Development of Evaluation Testing Method of COTS Lithium-Ion Secondary Batteries Suitable for Lean Satellites

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1. Research Background & Purpose

Currently, we are observing the lithium ion battery (LIB), which has a higher capacity in comparison with the NiMH battery. Moreover there are no bottlenecks associated with memory effects. From these characteristics, we can reduce the mass of the electrical power system (EPS) of the satellite. People frequently use LIBs on the ground. Also, space-qualified LIBs are already in use. The evaluation standard of LIB based on low cost and commercial-off the shelf properties suitable for micro/nano satellites is not yet clear. Our final goal is to develop such a standard.

Generally, a prolonged charge/discharge test is required for evaluation of a battery. However, many test costs, such as personnel expenses, are required in any prolonged charge/discharge test by manual operation. Automated charging/discharging is necessary to reduce the test cost. By controlling power, electronic load, and relay in LabVIEW®, we have developed a low-cost fully automated test system. LabVIEW® is a graphical language that National Instruments has developed. We have carried out lengthy charge/discharge tests of COTS batteries at various temperatures using this system. In addition, we evaluate the suitability of the space environment of the battery and determine whether the satellite suits the battery.

2. Research Method

2.1 Test Material

Fig. 1 shows units of the LIB type that was used in this research.

Fig. 1. LIB

Table 1. Specification of LIB

Voltage	3.6V
Capacity	2250mAh

2.2 Charge/Discharge Evaluation Test System

This system consists of Power, Electric Load, and Relay. They are controlled by LabVIEW®. In this system, we can set up some parameter (ex. Voltage, Current, etc.) freely, so we can do test for other batteries. Shown below is the circuit and test system that was used by the charge/discharge test.

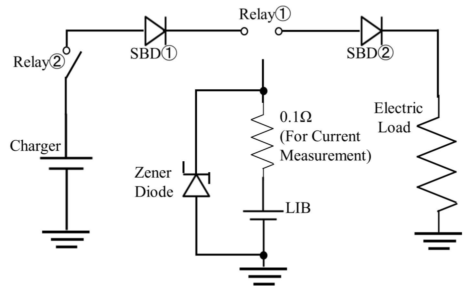

Fig. 2 Charge/Discharge Circuit

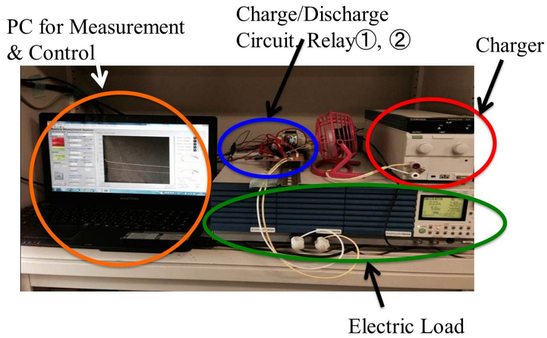

Fig. 3 Photo of Charge/Discharge Evaluation Test System

We used relays for the change (relay ①) of charge/discharge and for turning on/off the power supply (relay ②). This relay is a mechanical type.

We inserted a zener diode (zener voltage 4.1V) for preventing overcharge around the LIB. Moreover, we inserted a Schottky barrier diode (SBD ①, ②) for preventing adverse current in the charge side and discharge side.

3. Charge/Discharge Evaluation Test

3.1 Real Life Time Test

These tests were carried out under various conditions. In the charge side, we charged LIB by the most suitable constant current and constant voltage charging method. Here, the charge stop voltage is 4.0V. Charge time per 1 cycle is from 50 minutes to 90 minutes. This is because charge time depends on several conditions. We discharged LIB by a constant current discharge method and DOD 50%. It stops after arrival in the arrival back or 2.8V in discharge time for 30 minutes. The reason the DOD was set as 50% was to make it possible to begin to charge from a constant current charge just after the discharge.

