EnerSys 18650 Cell Characteristics and ZeroVolt™ Capability

Hiroshi Nakahara
Quallion R&D Group
EnerSys Advanced Systems
12744 San Fernando Road, Suite 03-100, Sylmar, CA 91342, U.S.A.
Hiroshi.nakahara@eas.enersys.com / 818-833-2000

Abstract

Quallion, a subsidiary of EnerSys Advance Systems (EAS) has been developing and manufacturing 18650 secondary lithium-ion cells (QL1500A) with primary focus for aerospace applications. QL1500A (1.5Ah, 3.6V) is expected to last more than 40,000 cycles under low earth orbit (LEO) cycle condition. This cell is EAS's baselined 18650 cell product developed over the past several years. EAS set up the manufacturing line for the QL1500A in Sylmar, CA, U.S.A. in 2013. In this paper, the characteristics of QL1500A is introduced including EAS's 18650 cell manufacturing capability. In addition, EAS added ZeroVolt™ feature [1-3] to QL1500A which enables long-term storage at 0V with no degradation (QL1500A-ZV). The Quallion patented cell provides the unique characteristic of an 18650 cell with ZeroVolt™ capability and is presented in this paper with low cell voltage tolerances of less than 2V. This ZeroVolt™ technology provides low cost and maintenance storage requirements as well as ease of operations. Furthermore, EAS is actively developing the new cell products with higher energy densities of 18650 cells associated with the advanced cell material developments. The status of development in EAS with the methodology to increase energy density on 18650 cell product line is discussed.

Keywords

Lithium secondary battery; Cylindrical cell; 18650; Overdischarge; ZeroVolt; High energy density; Aerospace; Satellite

Introduction

The lithium-ion secondary battery market is growing dramatically in recent years because of its high energy density for a variety of applications. Applications for electric vehicle and mobile devices are accelerating the market-size growth and further technology advancement in energy density. In addition, the supply chains of lithium-ion cells and the raw materials has been challenging domestically, and the major manufacturing locations of lithium-ion cells are localized outside the United States causing geopolitical and logistical concerns. Many automobile manufacturers have been focused on setting up lithium-ion cell mass production and increasing production capacity in the United States to control supply chains of batteries and raw materials.

EAS has been manufacturing lithium-ion secondary cells including 18650 cells for more than two decades, which feature long life and high reliability for medical device and aerospace applications. For those niche applications, EAS developed ZeroVolt™ to enhance long cell life performance. EAS's 18650 cell products include standard type (product code name: QL1500A) and ZeroVolt™-integrated type (QL1500A-ZV). ZeroVolt™ technology increased the reliability of a power source modules in devices by enabling operation in low cell voltage ranges of less than 2V. This low voltage technology requires little maintenance and is able to use a simplified battery management system, making it ideal for long term storage before a mission, and long periods of dormancy during mission operations. The ZeroVolt™ technology has been validated to preserve the performances of lithium-ion cells after 10-year storage at 0V. EAS is actively improving cell energy density because of the high demand of increasing energy density of EAS's 18650 cell products. As a part of energy density improvement, EAS has developed an 18650 cell with 2.5Ah assembled into power modules for a satellite which was deployed. Furthermore, a 3Ah-class cell was prototyped, which is currently undergoing chemistry and manufacturing optimization.

In this paper, the cell characteristics of QL1500A, QL1500A-ZV, and ZeroVolt™ technology are introduced. Furthermore, improving cell energy density up to 3.4Ah / 270Wh/kg is discussed.

EAS's 18650 Cell Characteristics

QL1500A and QL1500A-ZV cell characteristics baselines are summarized in Table 1. A typical discharge curve of QL1500A-ZV cell is shown in Fig. 1. Cell envelope sizes for QL1500A cell and QL1500A-ZV cell are the same. Cell capacities for both cells at low C-rate discharge are the same as well. AC impedance is for QL1500A-ZV is higher than QL1500A due to the electrode mechanical design. However, QL1500A-ZV has an advantage in its light weight (higher weight energy density) compared with QL1500A (145Wh/kg vs. 120Wh/kg).

