Update on Performance Improvement of Sandia-Built $Li/(CF_x)_n$ and $LiFePO_4$ Cells

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National Nuclear Security Administration

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Outline

- Sandia in-house facility
- $(CF_x)_n$ powder commercially available with x>100% to x<90%
  - Highest theoretical capacity and very low self discharge and hence very long shelf life
  - Operating Voltage ~2.5 V commensurate with modern electronics for operation
- Low temperature electrolyte was used in our studies
  - EC:DEC:DMC:EMC(1:1:1:3 v%)/1M LiPF6

Electrochemical Studies

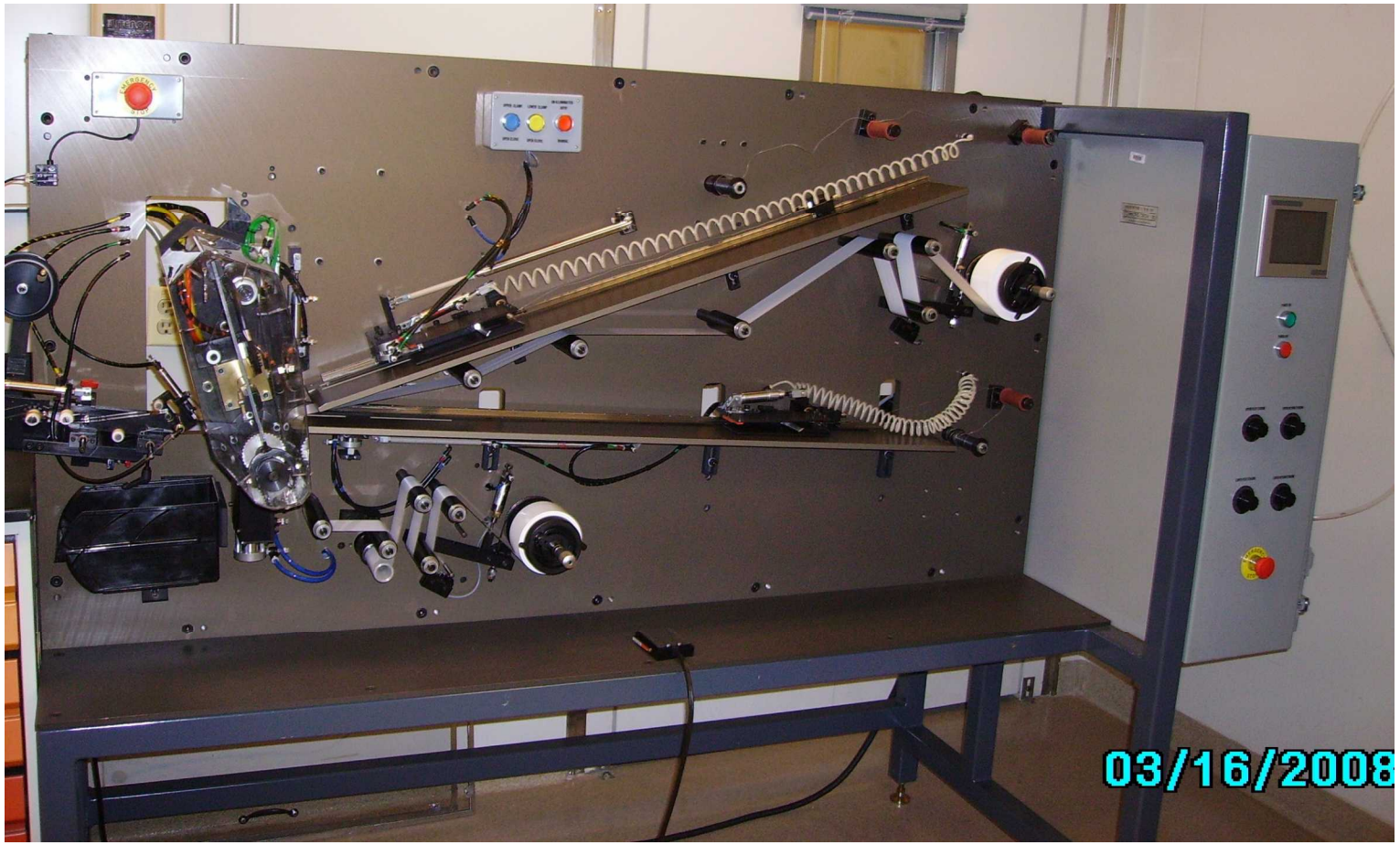
- Capacity Improvement
- Low temperature pulse studies on $(CF_x)_n$ cells with different "x" values. CFx with x~0.9 gave better performance compared to x>1
- Low temperature studies with 2500 Celgard separator

- Initial Studies on $LiFePO_4$
  - Relative capacity at low temperature (-40°C) is higher for SNL-Built cells than for commercial cells.

