EaglePicher™ Technologies, LLC

An OM Group Company

High Energy Manportable Battery

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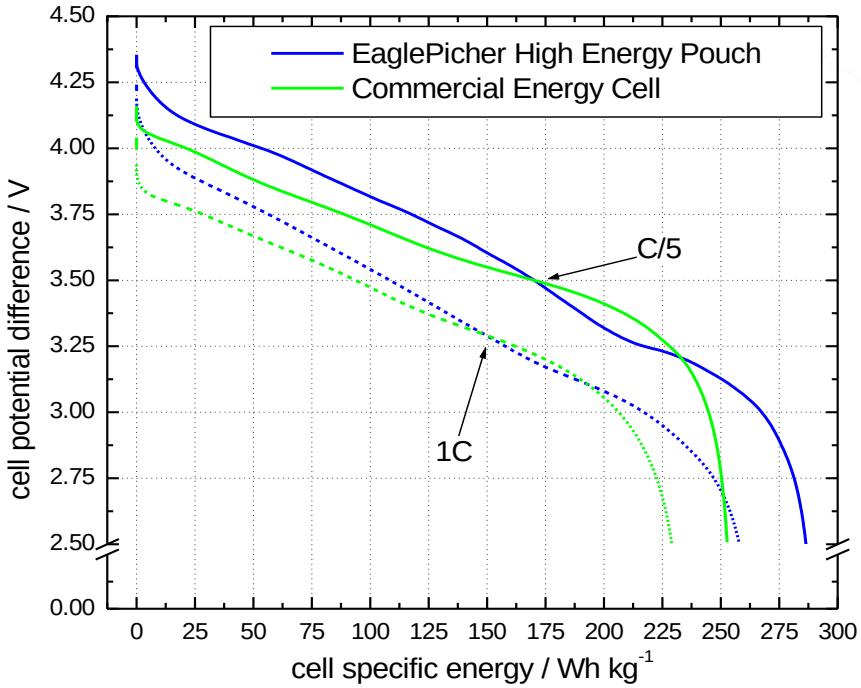
Background



- Improving the energy of Li-ion cells desirable for many applications including personal power, transportation, etc.
- COTS cells with carbon based anode and typical metal oxide cathode currently deliver 200-240 Wh kg^{-1}
- EPT pouch cells with carbon or silicon-carbon anode and high nickel cathodes deliver 220-300 Wh kg^{-1}

Outline

- 1.75 Ah pouch for conformable wearable battery
  - Requirements
  - Initial cell performance
  - Cell performance at various temperatures
  - Cell safety report
  - Battery performance
- Improving energy density
  - Incorporation of Si-C composite anode
  - Improving specific capacity of cathode material

CWB-R battery requirements

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Battery PIN:	M32383/4-3 and M32383/4-4
Type Classification:	BB-0150/U
Chemistry:	M32383/4-3 Li-Ion / M32383/4-4 Lithium Polymer
Color:	M32383/4-3 "Tan 686A" / M32383/4-4 "Earth Yellow"
Weight (max):	2.6 lbs (1180 grams)
Voltage Range:	10-16.8
Nominal Voltage:	14.8
Nominal Capacity:	10.0 Ah
Nominal Energy (new battery):	148 Wh at C/5
Battery Life:	≥ 224 cycles, ≥ 3 years
Rated power output:	≤ 148 W
Continuous load rating:	≤ 5.0 A
Pulse load rating:	35 A (915 µSEC) setting 30A ((≤25ms) Test
Charge temperature range:	-4 to 122ºF (-20 to 50ºC)
Operating temperature range:	-4 to 140ºF (-20 to 60ºC)
Storage temperature range:	-27 to 160ºF (-32 to 71ºC)
MAX abusive temperature (non-operating):	199ºF (93ºC)
Connector:	Glenair Part Number 8071-1472-12 / 8070-1299ZNU7-7DY - 807-663-12/807-348-01ZNU6-7SY equivalent
Overall Dimensions:	8.7 in. x 7.66 in. x 0.70 in.
Non-rechargeable equivalent:	N/A
Note 1: Maximum charge current for connector is 5A for connector and 5A bottom contacts	

17.2V in recent RFQ

- High energy rechargeable battery to reduce Soldier's burden
- Flexible to conform to Soldier's body armor

CWB-R cell and battery specs

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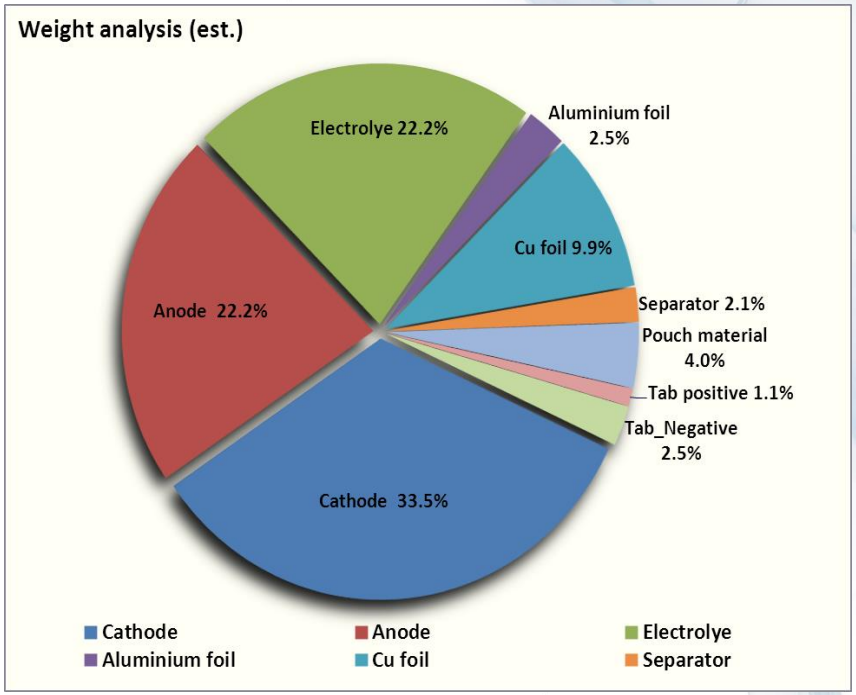
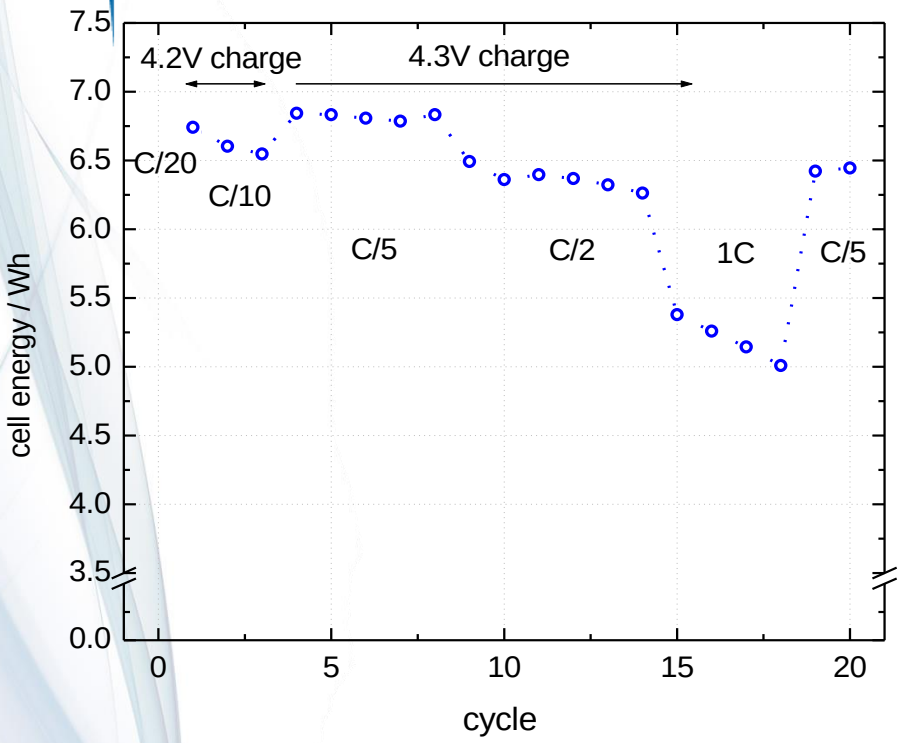
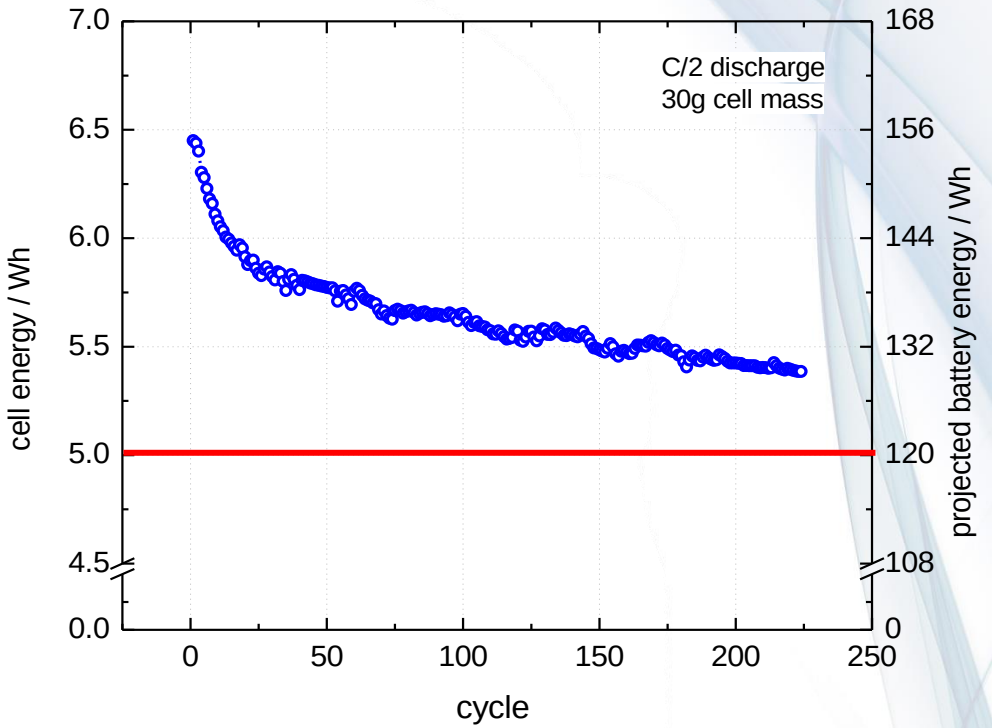
	Specification
Cell nominal capacity	1.75 Ah
Cell dimension	50 mm (W) x 57 mm (H) x 6.5 mm (T)
Cell average voltage	3.65 V
Cell max. voltage	4.3 V
Cell weight	~32 g
Cell numbers in a battery	24 cells (6s4p)
Battery capacity	>10.5 Ah
Battery energy	>150 Wh
Voltage range	10.0 V – 17.2 V
Battery dimension	Within the required dimension



