Performance and Safety Tests on Samsung 18650 Li-ion Cells with Two Capacities

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Schlumberger Perforating and Testing

Abstract
In order to meet the applications for Space Shuttle in the future, Samsung 18650 cylindrical Li-ion cells with two different capacities have been evaluated. The capacities are 1800 mAh, and 2000 mAh. The studies focused on the performance and safety tests of the cells.
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Introduction

In order to meet the applications for space shuttle in future, two types of Samsung cells, with capacity 1800mAh and 2000mAh, have been investigated. The studies focused on:

• Performance tests
  Completed 250 cycles at various combinations of charge/discharge C rates
  Discharge capacity measurements at various temperatures

• Safety tests
  Overcharge and overdischarge
  Heat abuse
  Short circuit: Internal and external short
  Vibration, vacuum, drop tests
Performance tests
Plot of CC/CV charge for 1.8 Ah Samsung Li-ion cells at two different rates.
Plot of discharge of Samsung 1.8 Ah li-ion cells at various C rates
Cycle life tests for 1.8 Ah Li-ion cells at various C rate combinations of charge/discharge
Characterization of capacities of 1.8 Ah cells at various temperatures
Discharge capacity at different temperatures

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Capacity of discharge (Ah)</th>
<th>Capacity of discharge (Ah)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1.71 95.6%</td>
<td>40</td>
</tr>
<tr>
<td>25</td>
<td>1.79 100%</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>1.62 90.6%</td>
<td>10</td>
</tr>
<tr>
<td>-10</td>
<td>1.41 78.8%</td>
<td>-10</td>
</tr>
</tbody>
</table>
Summary for performance tests

- In 250 cycles, the capacity drops with 100% DOD were 11%-12% both for 1.8Ah and 2.0Ah cells regardless combination of C rate at range from 1C to C/4.

- Comparing with 25 °C discharge capacities (100%) of cells, the 1.8Ah cell delivered 95.6% at 40 °C, 90.6% at 10 °C, and 78.8% at -10 °C. For 2.0Ah cell, it delivered 95.8% at 40 °C, 92.1% at 10 °C, and 70.5% at -10 °C.
Safety tests
3C high rate discharge of 2.0 Ah cell

Graph showing the relationship between time, current, voltage, and temperature during a 3C high rate discharge of a 2.0 Ah cell.

- **Time (Sec)**: The x-axis represents time in seconds, ranging from 0 to 160 seconds.
- **Current (A)**: The y-axis on the left represents current in amperes, ranging from -7 to 5 amperes.
- **Voltage (V)**: The y-axis in the middle represents voltage in volts, ranging from 0 to 5 volts.
- **Temperature (Degr. C)**: The y-axis on the right represents temperature in degrees Celsius, ranging from 30 to 50 degrees Celsius.

The graph shows how current, voltage, and temperature change over time during the discharge process.
Over-discharge of Samsung 2.0 Ah li-ion cell at 1C rate into reversal

Deep discharge to reverse 150% of 1C capacity
Over discharge 1.8 Ah cell to 0.0V

1C rate discharge to 0.0V and held at open circuit for two weeks
Deep discharge of 1.8Ah cell at 1C rate into reversal with two week open.

Cell reversal by removal 150% more than original capacity.
1C overcharge 2.0Ah cell to 5.0V
3C overcharge 2.0Ah cell to cut-off voltage at 12.0V max.
Heat abuse test
High temperature exposure and heat-to-vent
Internal short circuit test
Short circuit: Internal short
Short circuit: External short

2.0Ah cell with 0.05 mΩ load
## Summary for safety tests

<table>
<thead>
<tr>
<th>Number of 1.8Ah cells tested</th>
<th>Number of 1.8Ah cells passed</th>
<th>Number of 2.0Ah cells tested</th>
<th>Number of 2.0Ah cells passed</th>
<th>Safety test</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>High rate (3C) charge to 4.2V</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1C rate overcharge to 4.5V</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1C overcharge to 5.0V</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>High rate (3C) discharge to 2.7V</td>
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<tr>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1C overdischarge to 0V and reverse 150% of 1C capacity</td>
</tr>
<tr>
<td>2</td>
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<td>2</td>
<td>65°C heating test</td>
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<td>0</td>
<td>Exposure at temperature higher than 65°C</td>
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<tr>
<td>2</td>
<td>Venting at 80°C</td>
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<td>Venting at 150°C</td>
<td>Vacuum test</td>
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<td>2</td>
<td>Drop test</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Vibration test at 0.1 g²/Hz level</td>
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<tr>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>Short circuit: internal &amp; external</td>
</tr>
</tbody>
</table>
Acknowledgment

Thanks Samsung for supplying the li-ion cell samples.