Hohsen Coater

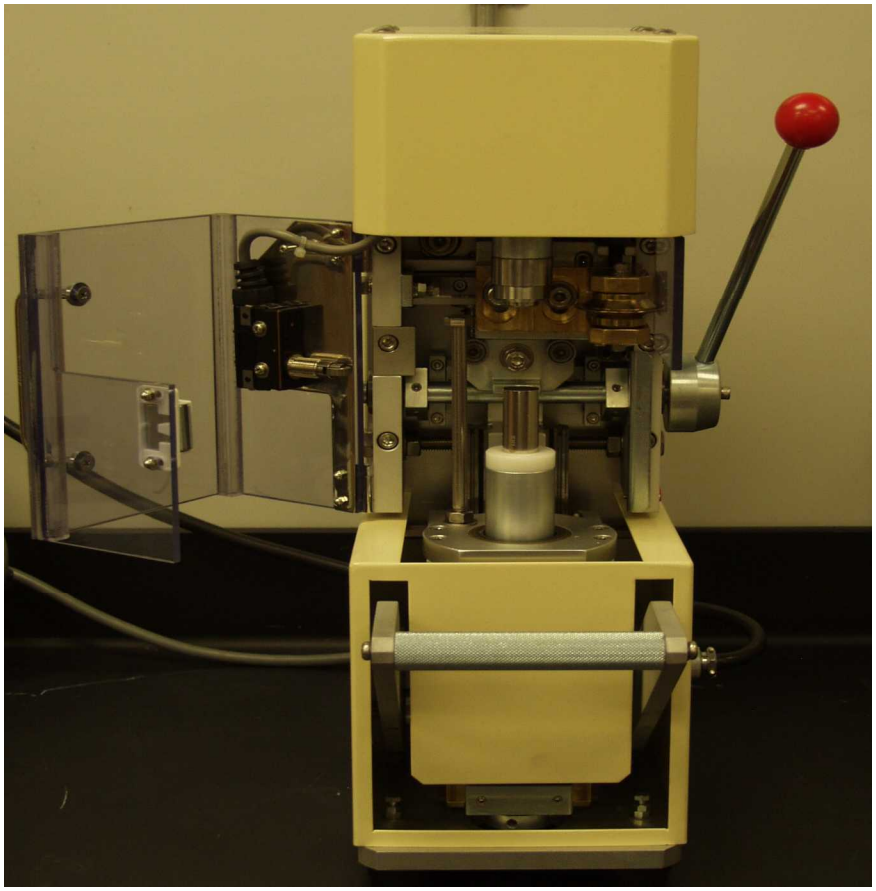
Hohsen Electrode Coater Model # HSCS-200

Micro Tech Winder



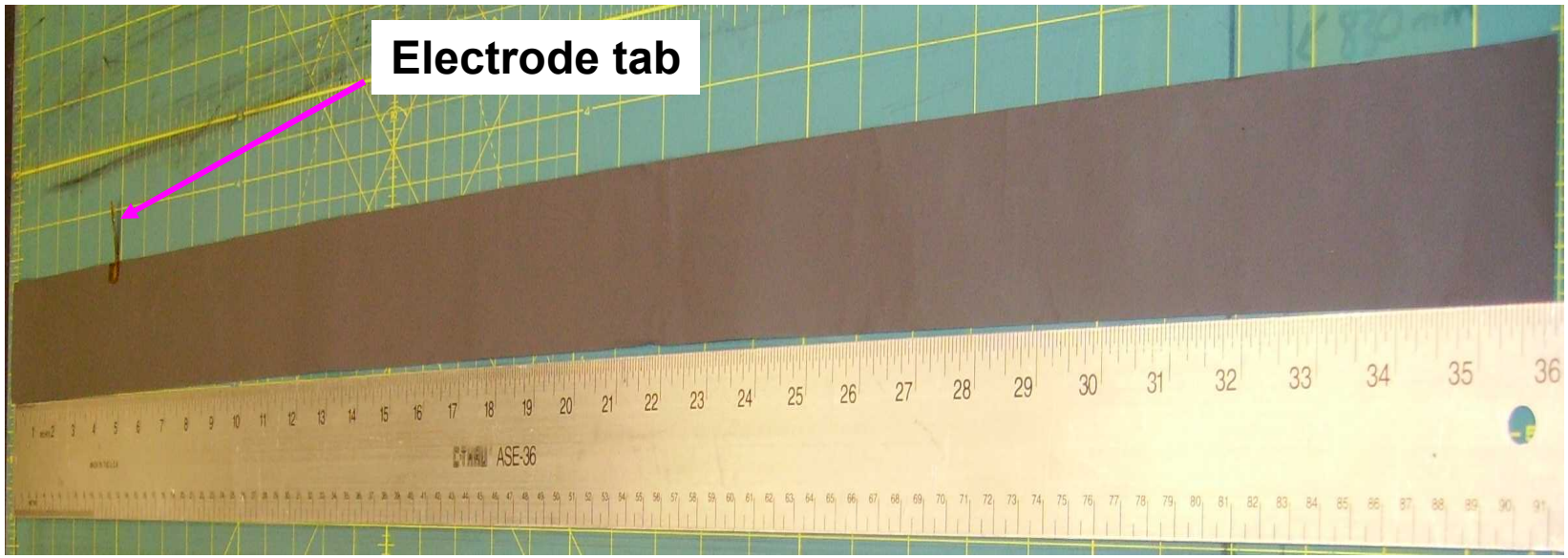
Capable of winding longer electrodes, different cell sizes and not limited to 18650