Cell performance	Design target	Test value	Requirement
Capacity @ C/5	>1.79 Ah	>1.75 Ah	>1.75Ah
Capacity @ C/2	>1.61 Ah	~1.72 Ah	>1.60 Ah
Cell Energy @ C/5	> 6.4 Wh	~6.4 Wh	>6.25 Wh
Cell Energy after 224 cycles	> 5.5Wh	5-5.5 Wh	>5 Wh
Battery energy @ C/5	>150 Wh	>150 Wh	>148 Wh
Battery energy after 224 cycles @ C/2	>130 Wh	Under test	>120 Wh

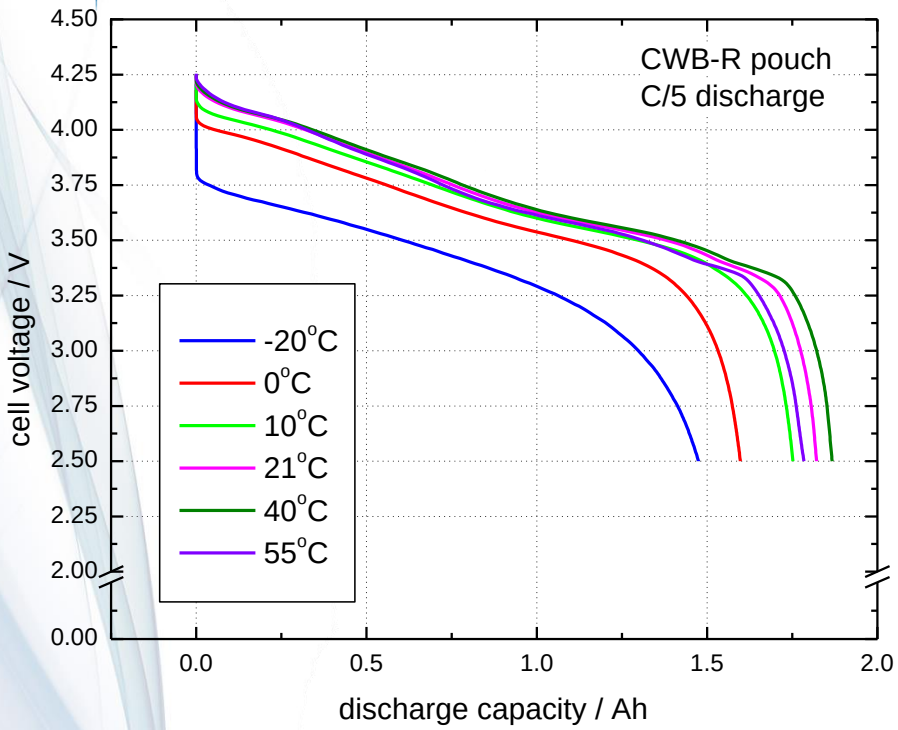
Initial CWB-R cell performance

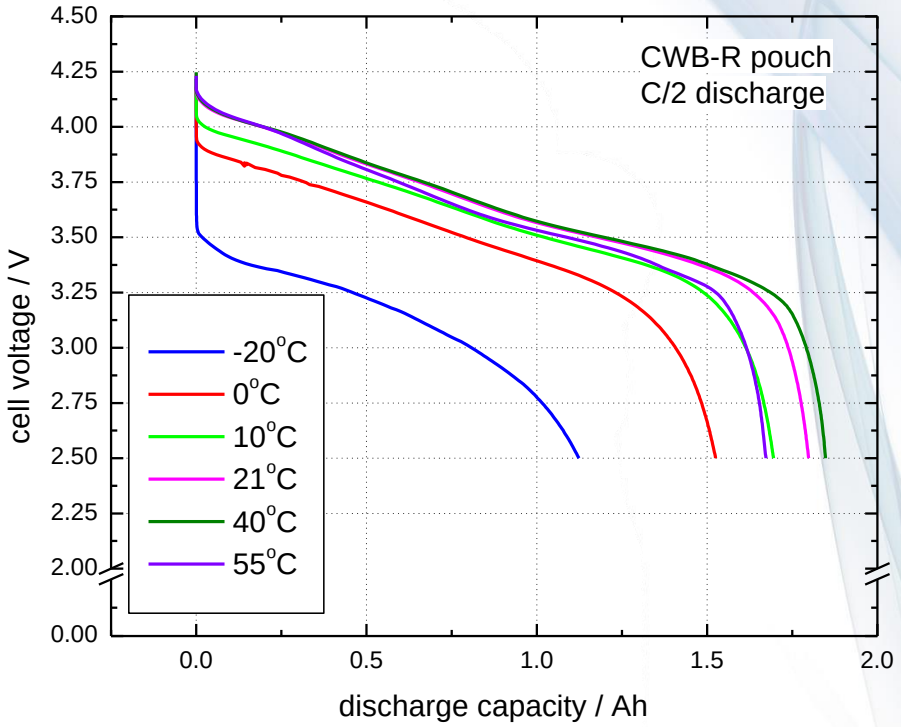




- Meets performance, cycling, and weight design requirements

