Li-ion Pouch Cell Designs; Performance and Issues for Crewed Vehicle Applications

by

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Outline

- Purpose and Motivation
- Cell designs evaluate
- Cell lot uniformity, why that’s important
- Forward plans
  - High rate performance
  - Cycle life durability
  - Seals
  - Corrosion susceptibility
  - Manufacturing quality
- Conclusions

Purpose & Motivation

- Compelling Advantages
  - Li-ion pouch cell designs provide the highest specific energy (> 220 Wh/kg), energy density (> 450 Wh/L) of all commercially available designs
  - Many high power designs also exist with very impressive performance (> 2000 W/kg and > 4000 W/L)
  - Numerous designs are being produced world wide in high volumes for the emerging EV/HEV/PHEV market
    - As such, calendar life, cycle life, and durability has been improved over the last 5 years
    - Many designs have extensive field testing and therefore, maturity
- Our purpose: Are there any performance show stoppers for spinning them into spacecraft applications?
  - Are the seals compatible with extended vacuum operations?
  - How uniformly and cleanly are they made?
  - How durable are they?
- Why now?
  - Electric vehicle market has driven significant improvements
  - Many of our applications (VASIMR, R2, etc) could benefit right now
  - We have access to several high volume cell suppliers which will soon have US production lines up and running

Maturity of Pouch Cell/Module Designs

- Dow Kokam
  - 15 high power cell designs offered
  - From 145 mAhto 200 Ah
  - Z-fold separator stacking method
  - PHEV battery module, liquid cooled, optimized for high energy, with 4 years, 1 million km of fleet testing
    - 98.4V, 7.1 kWh, 85 kg module

- EIG
  - 4 high power designs with good energy density
  - From 8 to 25Ah
  - Standard pack module is fan cooled for scooters, bikes, robots
    - 48V, 960Wh, 8.9 kg

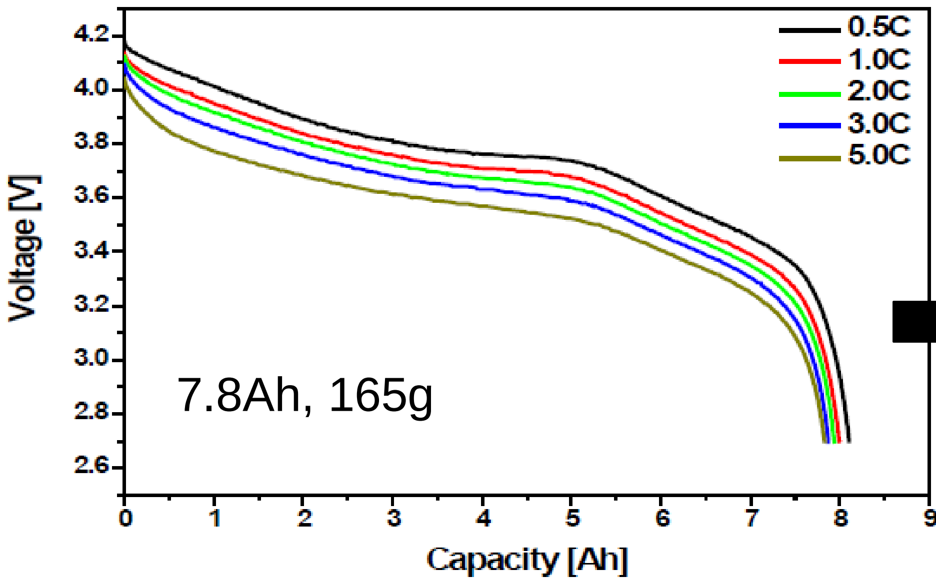
- LG Chemis providing cells in high volume for Chevy Volt battery packs
- A123 Systems also preparing for high volume cell production in US