Table.2 List of Real Life Time Test

Test Contents	Cycle Number
Atmosphere (25℃, 1day)	19
Atmosphere (25℃, 1week)	120
Vacuum (25℃, 1 day)	11
Atmosphere (45℃, 1 day)	15
Atmosphere (0℃, 1 day)	15
Atmosphere (-3℃, 1 day)	16
Atmosphere (25℃, 1 day)	14
Total Cycle Number (13 days)	210

We imitated the vacuum environment using a small thermal vacuum chamber. Moreover we imitated hot and cool-temperature environments using a small thermostatic chamber. Fig. 4 shows the discharge capacity before/after these tests.

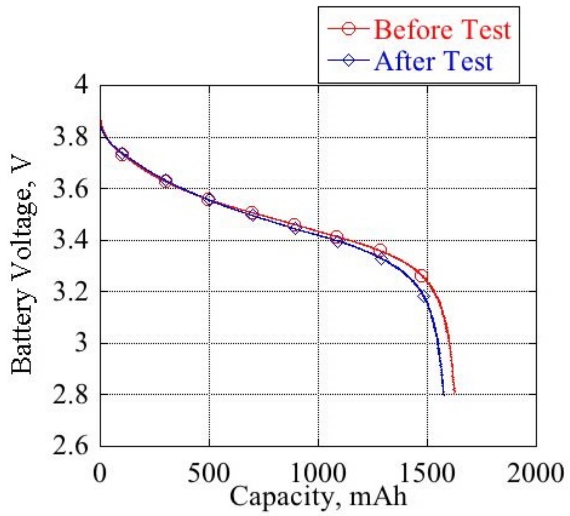

Fig.4 Discharge Capacity before/after Real Life Time Test

We could measure battery degradation of about 3% from the result of the real life time test.

3.2 Acceleration Test

In this test, we carried out test under the room temperature environment and high temperature environment where degradation may be most developed[1]. Moreover, we changed DOD from 50% to 100%, and we carried out perfect charge/discharge.

Table.3 List of Acceleration Test

Contents	Test Term	Cycle Number
Atmosphere (70℃)	1week	84
Atmosphere (25℃)		105

We carried out high temperature tests using the small thermostatic chamber and carried out this test in the laboratory while maintaining room temperature (25℃).

Fig. 5 shows the battery degradation progress in the high temperature and room temperature test. In this graph, the vertical axis is capacity retention and the horizontal axis is test term.

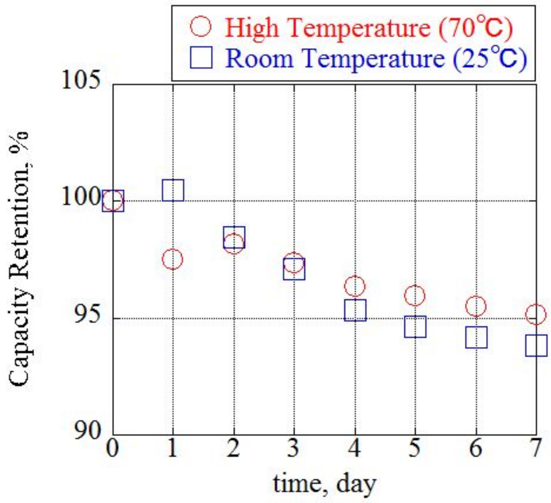

Fig. 5 Capacity Degradation Progress in High Temp. and Room Temp. Acceleration Test

We could measure battery degradation of about 5% from the result of the high temperature test. We also could measure degradation of about 6% from the result of the room temperature test. Here, we compared these results to that of the real life time test. When we cut test term by half, battery degradation was about 2 times. This shows that there was big significance in implementation of the acceleration test.

4. Conclusion & Future Task

We built an inexpensive charge/discharge automation system using a power supply, electronic load, and a relay. Moreover, we carried out the charge-and-discharge examination of LIB under various conditions by using the system. However, we need to carry out test under the space environment.

Reference

[1]H. YOSHIDA., et al, “Verification of Life Estimation Model for Space Lithium-Ion Cells”, Electrochemistry, pp. 482-488(2010)