Discharge curves





- Cells deliver good capacity from -20 to 55 ºC

Temperature effects

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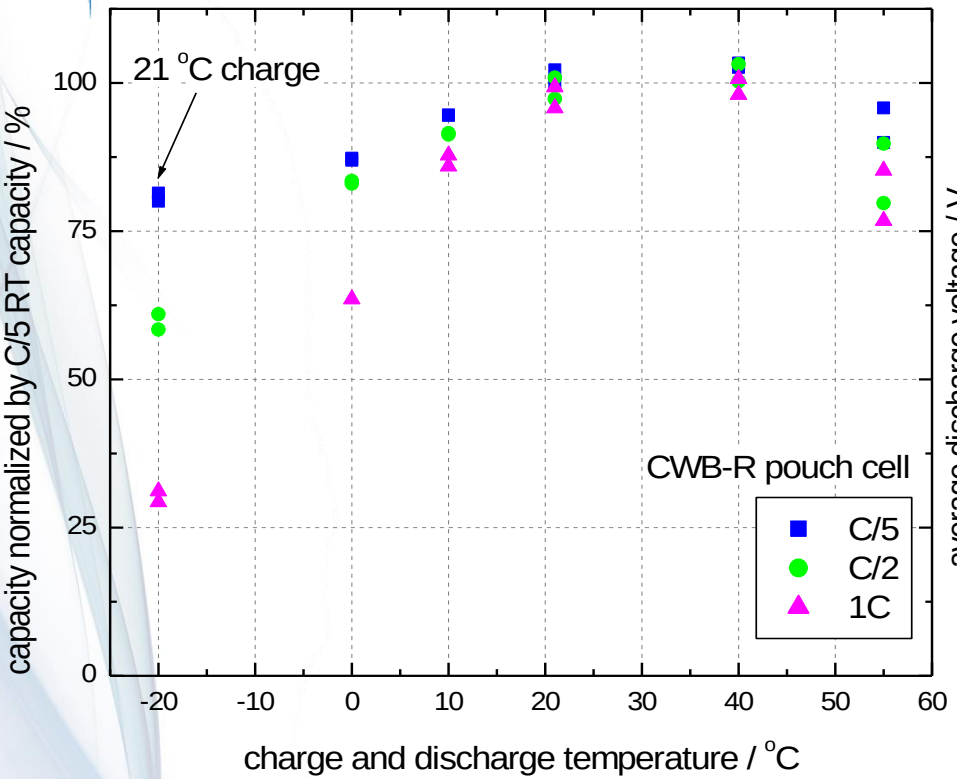

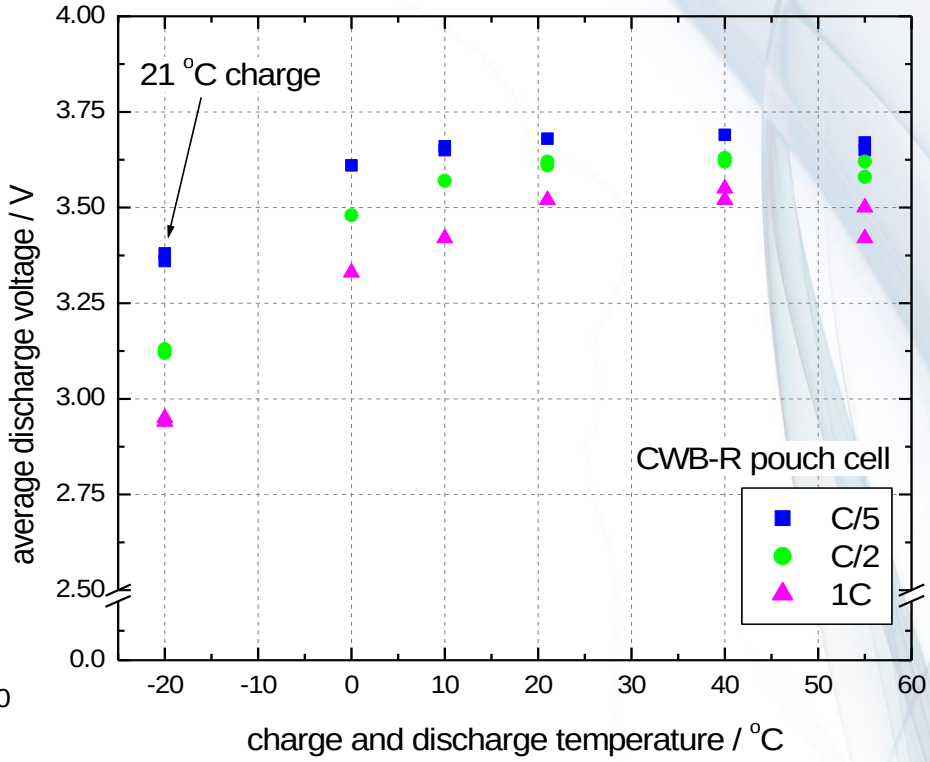

- Retention >80% for C/5 rate across the temperature range
- Minimal temperature effect on discharge voltage for ≥0ºC

Low temperature charging capability

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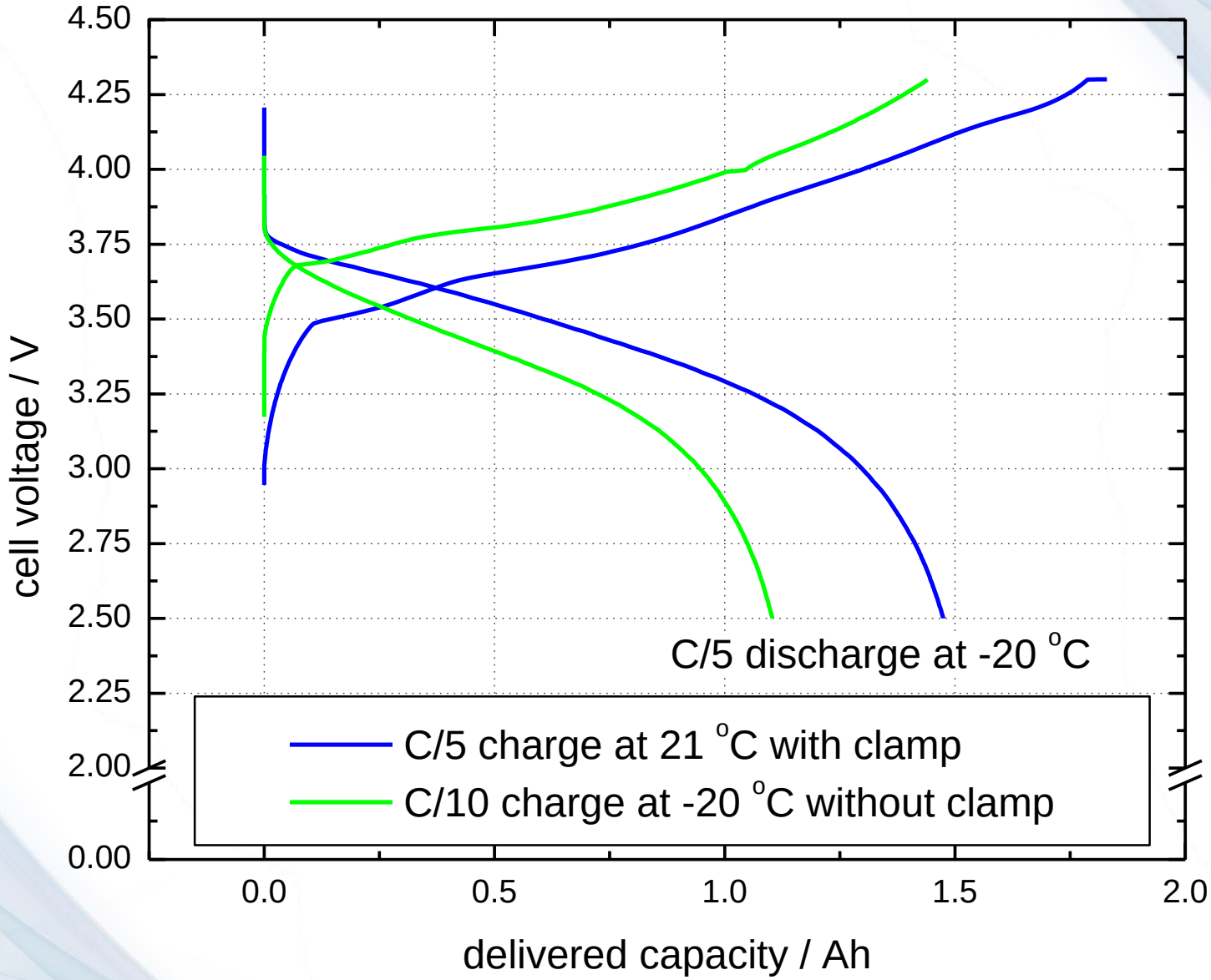