Table 1 18650 ZeroVolt cell characteristics

	QL1500A (Standard)	QL1500A-ZV (ZeroVolt-Integrated)
Diameter (mm), max.	18.5	18.5
Length (mm), max.	65.2	65.2
Weight (grams), max.	44	37
AC impedance (Ohms), max.	0.05	0.11
Discharge Capacity (Ah), typical	1.45	1.45
Weight energy density (Wh/kg), typical	120	145

*1 measured at 1kHz, room temperature
*2 measured under the condition of discharging at C/5 after charging under C/5 to 4.1V with tapered current to C/100 at 25ºC

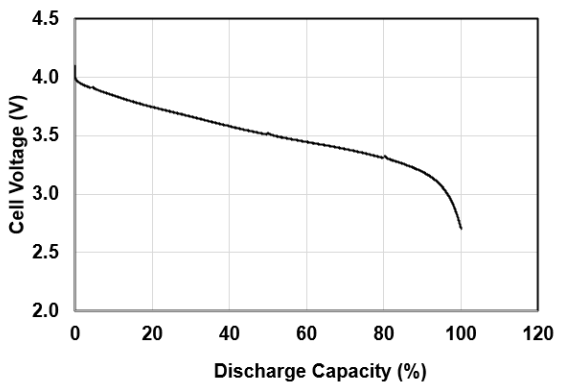

Fig. 1 Discharge curve of EAS 18650 ZeroVolt™ cell under discharging at C/2 after charging under C/5 to 4.1V with tapered current to C/100 at 25ºC

ZeroVolt Characterization Results

QL1500A long term characteristic was evaluated under 40% DOD LEO cycling at room temperature. Full discharge capacity to 100% DOD at C/2 and room temperature was measured during 40% LEO cycling every 400 cycles. Fig. 2 shows the measured capacity during 40% LEO cycling at room temperature. Fig. 3 shows the cell voltage at the end of discharge during 40% DOD LEO cycling with QL1500A-ZV. QL1500A cell (R&D test cell) demonstrated more than 98% of capacity retention (measured at 100% DOD at room temperature) after 6,900 LEO cycling. It is expected more than 80% of capacity retention after 40,000 LEO cycles based on this result. In addition, EAS's cell manufacturing capability was evaluated under the same test condition. The cell test results were compared between R&D test cells and production cells manufactured at the cell manufacturing facility in Sylmar, CA. Production cells demonstrated the same capacity retention to R&D cell at 4,000 LEO cycle with the same linear trend on capacity retentions during LEO cycling.

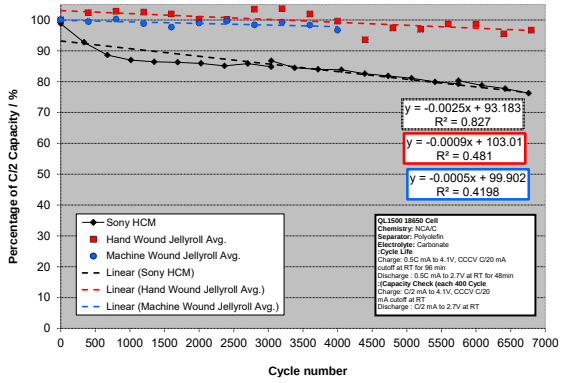

Fig. 2 Capacity retention of QL1500A measured under 100% DOD discharge during 40% DOD LEO cycling at room temperature

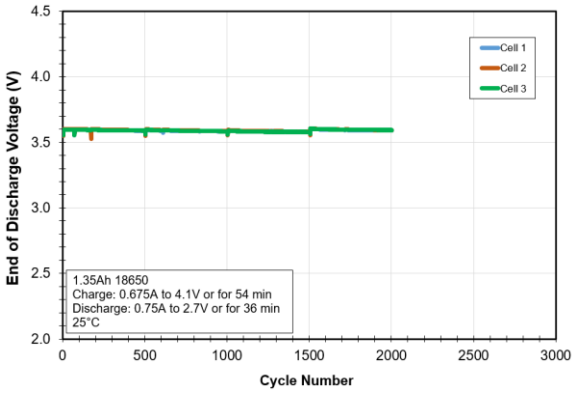

Fig. 3 Capacity retention of QL1500A measured under 100% DOD discharge during 40% DOD LEO cycling at room temperature

