Evaluation of 20 Ah Li Ion Cells

Marshall Smart, B. V. Ratnakumar, C. K. Huang and S. Surampudi
Electrochemical Technologies Group, Jet Propulsion Laboratory
4800 Oak Grove Dr., Pasadena, CA

Carole Hill and Dan Radzykewycz
Air Force Research Lab, Albuquerque, NM

R. A. Marsh
Air Force Research Lab, Dayton, OH

ABSTRACT

Lithium ion cells of 20 Ah capacity were fabricated by Bluestar Advanced Technology Corporation, Canada under a developmental contract from US Air Force. In this paper, we report our studies on the evaluation of these cells under various test conditions. These include generic test conditions such as discharges and charges at different temperatures to understand the rate-limiting processes in the discharge/charge processes as a function of temperature, and cycle life under standard cycling conditions (100 % DOD) at ambient temperature. In addition, tests are being done to ascertain the performance of the cells in the Mars 2001 Lander application, which includes pulse testing of the cells at 60 A and 40 A loads for 100 mS and 1 min., respectively at different states of charge and temperatures, and cycling at low temperature at partial depths of discharge.
EVALUATION OF 20 Ah LITHIUM ION CELLS (BLUESTAR)

Marshall Smart, Kumar Bugga
Chen-Kuo Huang and Rao Surampudi
Electrochemical Technologies Group, JPL

and

Carol Hill, Dan Radzykewycz and R. A. Marsh
Air Force Research Laboratory

November 18, 1997

NASA Aerospace Battery Workshop
November 18-20, 1997, Huntsville, AL
Blue Star Lithium-Ion Testing Flow Chart

Blue Star Cells

Incoming Physical Inspection (All Cells)
- Physical Inspection
- Electrical Inspection

Conditioning Cycles (All Cells)
10 cycles

Electrical Characterization (3 Cells)

Discharge Characterization

Charge Characterization

Temperature Effects

Self-Discharge Tests

Cycle Life Characterization (5 Cells)

100% DOD Cycle Life Test (2 Cells)

Mars 2001 Lander Life Simulation Test (Pulse Test) (3 Cells)

Mars 2001 Lander Life Simulation Test (50% DOD Cycle Life Test) (3 Cells)
# Characterization Tests

<table>
<thead>
<tr>
<th>Temp.</th>
<th>Charge Rate</th>
<th>Discharge Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C/10</td>
<td>C/5</td>
</tr>
<tr>
<td>20°C</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>0°C</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>- 20°C</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>- 30°C</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>- 30°C</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>RT/-20°C</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

(Charge at room temp. and discharge at -20°C for 5 cycles)

- Self-discharge at 20°C will be performed as described below.

<table>
<thead>
<tr>
<th>Temp.</th>
<th>Charge Rate</th>
<th>Discharge Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>50°C</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

- Self-discharge at 50°C will be performed as described below.
Weight Distribution

Cell weight more consistent among the cells compared to the cathode weight.

Cathode Weight, g

Weights of 20 Ah (Blue Star) Li Ion Cells
Capacity increases with increasing cathode weight.

Capacity vs. Weight

Cell Weight

Cathode Weight

20 Ah (Blue Star) Li Ion Cells
Conditional Cycles

Conditional Cycles of 20 Ah (Blue Star) Li Ion Cells

Cell capacity around 23 Ah

1997 NASA Aerospace Battery Workshop

Lithium-Ion Focused Session
AC IMPEDANCE OF 20 Ah CELL

• Impedance reflective of a slow charge transfer process followed by diffusion.
EIS of JPL Experimental Li Ion Cells

Cathode impedance dominant portion of the total cell impedance.
Pulses at 60 A at 25°C

Pulsing of Blue Star 20 Ah Cell at 60 A (120 mS)

After 3rd discharge at 25°C

Cell# BS08

- BS24(19.7%SOC, p1)
- BS24(19.7%SOC, p3)