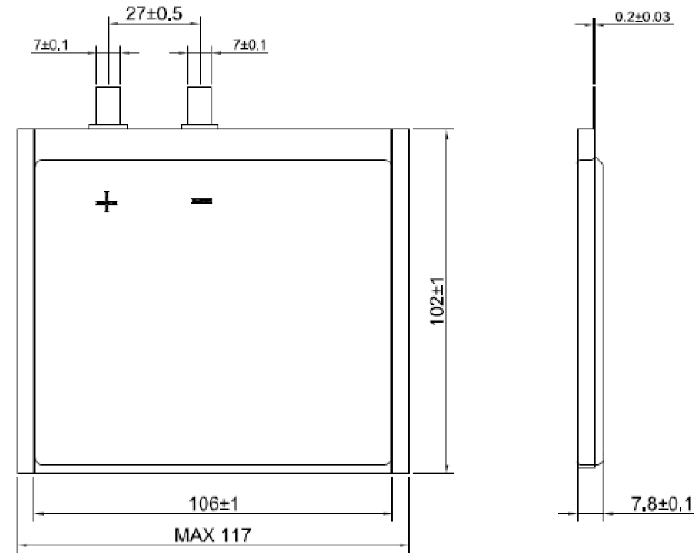
Assessment of Cell Designs

#	Vendor	P/N	Mass (g)	Rated Discharge Capacity (Ah)	Standard Charge Regime	Max Discharge
1	A123	PHEV	480	20	3.6V at C/2 with C/50 taper current limit	80A to 2.0V
2	Dow Kokam	SLPB75106100	165	8	4.2V at C/2 with C/50 taper current limit	32A to 2.7V
3	EIG	C020	425	20	4.15V at C/2 with C/50 taper current limit	80A to 2.5V
4	LG Chem	P1	383	15	4.15V at C/2 with C/50 taper current limit	60A to 2.8V

- All 4 are mature cell designs, made in high volume production lines
- All 4 provide a blend of high power and energy density capability

From the Dow-KokamDatasheet





- Specific Energy at 4C, RT → 158 Wh/kg
- Energy Density at 4C, RT → 278 Wh/L

- Thin tab termination
- Blend of high power (up to 5C continuous discharge rates) with high energy capability

Energy Innovation Group

Technology

Lithium Ion Polymer Battery
Li[NiCoMn]O₂-based Cathode
Graphite-based Anode
High Energy Density
Optimized for PHEV, EV

Product General Specification

Mechanical Characteristics

Model	C020
Length	216.0 ± 1 mm (excluding terminal)
Width	130.0 ± 1 mm
Thickness	7.2 ± 0.2 mm
Weight	approx. 425 g

Electrical Characteristics

Nominal Voltage	3.65 V
Nominal Capacity	20 Ah
AC Impedance (1 KHz)	< 3 mΩ
Specific Energy	175 Wh/Kg
Energy Density	370 Wh/L
Specific Power(DOD50%, 10sec)	2300 W/kg
Power Density(DOD50%, 10sec)	4600 W/L

Operating Conditions

Charge Conditions :	
Recommended Charge Method	CC/CV
Maximum Charge Voltage	4.15 V
Recommended Charge Current	0.5 C Current

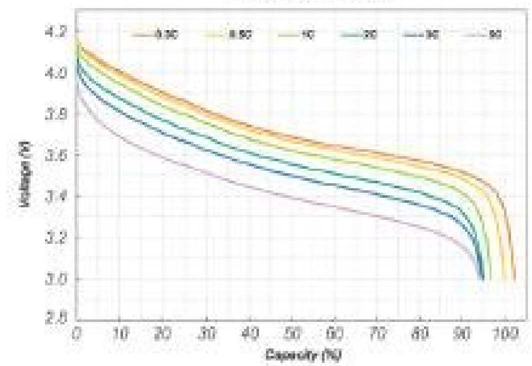
Discharge Conditions :	
Recommended Voltage Limit for Discharge	3.0 V
Lower Voltage Limit for Discharge	2.5 V
Maximum Discharge Current (Continuous)	up to 5 C Current
Maximum Discharge Current (Peak < 10 sec)	10 C Current

Operating Temperature :	-30°C / + 50°C
Recommended Charge Temperature	0°C / + 40°C
Storage Temperature	-30°C / + 50°C

Cycle Life at 25°C : (1 C Charge / 1 C Discharge, DOD100%)
1000 Cycles to 80% Nominal Capacity