Cell Groover



18650 Cell Groover

Sandia Coated $(CF_x)_n$ Electrode



SNL coated $(CF_x)_n$ electrode with tab welded ultrasonically

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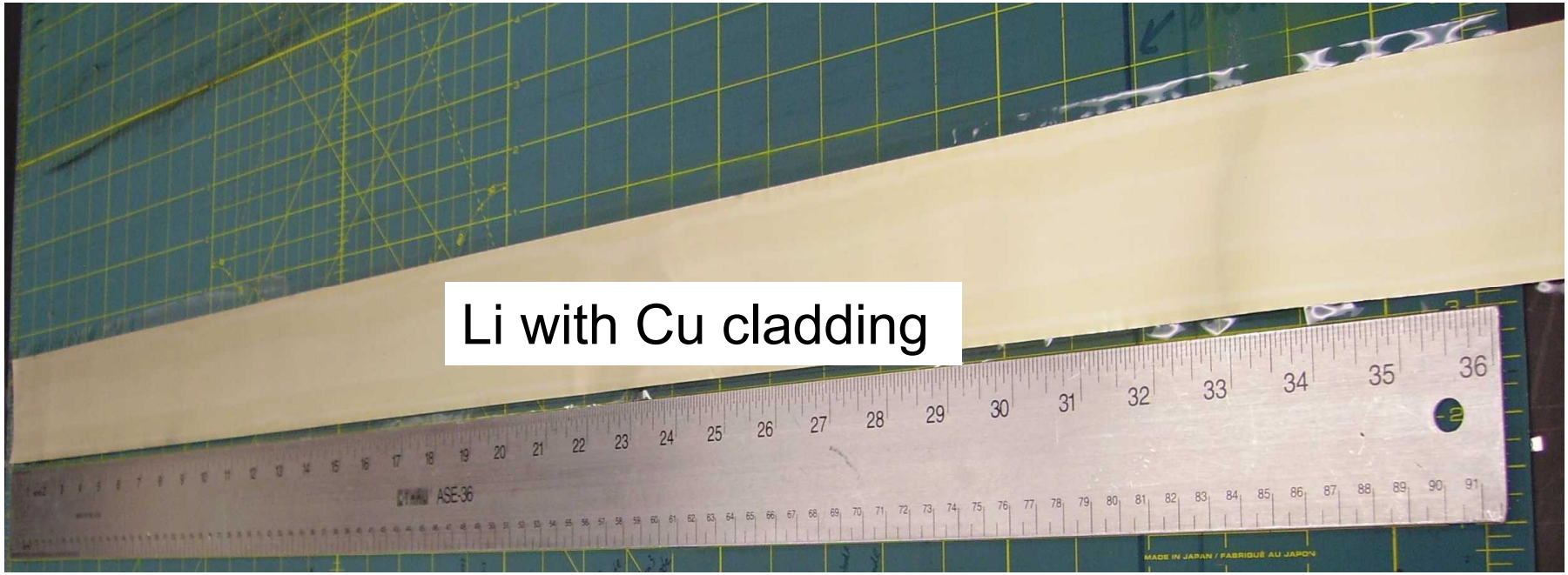
Thin Li Electrode on Copper



Li electrode with Cu cladding.

Company: Sidrabe: E-mail: pipkevics@sidrabe.eu
Website: www.sidrabe.com

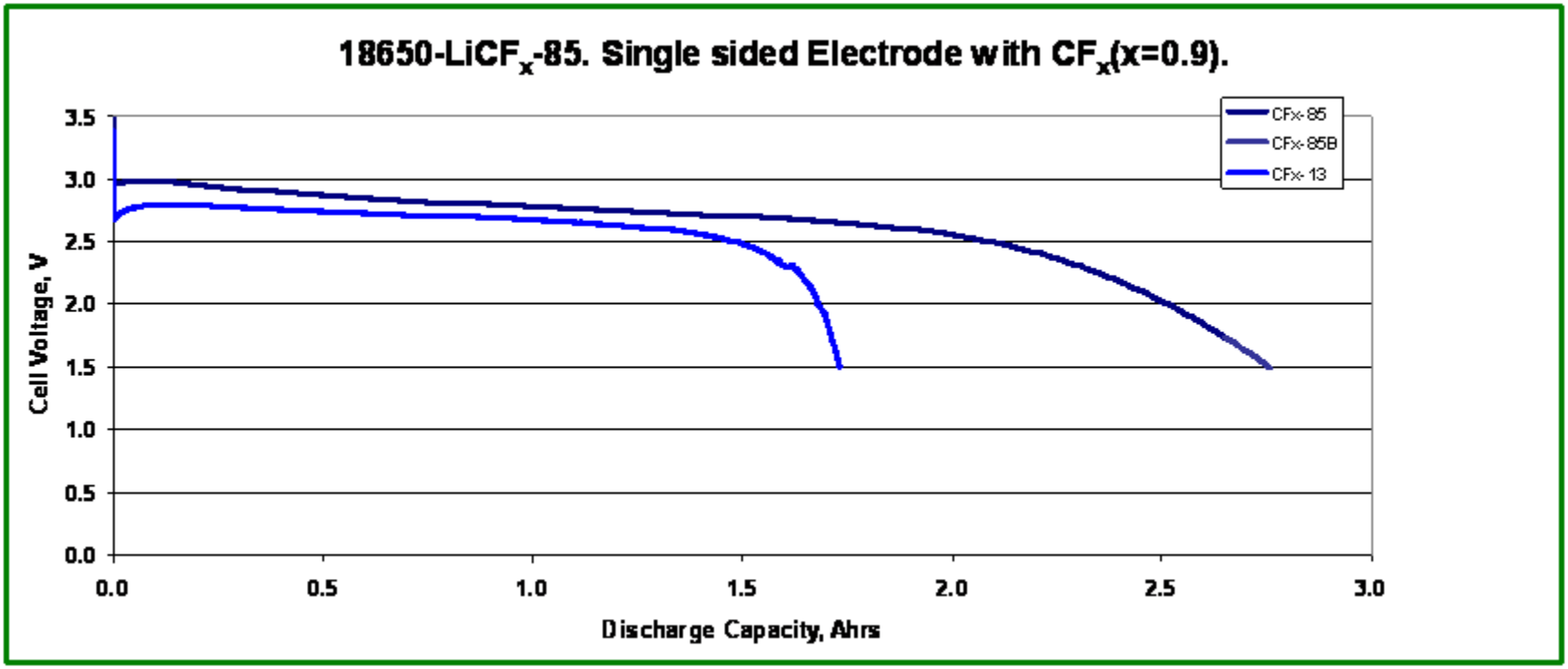
SNL Built 18650 CF_x cell.

SNL Built 18650 CF_x cell.