ZeroVolt™ technology was integrated to QL1500A-ZV to add more value for aerospace applications. ZeroVolt™ technology was developed by EAS to prevent cell degradations and safety concerns observed in conventional lithium-ion cells in low voltage range (<2V). This technology was originally developed for implantable medical device application cells (0.003 ~ 1.8Ah), and it was applied to QL075KA prismatic cells (72Ah, 3.6V) in the past.

Storage test at 0V was performed with conventional 18650 cells (no ZeroVolt™) and ZeroVolt™ integrated cells by externally shorting with 20-ohm resistor (Fig. 4). Shorted test cells were stored at room temperature for 3 days. After the storage, the test cells were charged to 3V at C/200 at room temperature. The cell discharge capacity was measured under CC-CV charge at C/2 with tapered current cutoff of C/20 followed by discharge at C/2 rate to 2.7V before and after 0V-storage to measure the degrees of cell performance degradation at 0V. Fig. 5 shows discharge curves of 18650 test cells before and after 0V-storage at room temperature. (a) and (b) are the discharge curves for conventional cell and ZeroVolt™ integrated cell, respectively. The conventional 18650 cell lost 77% of discharge capacity during 0V-storage (Fig. 5a). On the other hand, ZeroVolt™ integrated 18650 cells maintained 100% discharge capacity after 0V-storage (Fig. 5b).

ZeroVolt™ technology (QL1500A-ZV) was characterized extensively at lower temperatures between -70ºC and -20ºC for aerospace applications. The cell was discharged at a rate of C/5 at 20°C and held at zero volts. Cell temperature was ramped to the target storage temperature. Each cell was stored for 7 days at the selected test temperature. Each cell then was returned to 20°C after 0V-storage at the prescribed temperature. Each cell was recharged at a rate of C/20 to 2.7V, then charged at C/5 to 100% SoC with a taper to C/100. Discharge capacity was measured before and after 0V-storage. Each cell was electrically cycled for 100 cycles at a C/2 charge/discharge rate to 100% DoD. After the discharge capacity measurement cycles, 80% DOD cycling test took place at 20°C for the cells.

Fig. 6 shows the discharge capacity retentions of QL1500A-ZV after 0V storage at low temperatures between -70oC ~ -20ºC. At first, the discharge capacities measured after storage at 0V for 7 days at respective temperature are plotted. Furthermore, the discharge capacity retentions after 100 cycles under 80% DOD of charge and discharge cycling at 20ºC were overlaid on Fig. 6 to evaluate the impact of 0V-storage at low temperatures on cyclability.

Fig. 7 shows the discharge capacities during 80% DOD cycling at 20ºC. Discharge capacities of QL1500A-ZV cells after 0V-storage at low temperature were retained fully.

0V-storage did not affect cell cyclability at all. As a result, QL1500A-ZV is suitable for deep space exploration because of 0V-storage capability at wide range of operation temperatures.

Fig. 4 Photograph of 18650 test cell with a 20-ohm resistor under 0V storage test