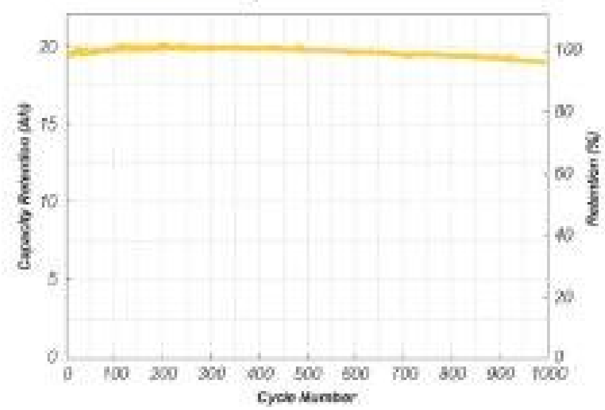
ePLB C020 Performance

Rate Capability



CHARGE : CC(0.5C)/CV(4.15V to 0.05C) at 25°C

Cycle Life



ual CHARGE : CC(1.0C)/CV(4.15V to 0.05C) at 25°C
DISCHARGE : CC(1.0C) to 3.0V at 25°C (DOD100%)

Energy Innovation Group

- From their datasheet
  - 148 Wh/kg
  - 311 Wh/L
- Max continuous discharge rate is 5C, capable of 10C pulses
- Beefy tabs

20Ah cell design

LG Chem15Ah Cell Design

- From their datasheet
  - 150 Wh/kg
  - 300 Wh/L
  - At 4C, RT
- Capable of >10C continuous discharge
  - Thick and wide tabs