Cell capacity is ~3.6 Ahrs. Cell Weight ~28 grams.
A 2.7 Ahrs Li-ion cell would weigh >42 grams.

Update on Capacity Improvement

Improvement in Capacity of Electrodes Coated on One Side



The improvement in capacity was achieved by optimizing aggregate particle size, viscosity of the slurry etc.

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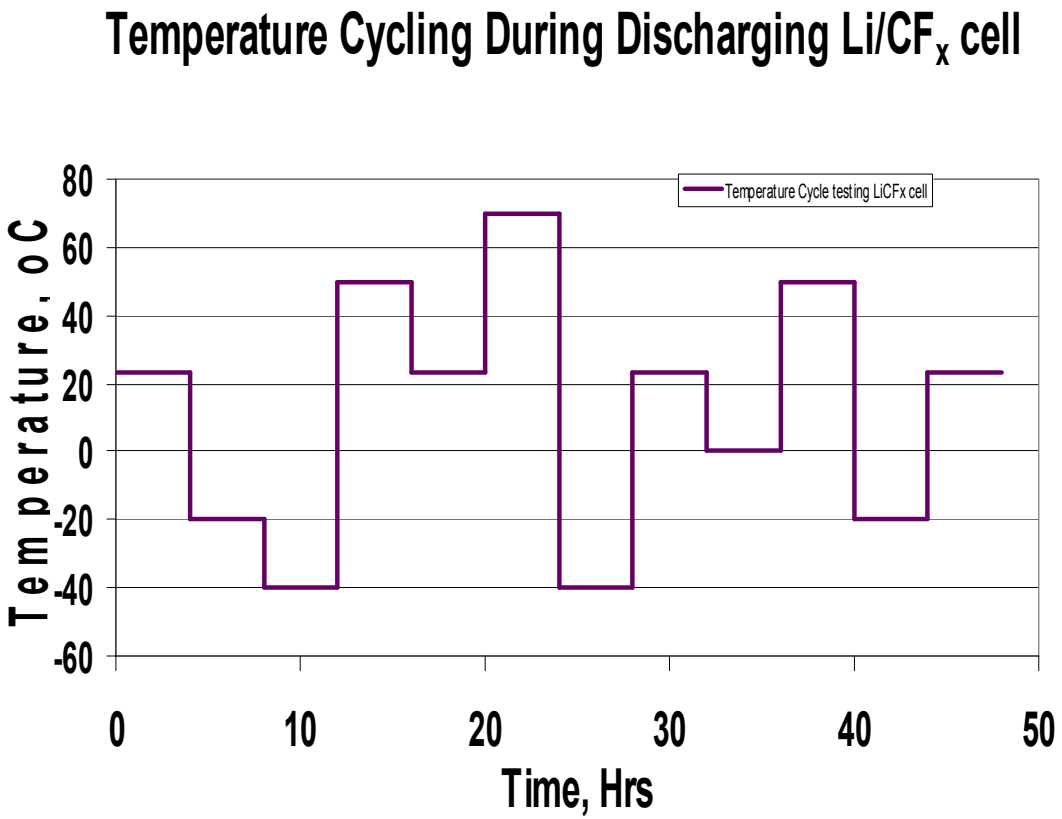
Comparison of Low Temperature Pulse Performance of 18650 $(CF_x)_n$ Cells with x~ 0.9 and x >1

Temperature Profile



Temperature Cycling while Pulse discharging Cells.
Pulse Current 4 mA for 4 mS and 6µA for 9.996 Sec.

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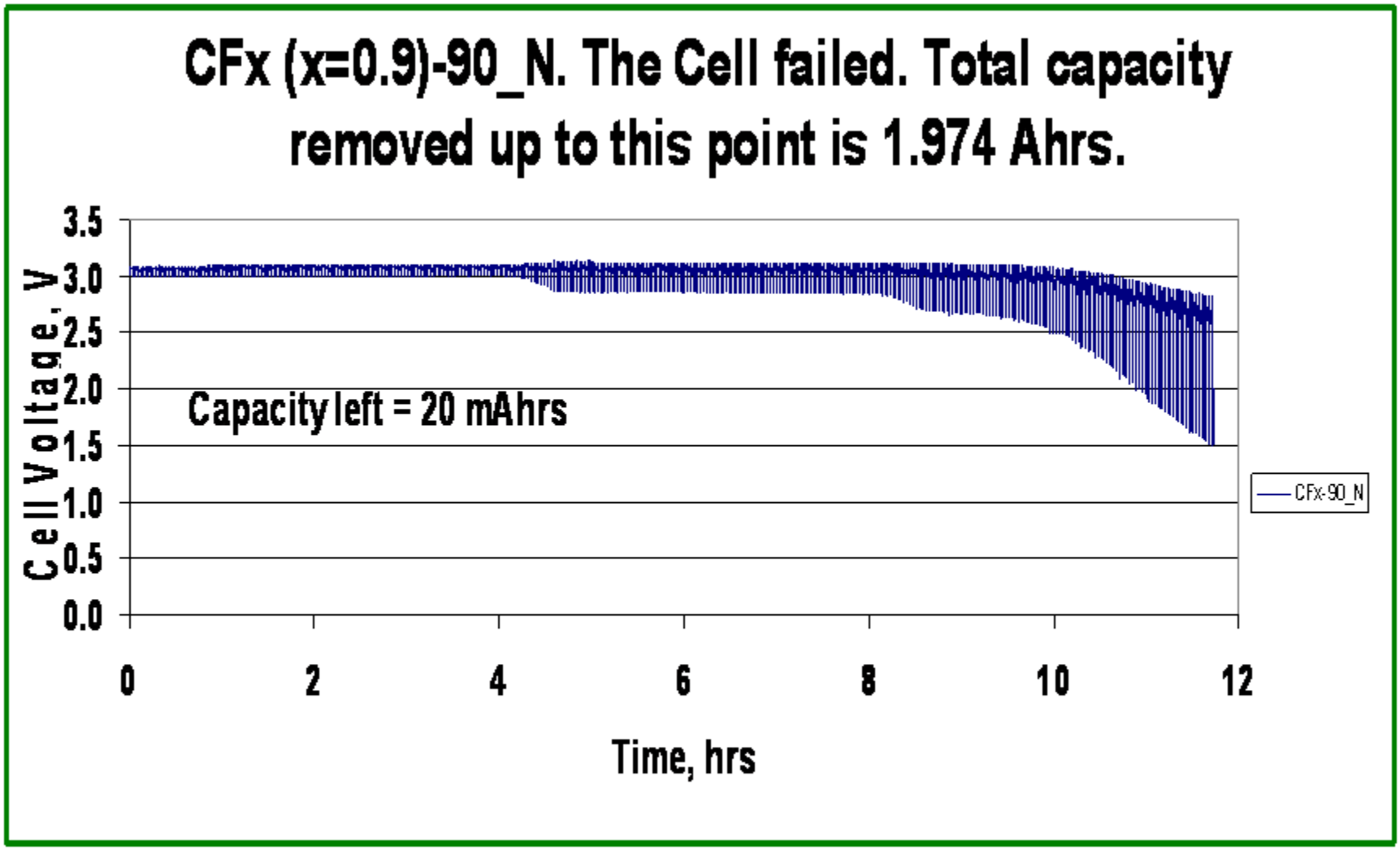
Test Protocol.