Low temperature cycling capability

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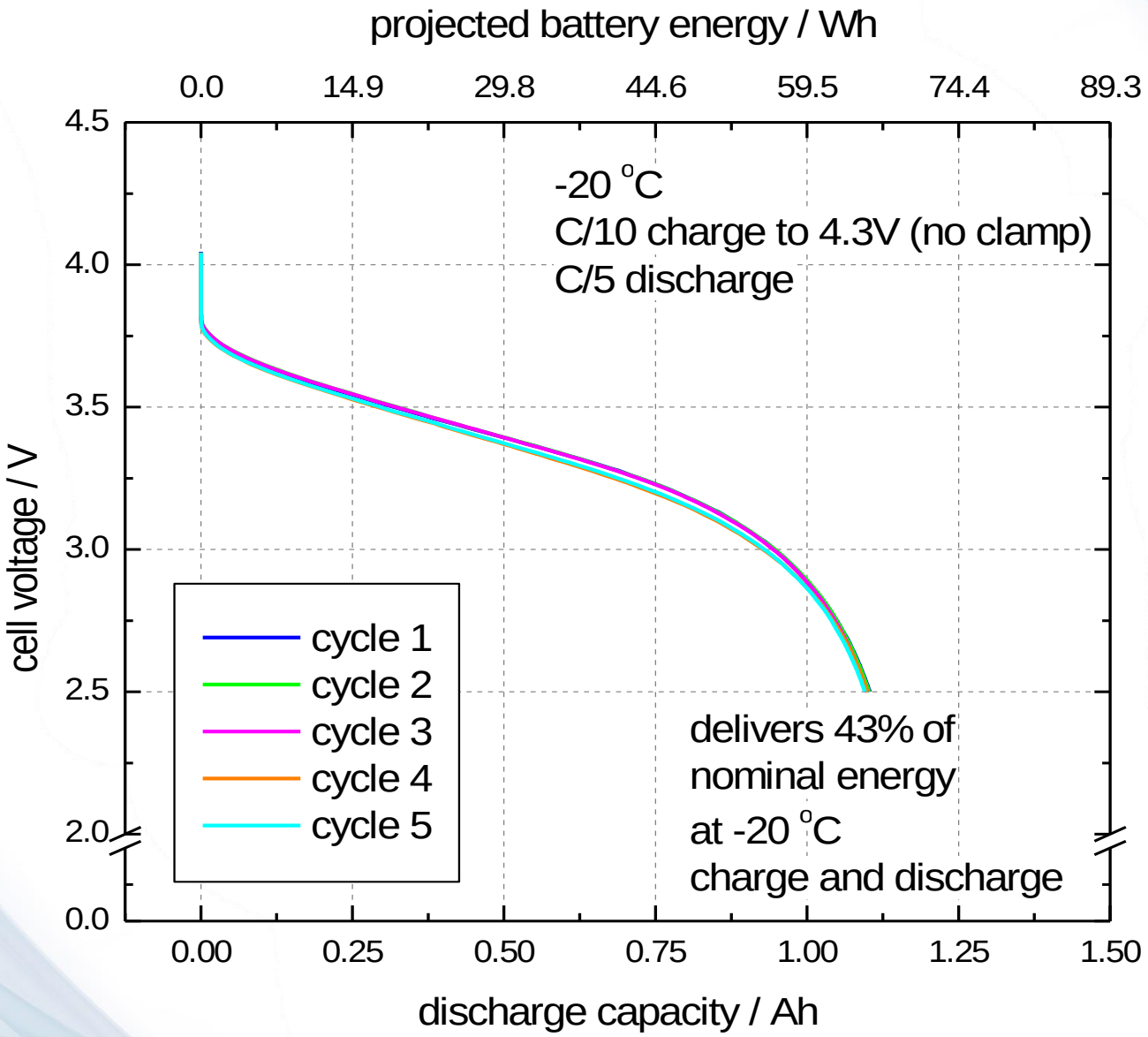

Nail penetration results

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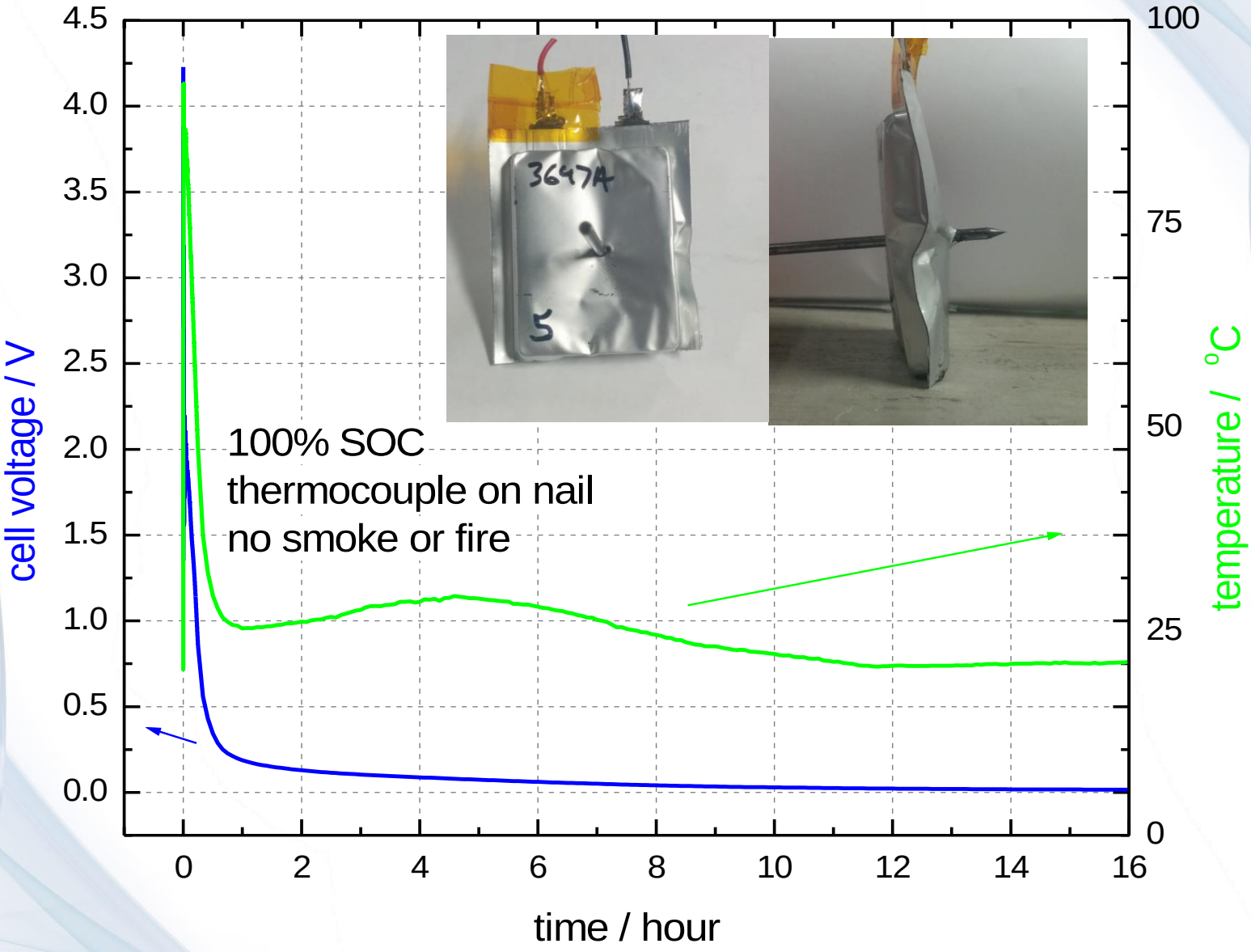