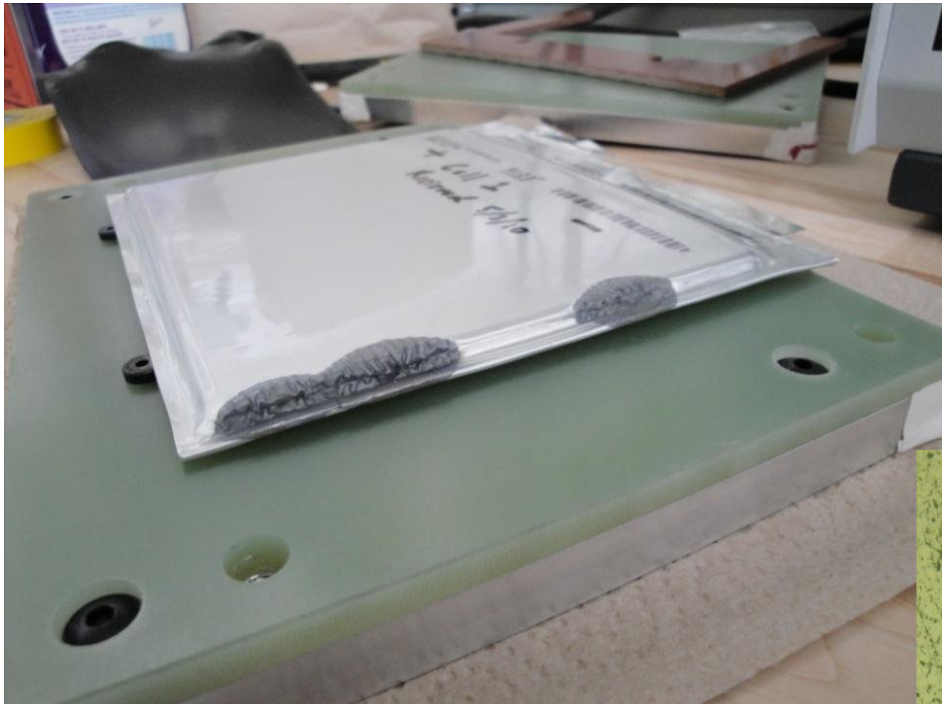
A123 Systems

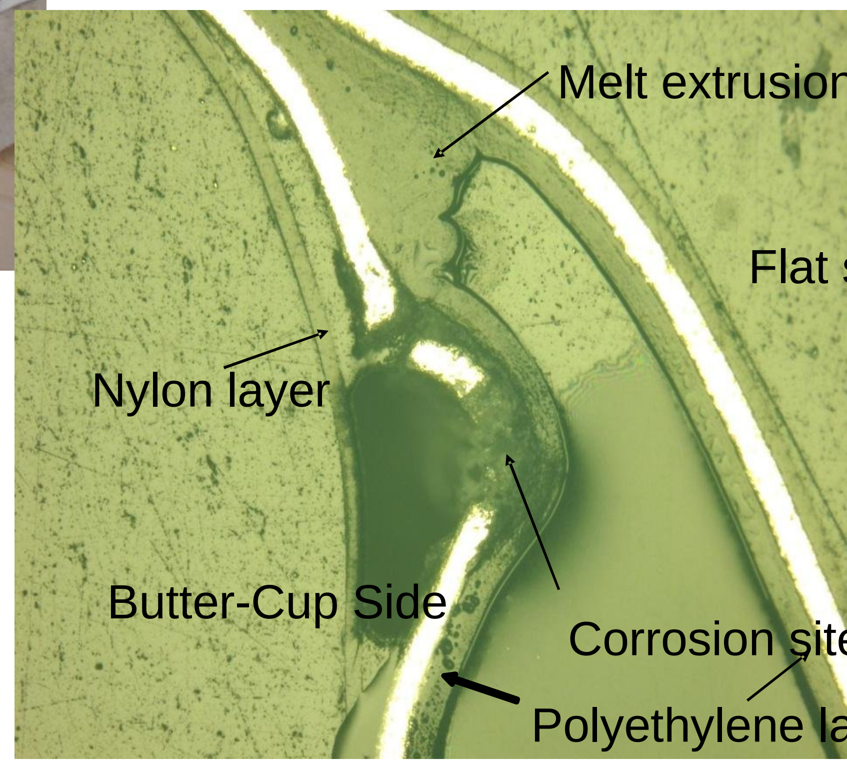
- $LiFePO_4$ cathode
  - More thermally stable
  - Flat discharge curve
- Very high power, but lower energy according to their datasheet
  - 120 Wh/kg
  - 219 Wh/L

Test Plan for Assessment of Cell Designs

- Acceptance Testing
  - Visual, OCV, AC Impedance, mass, dimensional
  - Pouch isolation resistance
  - Soft short (OCV bounce back after deep discharge)
- Capacity performance
  - Capacity/Energy vsrate
    - at ambient T, C/5, C/2, C, 2C, 4C with 3 cells per design,
    - all charging at manufrecomrate
- Cycling performance
  - Capacity/Energy vscycle number
    - 4C discharge, C/2 charge at ambient T for >100 cycles
    - Testing one 3S string per cell design and cycling condition (4 strings total) with cells under compression as per manufacturer's recommendation
- Evaluate cell design and manufacturing quality
  - Seal leak rate and compare to 18650 crimp seal rates
    - Seal cells in Al laminate bag
    - Then thermally cycling (vsnot) for 3 weeks
    - Sample container gas for electrolyte to determine leak rate and/or measure mass lost
  - Corrosion susceptibility
  - Destructive Physical Analysis (Tear down)