1. Pulse test as assembled cell using temperature profile (48 hr cycle)
2. Remove a predetermined amount of capacity using CC discharge at RT
3. Return cell to pulse testing
4. Repeat 2 and 3 until the cell voltage drops to failure point of 1.5 volts
5. Discharge the remaining capacity



Voltage response at different temperatures

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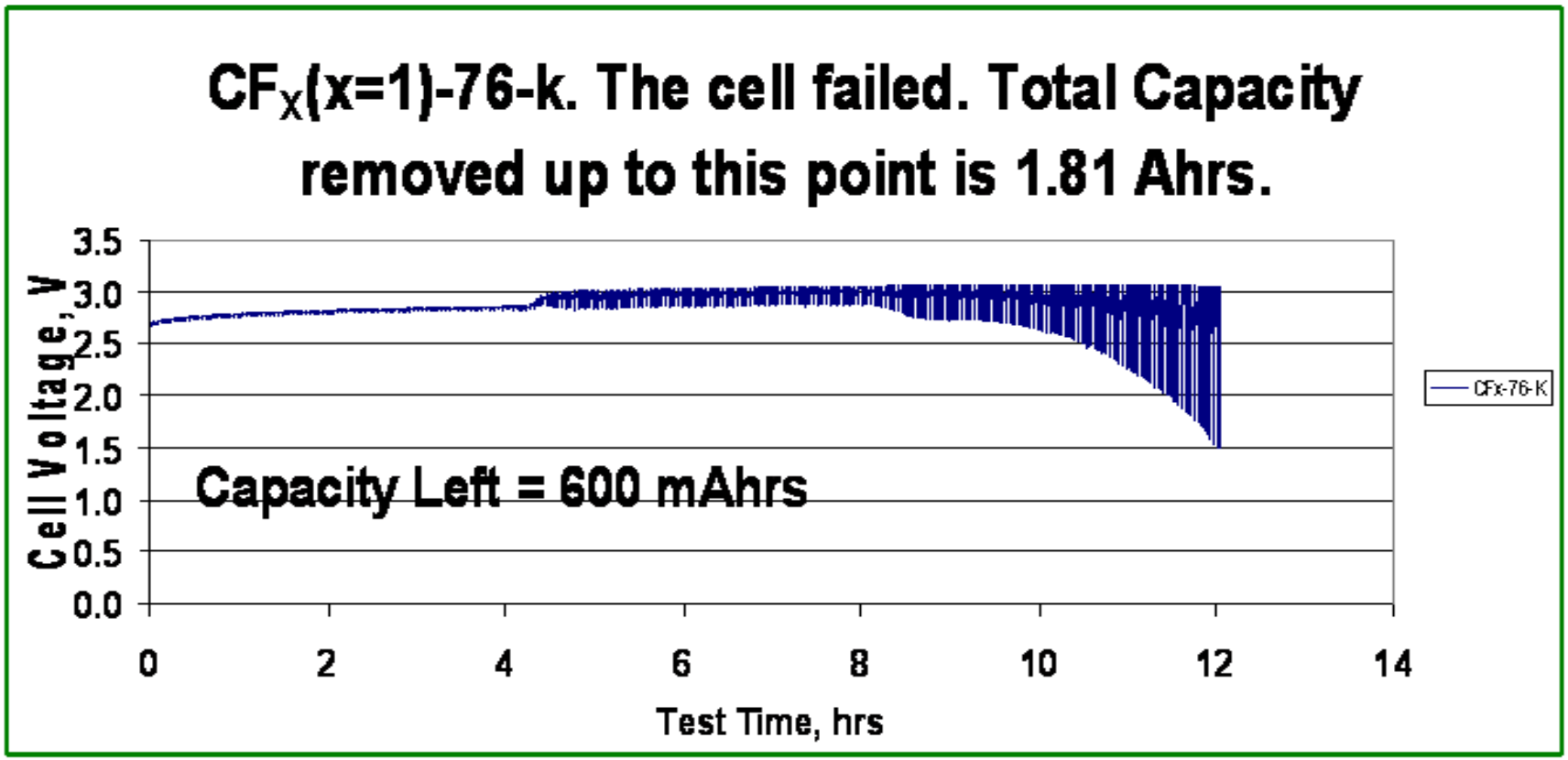

Cell Voltage vs. time at different temperatures.