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UN testing

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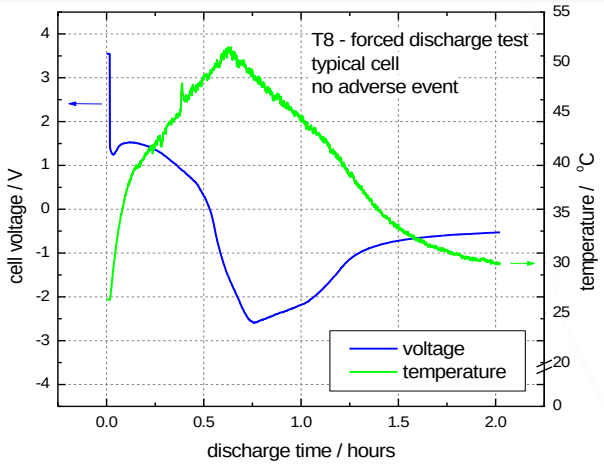
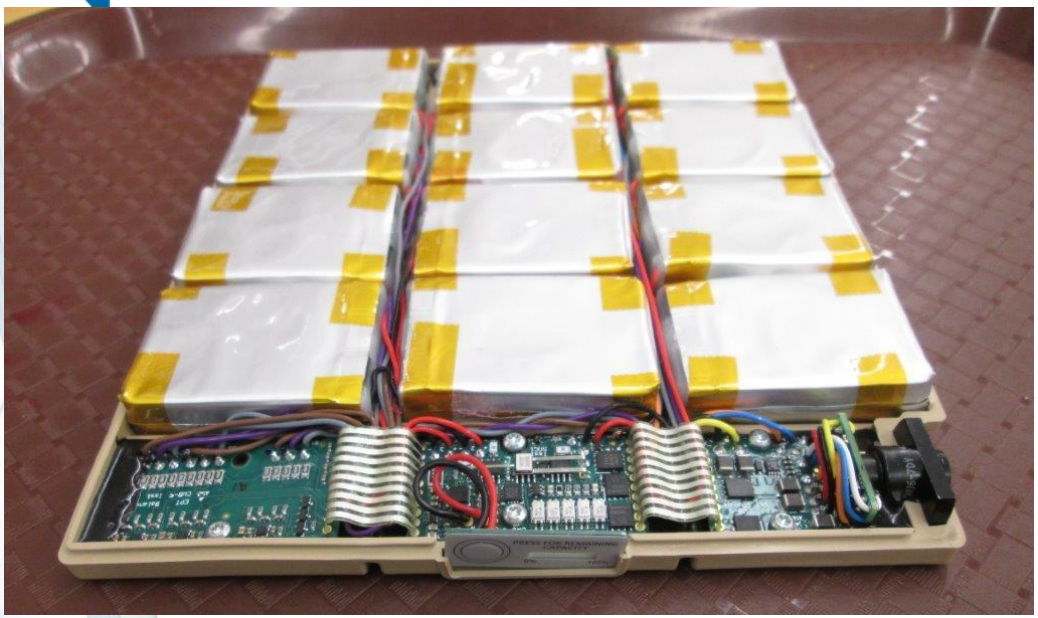
Cell level UN tests		
T1	altitude	pass
T2	thermal	pass
T3	vibration	pass
T4	shock	pass
T5	external short	pass
T6	crush	pass
T8	forced discharge	pass

UN T2 Thermal Test			
cell #	OCV before thermal cycles / V	OCV after thermal cycles / V	retention
1	4.19	4.17	99.5%
2	4.20	4.14	98.6%
3	4.20	4.14	98.6%
4	4.20	4.14	98.6%
5	4.21	4.14	98.3%
6	4.21	4.14	98.3%
7	4.21	4.14	98.3%
8	4.21	4.14	98.3%
9	4.22	4.15	98.3%
10	4.22	4.15	98.3%
no leakage, mass loss, venting, rupture, disassembly, or fire observed			



- CWB-R pouch cells pass UN testing (10 cells each test)
- Battery level UN test planned