Examples of Pouch Corrosion

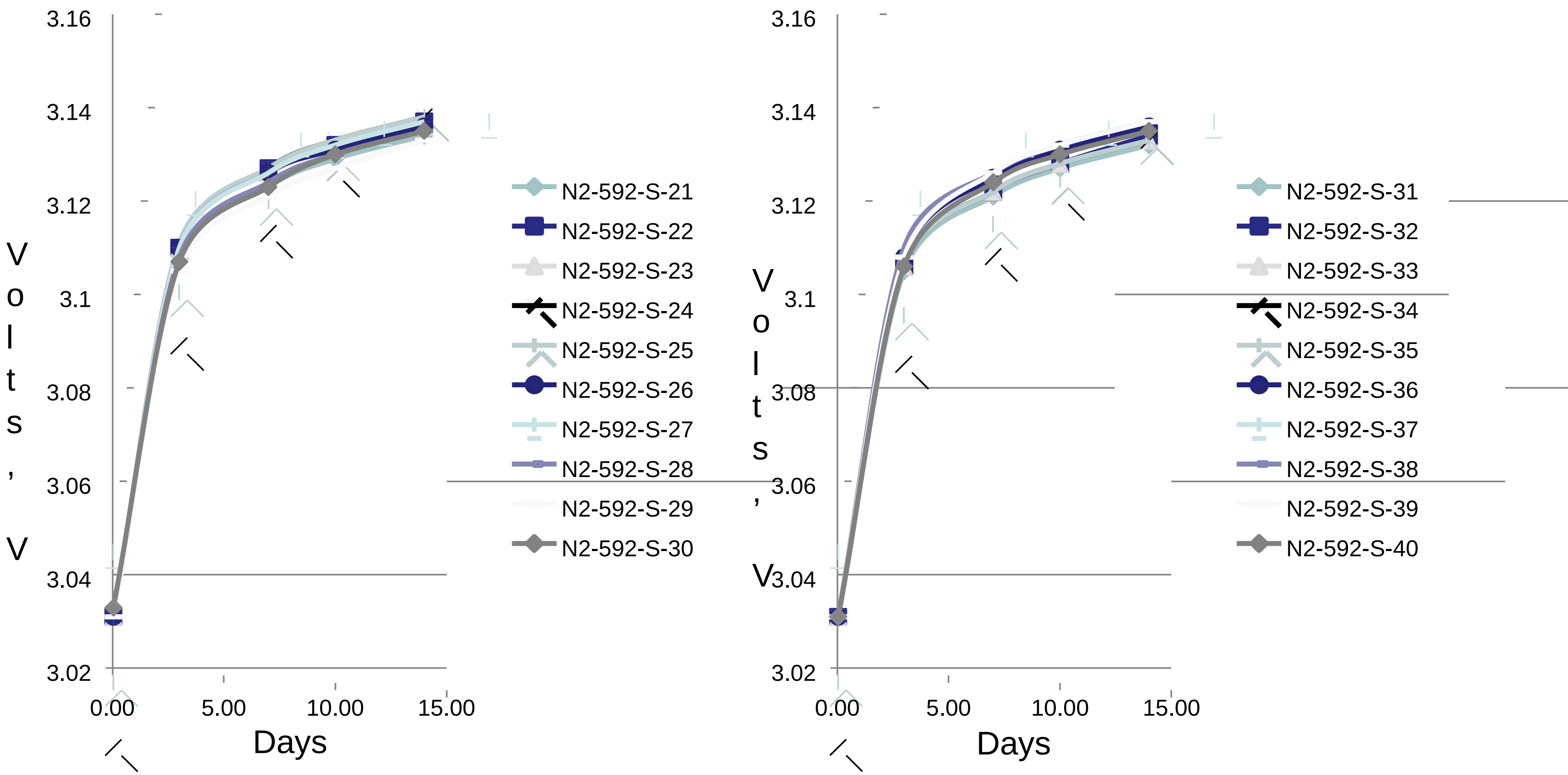




- Defective inner isolation layer of the laminate pouch results in corrosion of the Al layer
- Polarizing the Al layer to the (-) terminal is a quick test method

Soft Short (Small 18650 Cell)