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Summary of Low Temperature Pulse Study

- **Two cells were pulse tested**
  - **$(CF_x)_n$ Electrode composition x=0.9 and x>1**
- **Cell with x=0.9 performed better—delivered full capacity.**
- **Cell with x>1 gave only 75% of the total capacity**

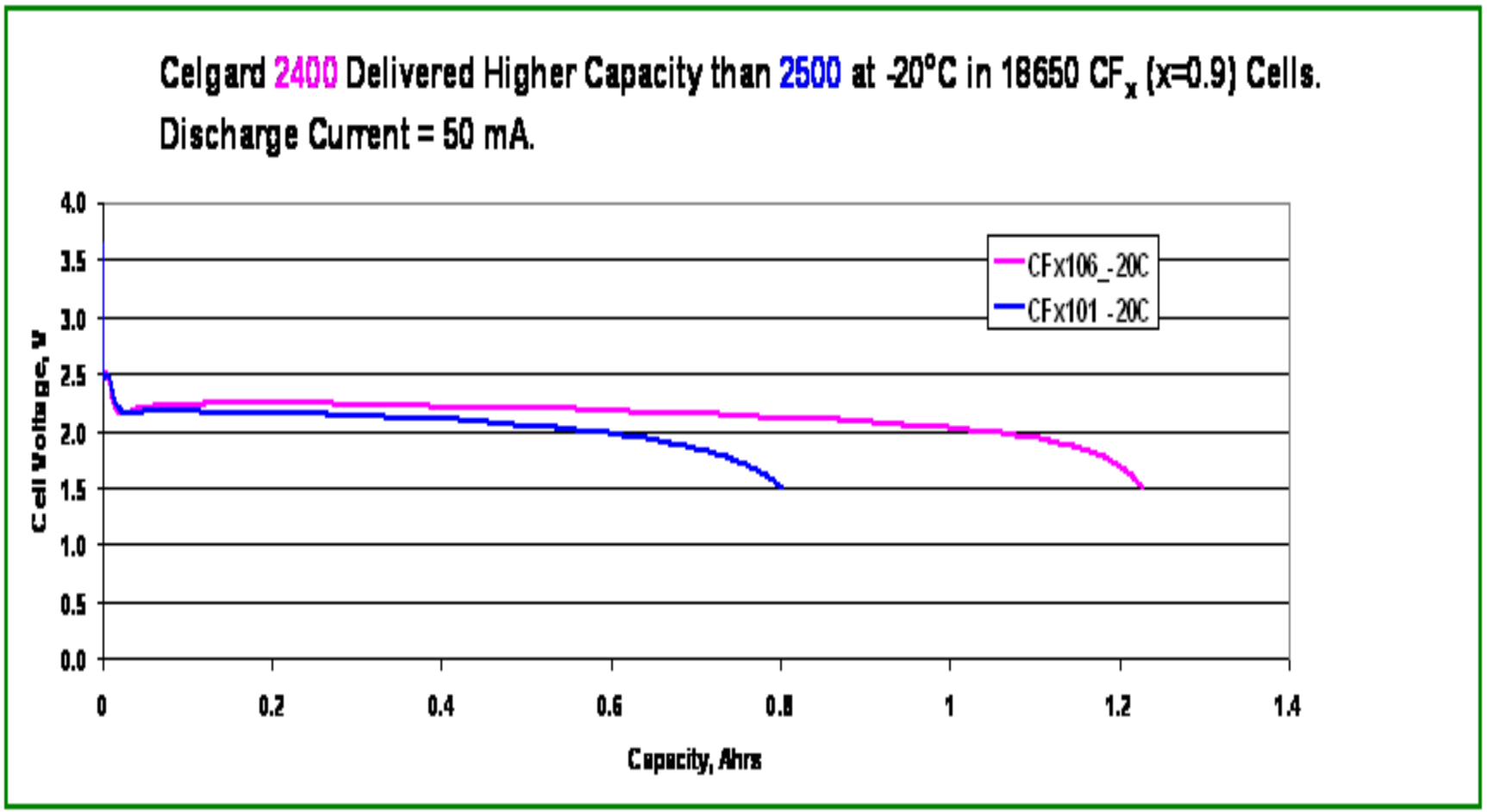
Low Temperature Performance of SNL Cells with $(CF_x)_n$ Coated on One Side [x=0.9]

- 18650 Cells built with
  - 2400 and 2500 Celgard Separator
  - Low temperature electrolyte that remains liquid even below -65°C

Comparison of Typical Properties of Celgard Separators

Basic Film Properties	Celgard 2400	Celgard 2500
Thickness	25 micron	25 micron
Porosity	37%	55%
Pore Size	0.12x0.04 (μm x μm)	0.21x0.05 (μm x μm)