CWB-R battery



wired cells with BMS

finished battery in flexible case

CWB-R battery performance

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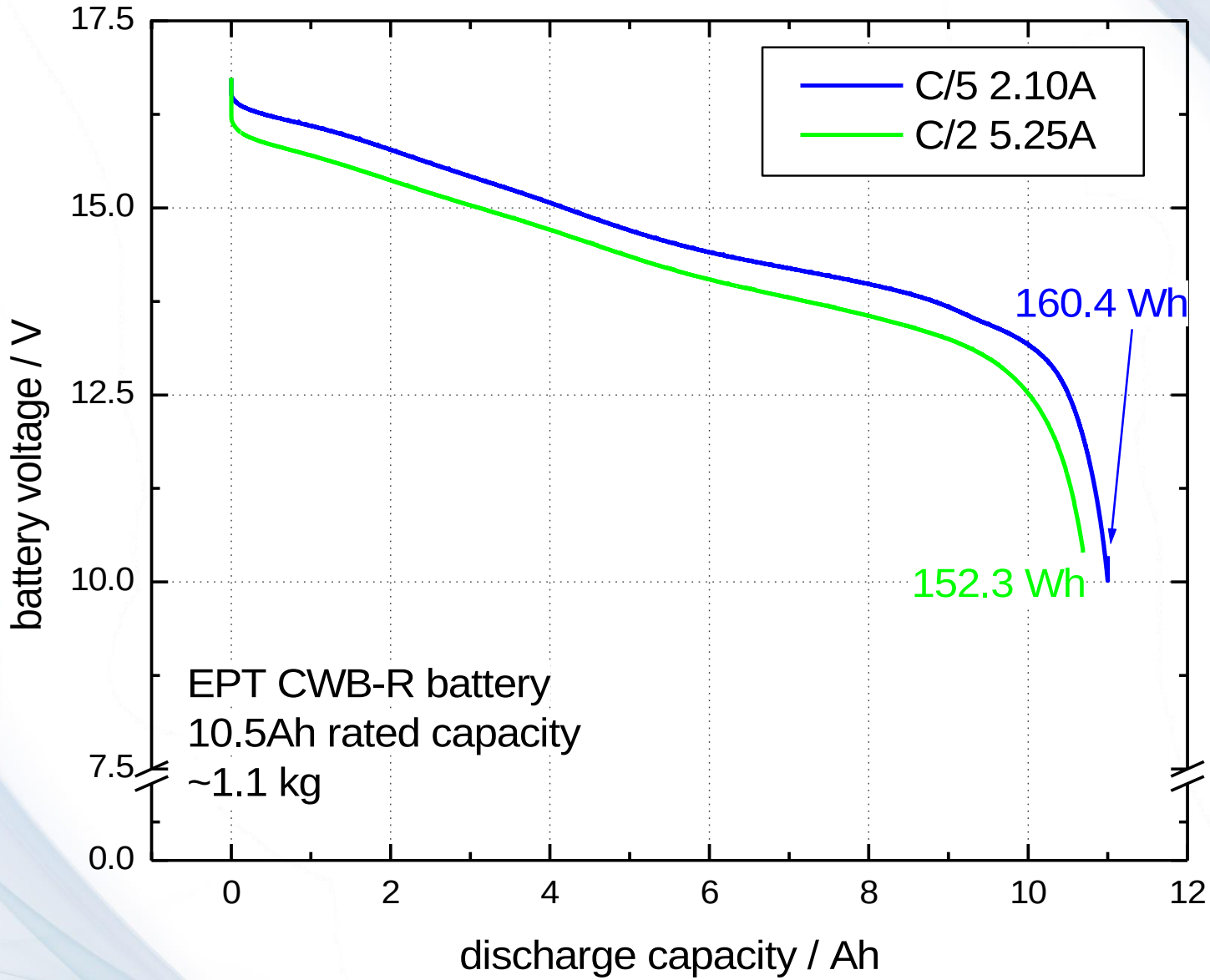

Next Generation Li-ion Chemistry