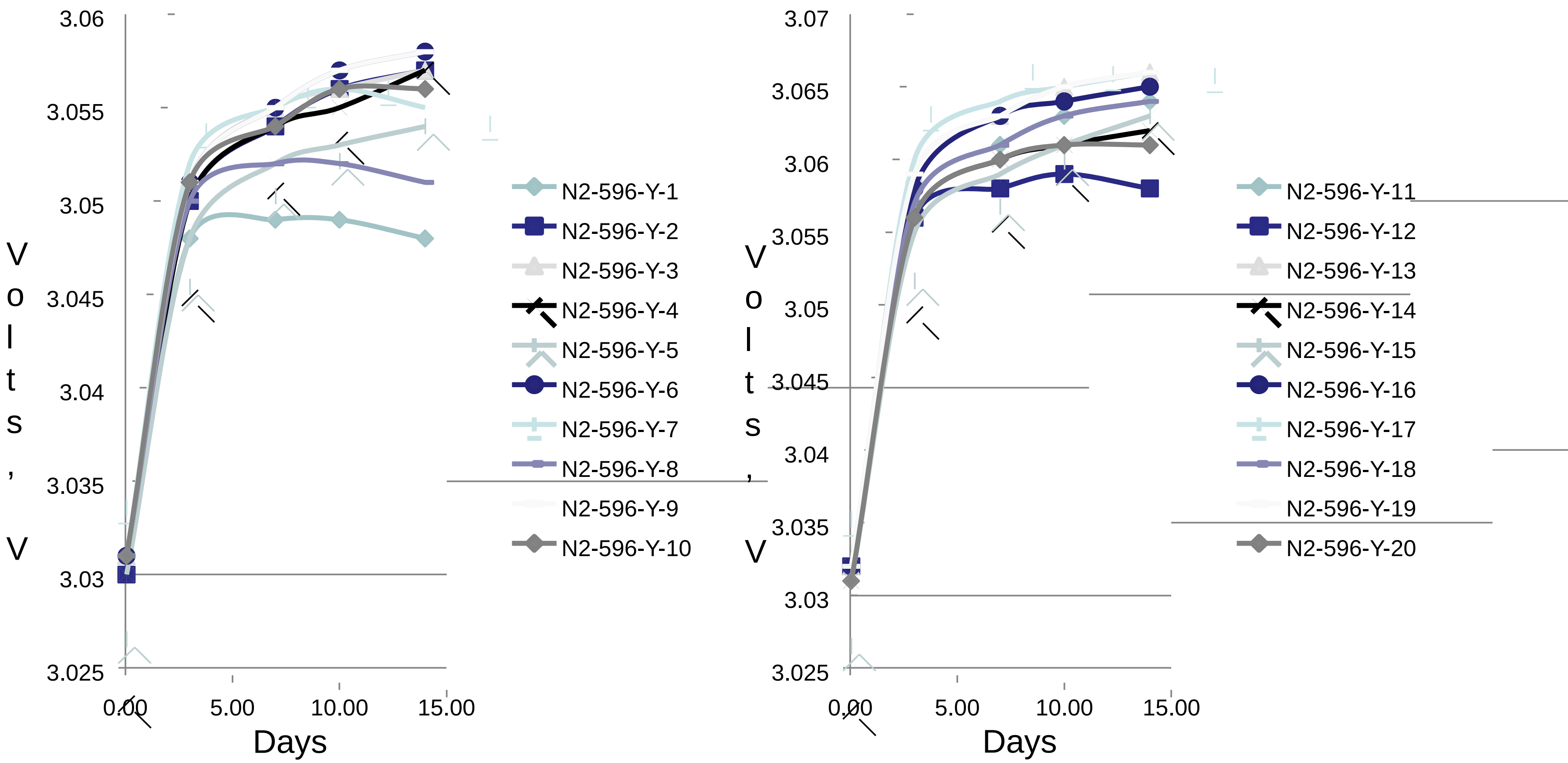
14-day OCV bounce back after deep discharge (constant voltage to 3.0V)



Very uniform OCV bounce back performance

Soft Short (Large Aerospace Cell Design)

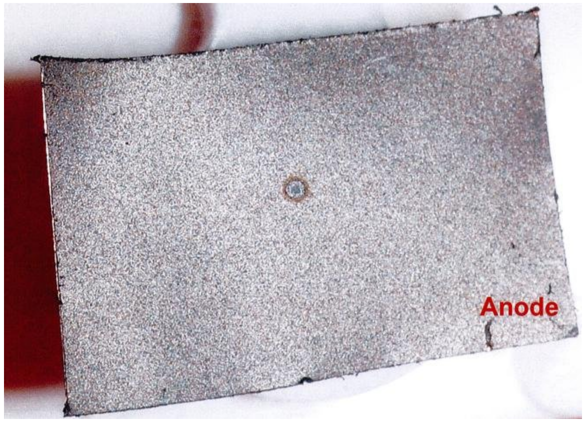
14-day OCV bounce back after deep discharge (constant voltage to 3.0V)



4 cells out of 20 had declining OCV between days 10 and 14

What to look for in DPAs?

- Consistent mechanical alignment
  - Anode overlapping cathode
  - absence burrs
  - No separator tears or wrinkles
- Lack of contamination
  - Heat effective zone halos
  - No foreign or native delaminationdebris
- No Li deposits or plating
- Consistent active material coating with smooth edges
- Solid weld connections without splatter



Photos courtesy of Exponent

Preliminary Conclusions

- Current Li-ion pouch cells designs for electric vehicle market are offering
  - Over 150 Wh/kg and 300 Wh/L at 15 minute (4C) discharge rates
    - Based on 2 manufacturer's data sheets (to be verified)
  - High maturity with numerous units fielded
  - Manufactured in high production lines
- Planned testing will determine their readiness for the demands of crewed spacecraft
  - Manufacturing quality
  - Effectiveness of the seals
  - Durability of performance
- Results will be available by August of 2011