Celgard 2400 Gave Higher Capacity Than 2500 at -20°C



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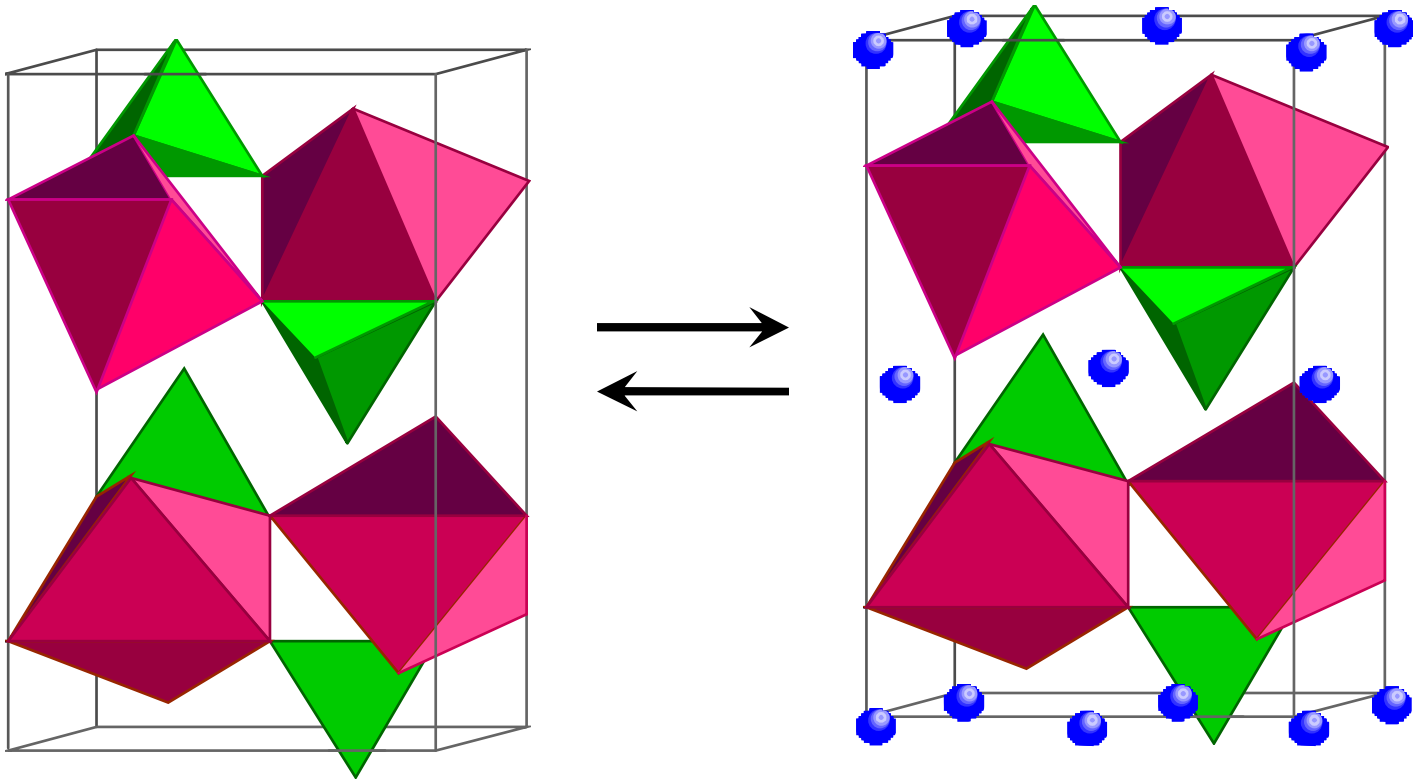
Electrochemical Performance of SNL-Built $LiFePO_4$ Cells

$LiFePO_4$ Structure
Un-lithiated and Lithiated



Heterosite Structure **Olivine Structure**

J. Goodenough and K. Padhi, 1996

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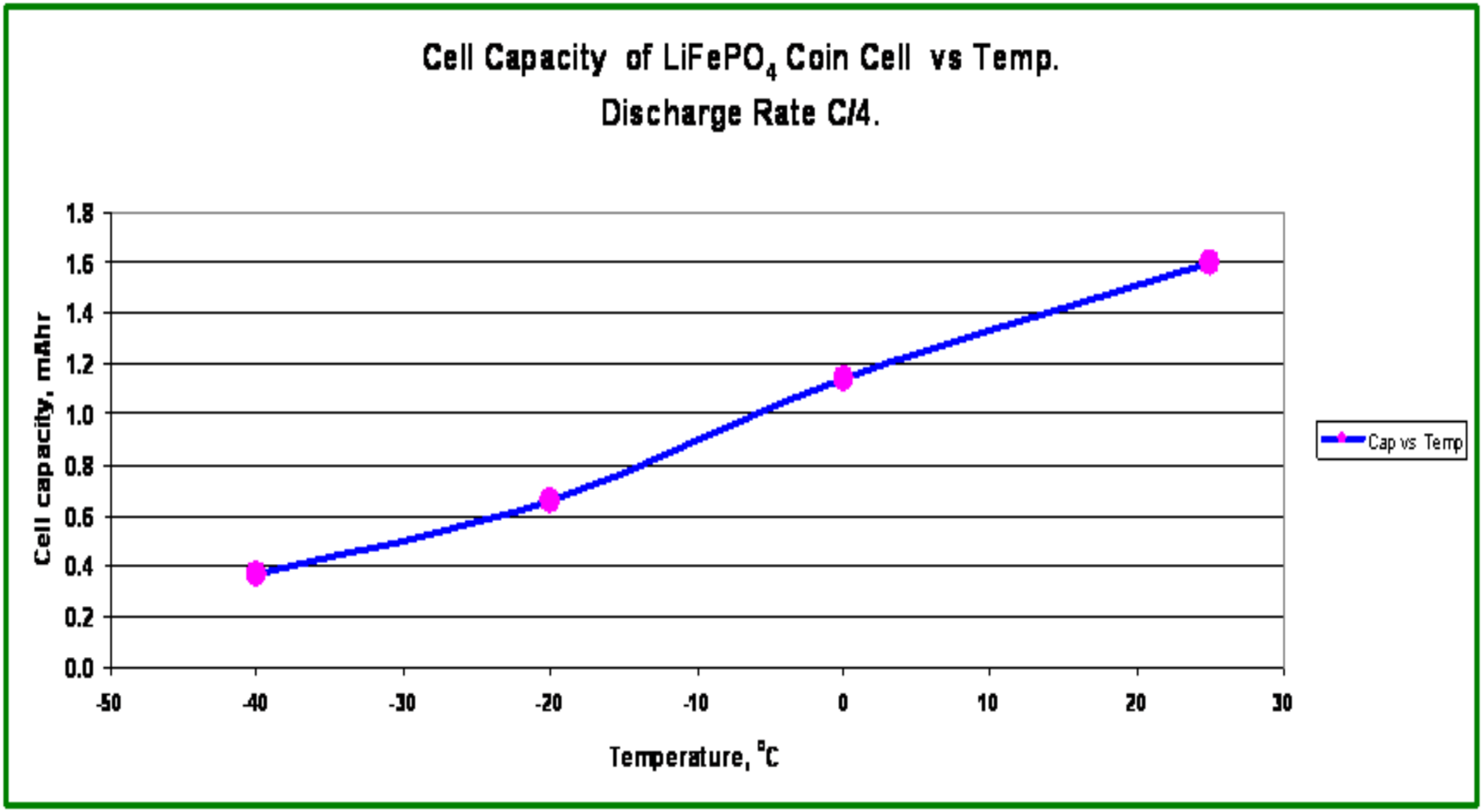
$LiFePO_4$ Delivers ~25% of the RT Capacity at -40°C at a C/4 rate