Si-C anode background

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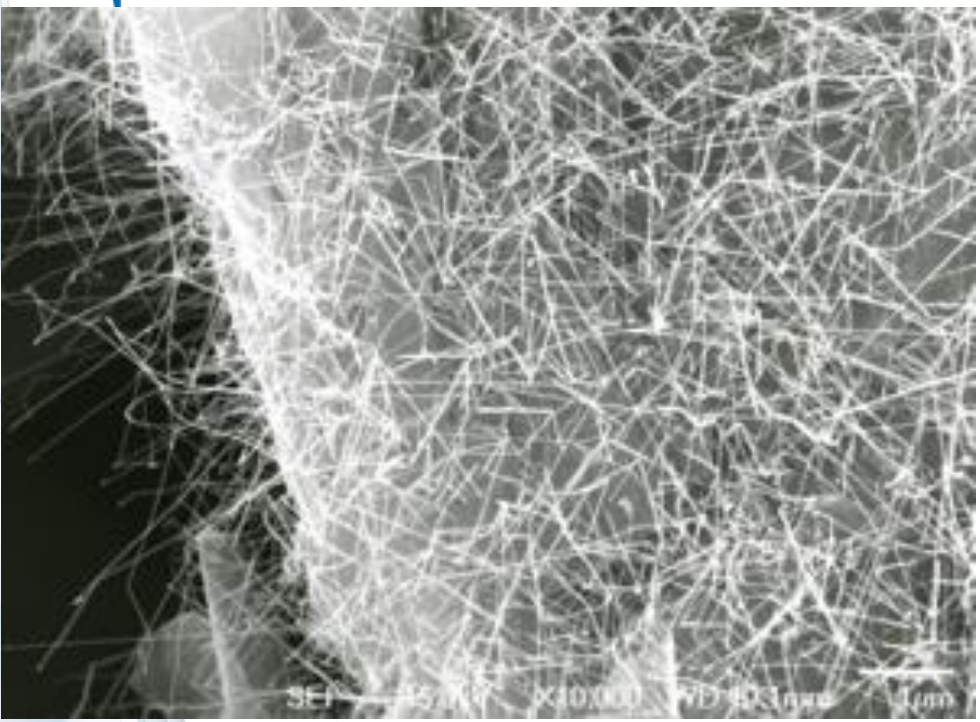
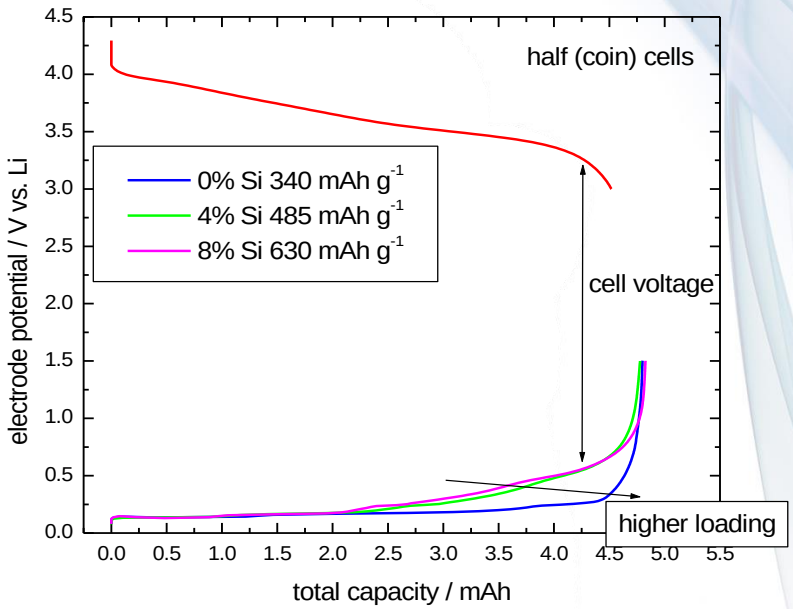
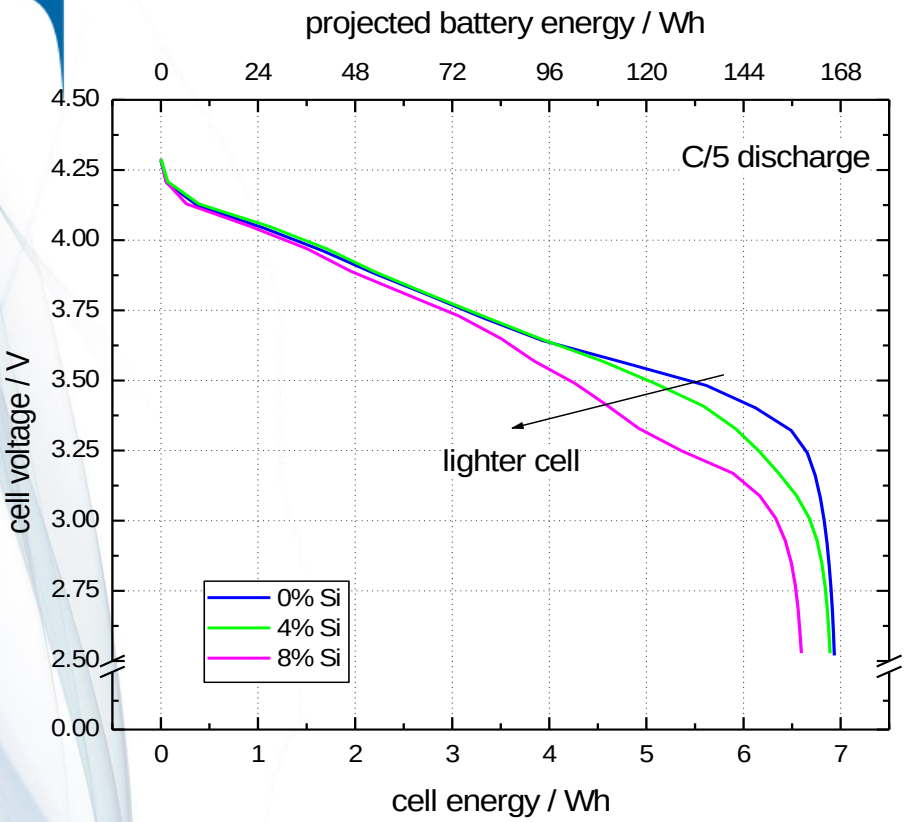
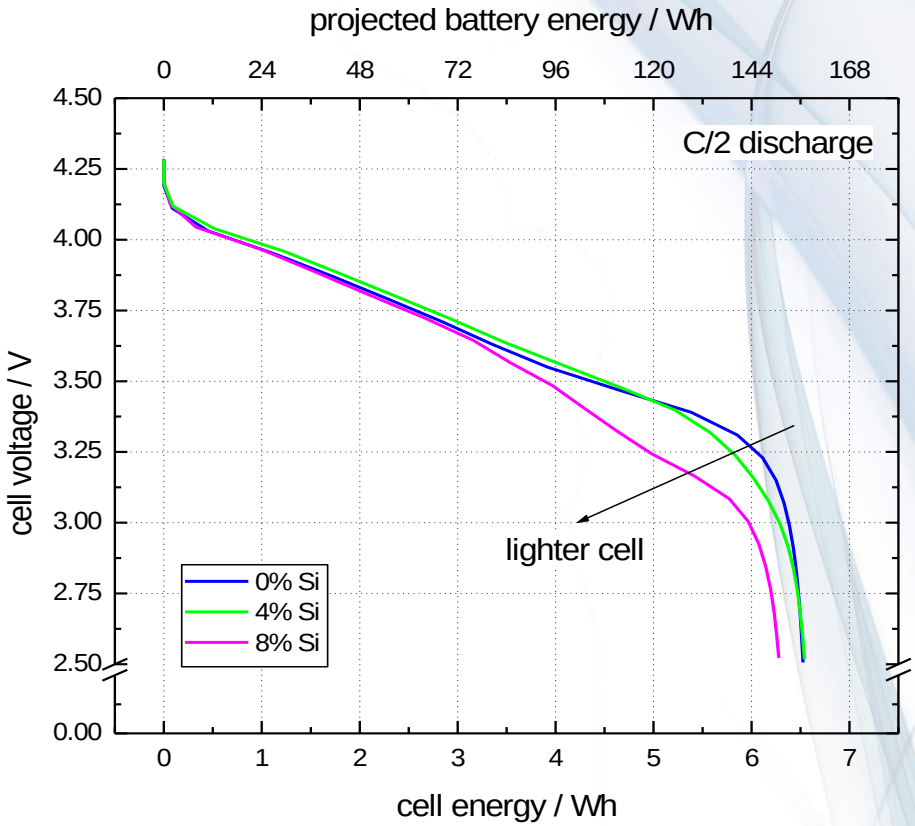




