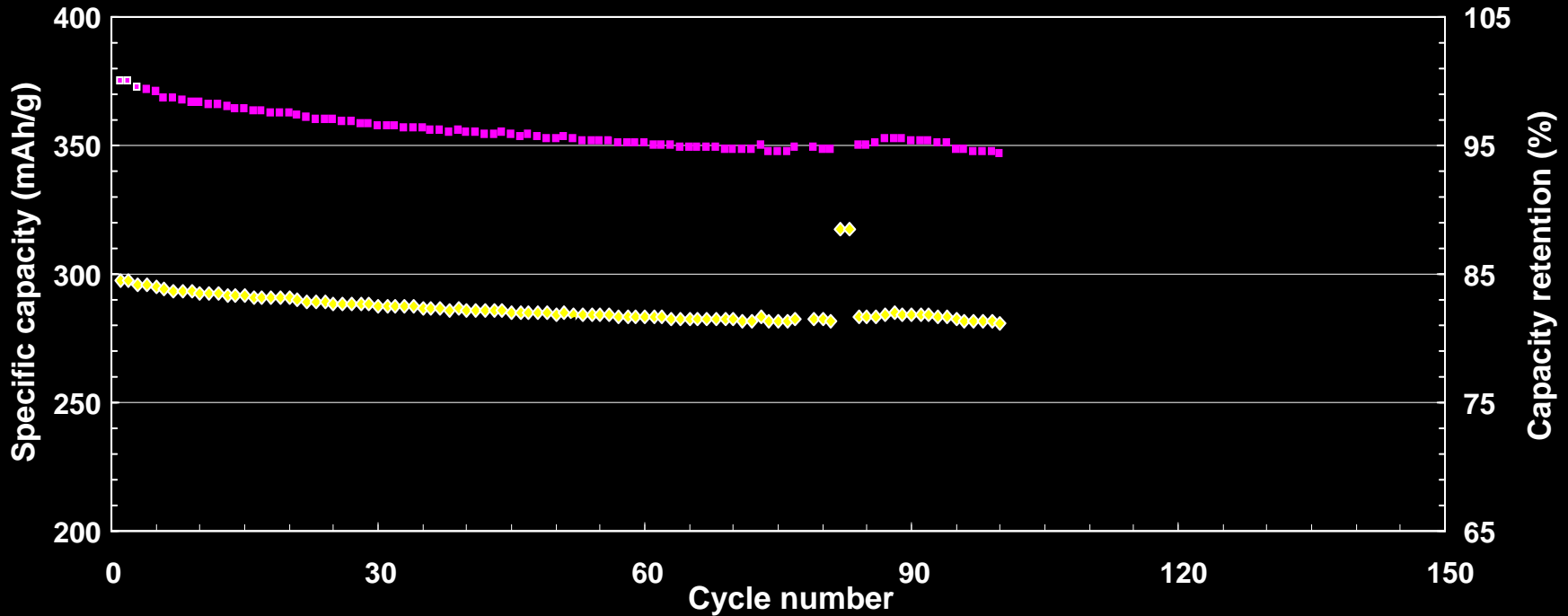
Cycle condition: 3-electrode cell at room temperature, 1.3 g/cc and 5 mg/cm<sup>2</sup>



# Performance Example of M5 Series vs. Lithium



# Cycling Characteristics of M5 vs. Lithium C/2 rate at 22 °C vs. Li



Item		M5	Hard Carbon	LTO
<b>Usable Capacity</b>				
Capacity	mAh/gm	300	500	155
% working capacity	%	83	50	90
<b>Available working capacity</b>	<b>mAh/gm</b>	<b>248</b>	<b>250</b>	<b>140</b>
<b>Energy Density</b>				
Cathode Voltage	Volts	4.0	4.0	4.0
Anode Voltage	Volts	0.2	1.0	1.5
Voltage Differential	Volts	3.8	3.0	2.5
<b>Energy Density</b>	<b>Wh/gm</b>	<b>0.94</b>	<b>0.75</b>	<b>0.35</b>
<b>Cost Comparison</b>				
\$ / kg		20.00	20.00	20.00
¢ / Wh		2.1	2.7	5.7
<b>Volumetric Efficiency</b>				
True density	gm / cc	2.0	1.8	3.3
Electrode density	gm / cc	1.5	1.0	2.2
<b>Volumetric Efficiency</b>	<b>mAh/cc</b>	<b>371</b>	<b>250</b>	<b>307</b>

# M5 - Product Summary

## Key Features:

- Voltage profile and 1<sup>st</sup> cycle efficiency are tailored to match Mn-Spinel cathodes
- Sloping voltage profile
- Higher working capacity and operational voltage differential
- Higher specific density and anode density

## Applications & Advantages:

- Mn Chemistry - reduced dissolution issues
- Highest energy density in class\*
- Highest volumetric efficiency in class\*
- Best cost-performance in class\*
- Long cycle life

## Status:

- Commercially available now

- *\* LTO, Hard Carbon commonly used with Mn Cathodes*