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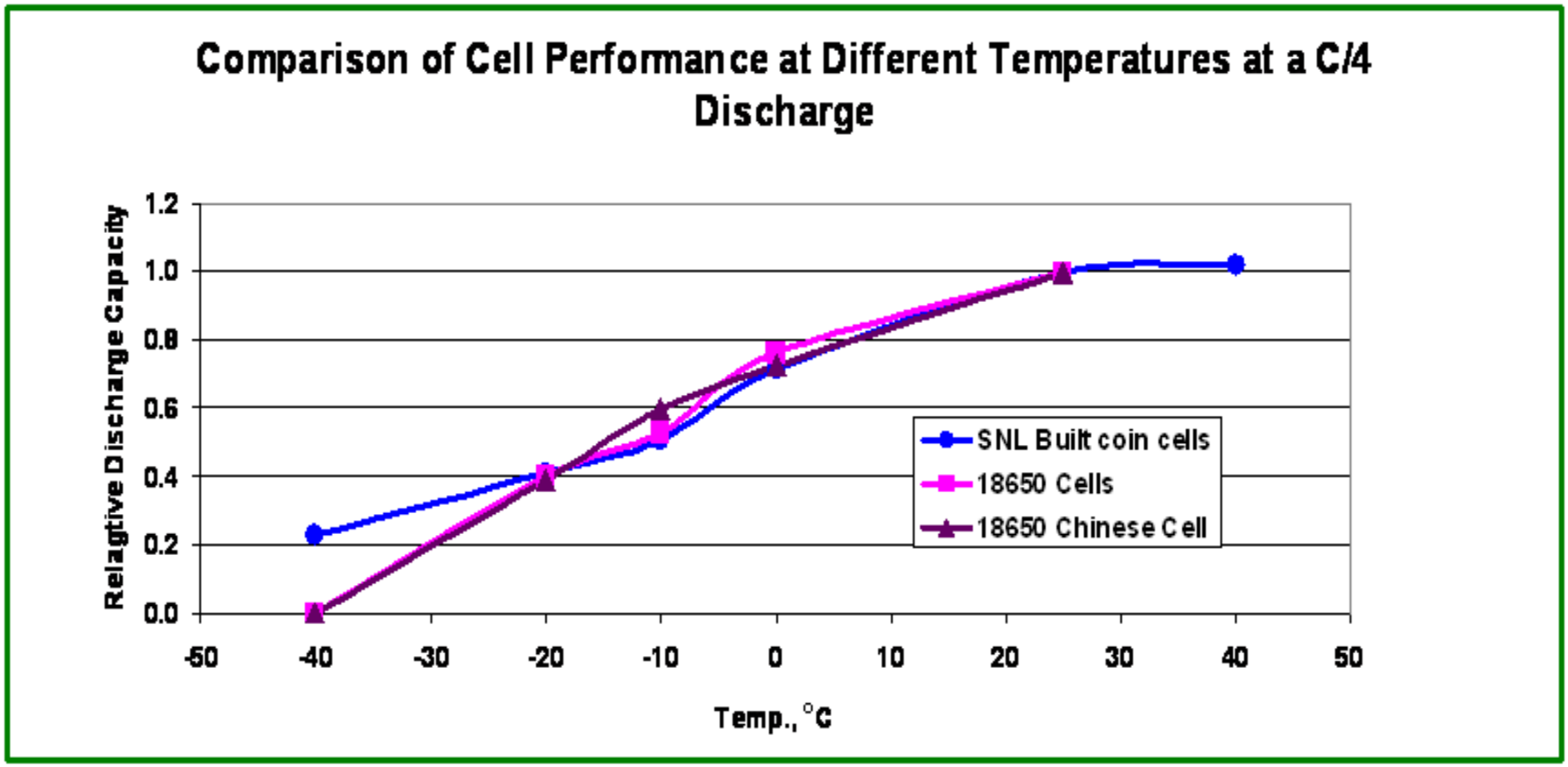
SNL Cell Performed Better at -40°C Compared to Commercial



Improved performance at -40°C might be due to the low temperature electrolyte

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Summary

- In-house facility for coating electrodes and making cells
- Demonstrated improvement in capacity to 2.9 Ahrs in single side coated electrodes.
- Celgard 2400 gave better performance over 2500
- Initiated $LiFePO_4$ electrode making activity
  - Coin cell performance was measured at different temperatures and compared with that of commercial 18650 cells
  - SNL coin cells performed better at -40^{o}C compared to commercial