- Si theoretically 10x specific capacity of conventional carbons
- Higher specific capacity allows for lighter anodes and cells
- EPT licensed OneD Si-C composite anode (formerly Nanosys) manufacturing technology in 4Q 2014

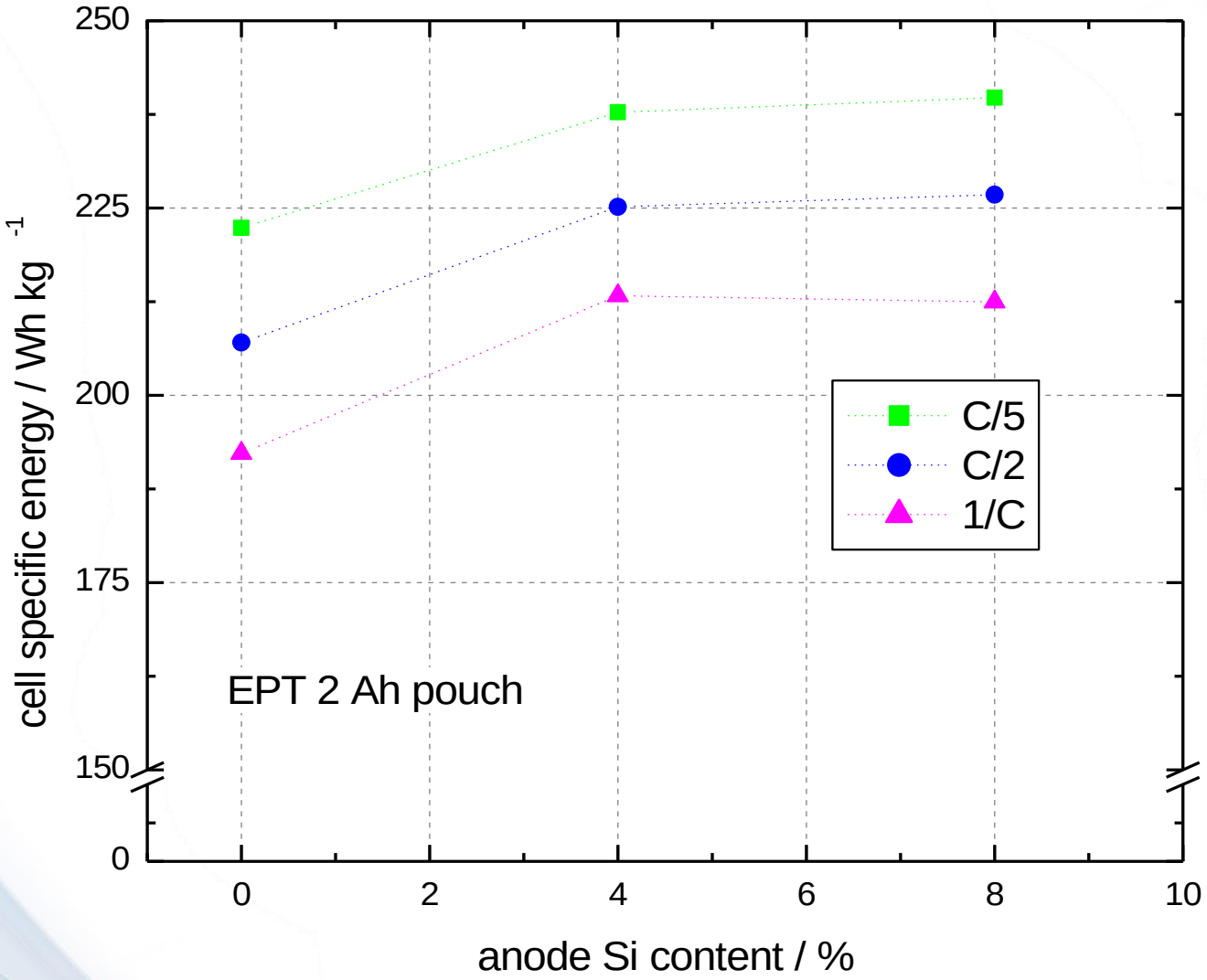
Effect of Si content on discharge





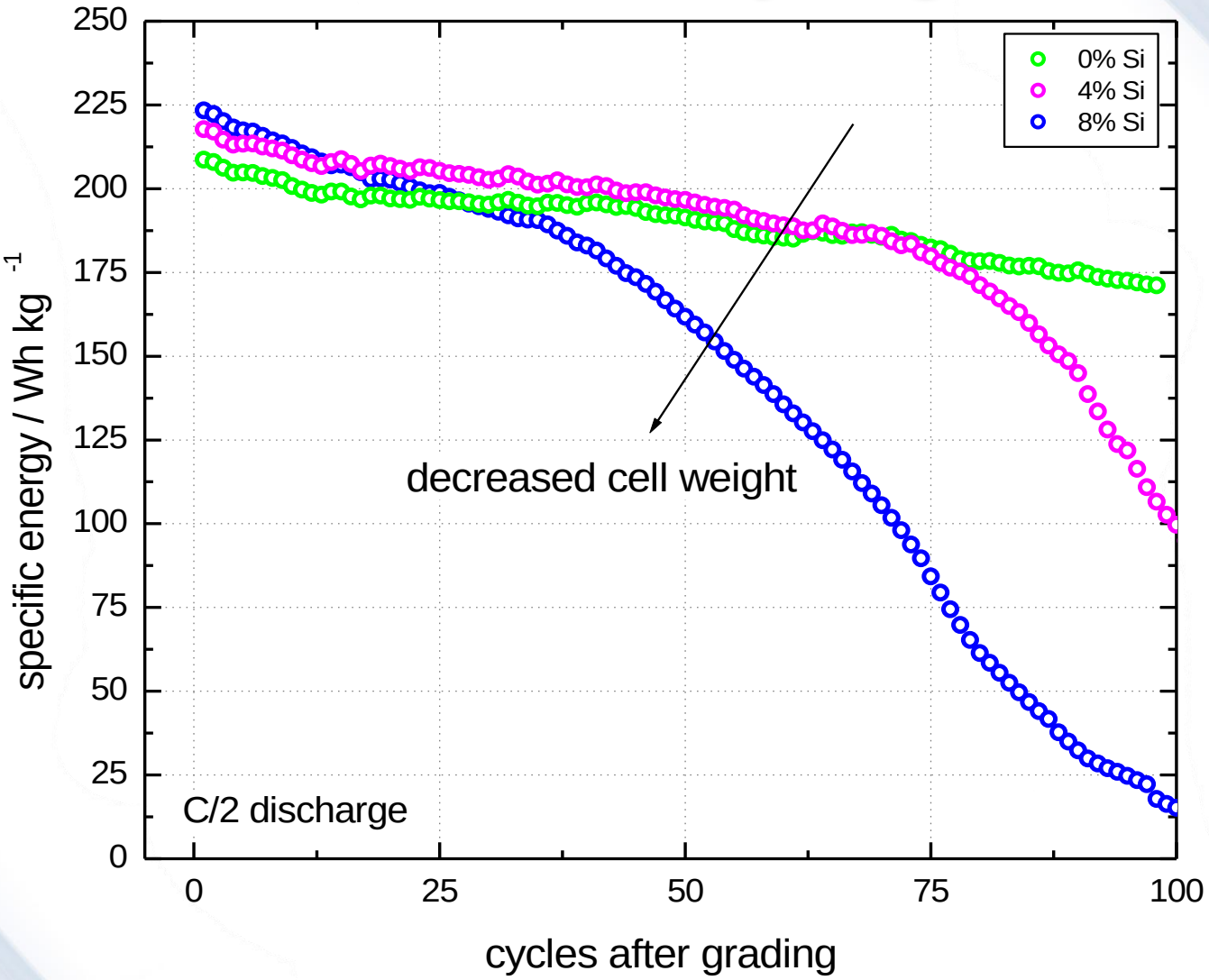
- Differences in energy caused by difference in the deintercalation profile of anodes

Effect of Si content on cell energy



- Specific energy plateaus at 4% Si for 2Ah pouch

Effect of Si content on cycling



- Collaboration with binder suppliers to improve cycleability

High specific capacity cathode

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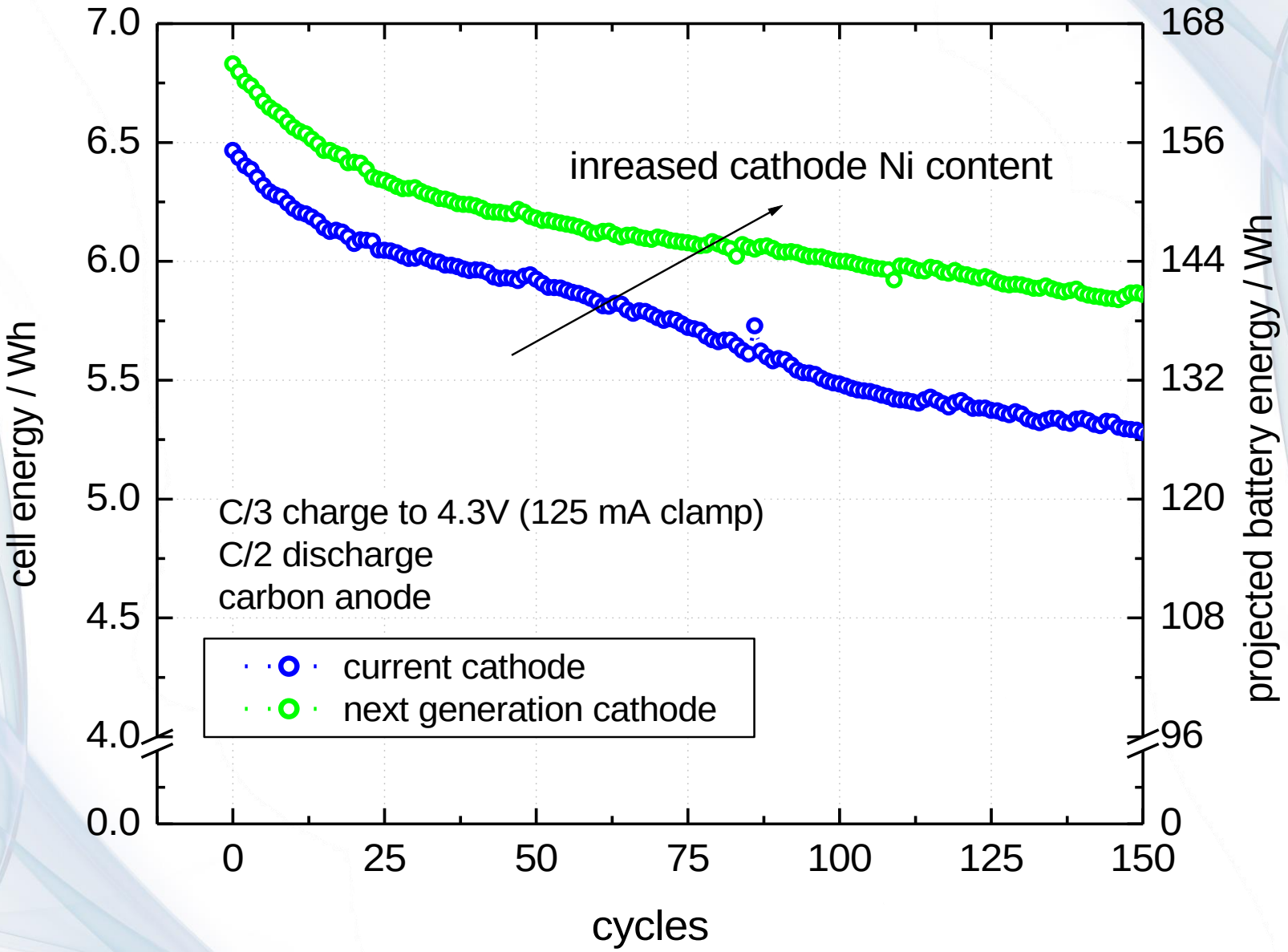

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Conclusions

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- EPT recently developed 1.75 Ah pouch cells with carbon anode and high energy cathode for the CWB-R battery
- Cell passed nail penetration and UN tests
- Battery delivers energy >150 Wh at ~1.1 kg weight
- Cell/battery specific energy will be improved further through incorporation of Si-C composite anode and improving specific capacity of the cathode
- 10 Ah class pouch also being developed that will deliver >250 Wh kg^{-1} at rates ≥1C