Evaluation of Li/CF$_x$ Cells For Aerospace Applications

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Objectives

Characterize Li/CF<sub>x</sub> Cells for

- Capacities at various discharge rates (C/10, C/5 and C/2) and temperatures (50, 20, 0, -10 and -30°C)
- Six-month storage at -10 and -30°C for AA, and at 20 and 50°C for C Cells, respectively
Background

- Panasonic commercialized Li/CF$_x$ cell technology in mid. 1970
- A promising primary battery for Aerospace applications such as Exploration missions, Launch vehicles, Tools and many more
  - Wide operation temperature range
  - Low self-discharge
  - High specific energy
- CF$_x$ cathode material has a theoretical specific energy of 2260 Wh/Kg
  - Specific energy however achieved as of now is only 10% of theoretical value unless used at a very low rate of C/1000
  - Research both at Government Labs and Industries is currently in progress to improve the performance
Cell Description

- Quallion Li/CF$_x$ 2.5 Ah AA and 6.5 Ah C cells
- Hermetically sealed cylindrical cells
- Li metal as anode
- CF$_x$/acetylene black as cathode
- Lithium tetrafluoroborate in Propylene carbonate and dimethoxyethane solvent as electrolyte
Cell Description - Contd.

#9 - AA cell and #10 - C Cell
## Results

### AA cells

<table>
<thead>
<tr>
<th>Cell ID</th>
<th>Temperature, °C</th>
<th>Discharge rate, A</th>
<th>Capacity, Ah to 2.0 V</th>
<th>Capacity, Ah to 0 V</th>
<th>Mid-dis Voltage, V</th>
<th>EOD Temp, °C</th>
<th>Specific Energy Wh/Kg</th>
<th>Energy Density Wh/L</th>
<th>Specific Power W/Kg</th>
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*storage test for six months

EOD = End-of-discharge
# Results - Contd.

C Cells

<table>
<thead>
<tr>
<th>Cell ID</th>
<th>Temperature, °C</th>
<th>Discharge rate, A</th>
<th>Capacity, Ah to 2.0 V</th>
<th>Capacity, Ah to 0 V</th>
<th>Mid-dis Voltage, V</th>
<th>EOD Temp, °C</th>
<th>Specific Energy Wh/Kg</th>
<th>Energy Density Wh/L</th>
<th>Specific Power W/Kg</th>
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</table>

*Storage test for six months  
EOD = End-of-discharge
Results - contd.

Discharge Profiles at C/10 Rate

- "C" cell at -10°C
- "AA" cell at 20°C
- "C" cell at 50°C
Results - contd.

Discharge Profiles at C/5 Rate

- "AA" cell at -30C
- "C" cell at -10C
- "AA" cell at 20C
- "C" cell at 50C

Normalized capacity (actual/rated) vs. Voltage (V)
Results - contd.

Discharge Profiles at C/2 Rate

Normalized capacity (actual/rated)
Results - contd.

Variation of C/2 Capacity with Temperature

Normalized Capacity (actual/rated)

Temperature (°C)
Results - contd.

Variation of Capacity at 20°C with discharge rate

Normalized Capacity (actual/rated)

Normalized discharge Rate
Results - contd.

Variation of mid-discharge Voltage with Temperature

Mid-discharge Voltage (V)

Temperature (°C)
Results - contd.

**Discharge Temp Profiles at C/5 Rate**

- "AA" cell at -30C
- "C" cell at -10 C
- "AA" cell at 20 C
- "C" cell at 50 C

Temperature (°C) vs Normalized capacity (actual/rated)
Discharge Temperature profiles at C/10 Rate

Normalized Capacity (actual/rated)
Results - contd.

Discharge Temperature profiles at C/2 rate

Temperature (°C)

Normalized capacity (actual/ rated)
Results - contd.

Variation of open-circuit voltage during storage

- 30°C
- 10°C
- 20°C
- 50°C

Storage Time (weeks)
Results - contd.

Variation of Impedance during Storage

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Data Points</th>
</tr>
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<tbody>
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<td>-30°C</td>
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<tr>
<td>20°C</td>
<td>△</td>
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<tr>
<td>30°C</td>
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</table>

Cell Impedance (mohms)

Storage Time (weeks)
Conclusions

- Capable of performing at C/2 rate or less from -10°C to 50°C
- Temperature increased to 113°C at the end of C/2 discharge
- The C cells delivered the maximum energy of 457.7 Wh/Kg at C/5 rate at 50°C and the AA cells yielded 434 Wh/Kg at C/10 rate at 20°C
- The rate capability and low temperature performance depends on the cell size
- Further work should include environmental, self-discharge, and safety studies to qualify for the Aerospace application of the technology
Acknowledgment

The authors thank Quallion for providing the cells and NASA- Goddard Space Flight Center for Sponsoring this work