Cell Voltage, V

<table>
<thead>
<tr>
<th>3.0</th>
<th>3.2</th>
<th>3.4</th>
<th>3.6</th>
<th>3.8</th>
</tr>
</thead>
</table>

time, s

1 2 3 4
Pulses at 60 A at 25°C

Pulsing of Blue Star 20 Ah Cell at 60 A (120 mS)

100% SOC at 25°C

Cell # BS 24

Cell Voltage, V

0 1 2 3 4

time, s

4.1 4.0 3.9 3.8 3.7 3.6 3.5
Pulses at 40 A at 25°C

Pulsing of Blue Star 20 Ah Cell at 40 A (60 S)

Cell Voltage, V

- BS24(100% SOC)
- BS24(97.1% SOC)
- BS24(94.2% SOC)

Cell# BS 24

time, s
Pulses at 40 A at 25°C

Pulsing of Blue Star 20 Ah Cell at 40 A (60 S)

Cell# BS 24

After 2nd discharge at 25 C

Cell Voltage, V

4.2 3.6 3.0 2.4 1.8 1.2

0 20 40 60 80
time, s
Pulses at 40 A at -20°C

Pulsing of Blue Star 20 Ah Cell at 40 A (60 s)

Current < 40 A?

- BS24(-20 C 4th)
- BS24(-20 C 1st)
- BS24(-20 C 2nd)
- BS24(-20 C 3rd)

-20 C Cell# BS 24

0 20 40 60 80

Cell Voltage, V

-10.0 -8.0 -6.0 -4.0 -2.0 0.0 2.0 4.0

time, s
Nearly 100% utilization at C/3 discharge rate.

Charge at C/10 to 4.1 V followed by taper to C/50

Cell# 18 at 20°C

Capacity, Ah

Cell Voltage, V

Discharge at 25°C
Charge at 25°C
- Above 2/3 capacity in constant current mode at highest rate tested, i.e., C/3/
Nearly 100% charge input in 3 hours of charging.

Discharge capacity (Ah)

Charge at 25°C
Discharge at 0°C

Charge current 2.3 A (C/10) to 4.1 V
Constant voltage charge taper to C/50

Cell BS 019

- 2.3 A Discharge (C/10)
- 4.6 A Discharge (C/5)
- 7.5 A Discharge (C/3)

- Nearly 90 % capacity realized at C/3 discharge rate at 0 °C
Charge Profiles at 0°C
Poor Performance at -20°C

Discharge at -20°C

Discharge Capacity (Ah)

Cell Voltage (V)

- 4.6 A Discharge current (C/5)
- 2.3 A Discharge current (C/10)
Capacity vs. Temperature

- Poor performance at -20°C
Cycling (100% DOD) at 25°C

- Capacity fade 0.025 % per cycle.

Constant current charge = 4.6 A (C/5)
Constant voltage (4.1V) taper to 0.46 A
Discharge current = 4.6 A (C/5)
Discharge cut-off voltage = 3.0V
EIS During Cycling

- Marginal increase in the charge transfer (Faradaic) impedance
- Additional charge transfer polarization.
- Decrease in the series (Ohmic) resistance.
Cycling at 50% DOD at -20°C - Mars 2001 Lander

- Performance at -20°C inadequate.
Cycling at 50% DOD at 0°C - Mars 2001 Lander

- Depression in the EOD Voltage: 0.2 mV/cycle.
Mars Exploratory missions.

- Low temperature performance needs to be improved to enable the
  mission.

- Charge and discharge characteristics are fairly good at moderate
  rates.

- 2001 mission point of view.
  Both at 100% and 50% DOD, which encouraging from the Mars
  BlueStar 20 Ah cells have so far shown good cycle life characteristics

SUMMARY
Acknowledgement

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract with National Aeronautics and Space Administration and in collaboration with the Air Force Research Laboratory. The cells were fabricated by Bluestar under Air Force contract.