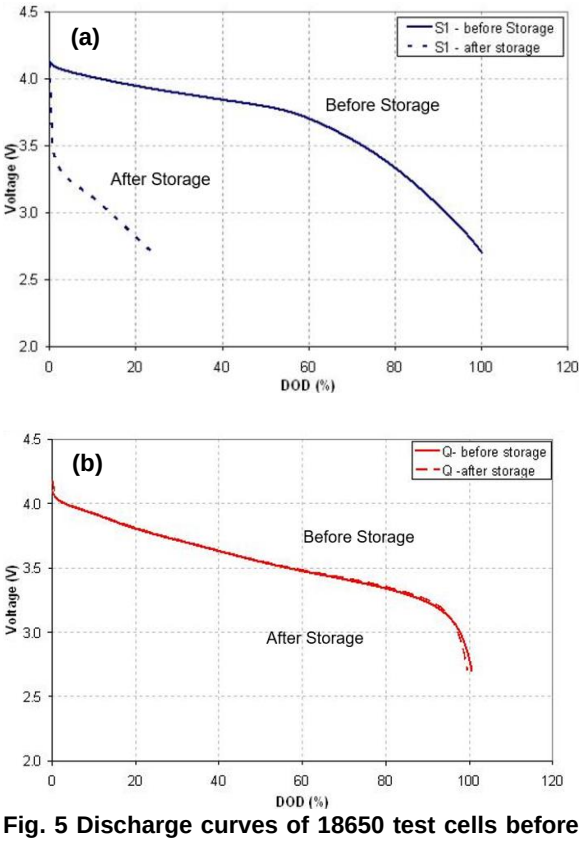

Fig. 5 Discharge curves of 18650 test cells before and after 0V storage at room temperature; (a) conventional cell, (b) ZeroVolt™ integrated cell

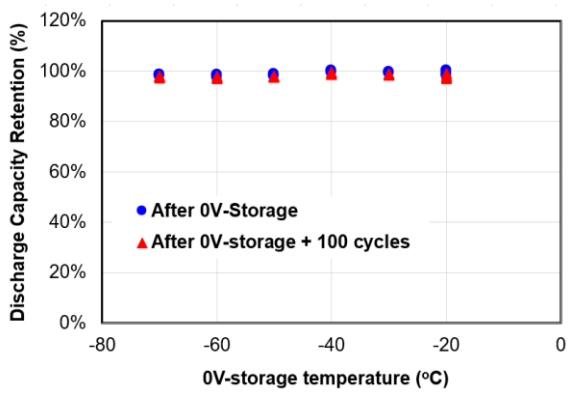

Fig. 6 Discharge capacity retention of QL1500A-ZV after 0V storage at low temperatures between -70°C ~ -20°C. Discharge capacities were measured after storage at 0V for 7 days at respective temperature and were measured one more time after 100 cycles of charge and discharge at 20°C.

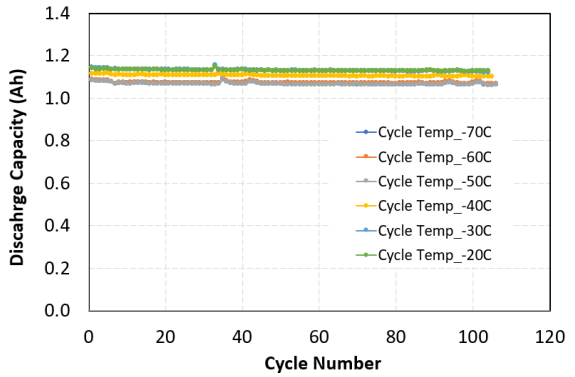

Fig. 7 Discharge capacity retention of QL1500A-ZV during 80% DOD cycling at 20°C

High Energy Density 18650 Cell Development

Improvement on energy density has been carried out in EAS. EAS established a brand name with highly reliable lithium-ion cell manufacturing for critical missions and operations in the medical device and aerospace industries. Because of recent demand for higher energy densities in those applications, EAS has been developing higher energy density 18650 cells. 2.5Ah-class 18650 cells with ZeroVolt™ capability for aerospace application were developed. The new 2.5Ah cell was assembled and has been deployed to a power module for a satellite in operation. This space mission is validating use-case of the cell mechanical design and high energy density chemistry currently day-by-day. Furthermore, EAS is continuing to increase energy density by introducing new chemistries including high nickel NMC cathodes and Si-based anodes. Fig. 8 shows an example of a high energy type 18650 prototype cell (3-Ah class 18650 cell). Discharge capacity was measured under C/10 rate at room temperature. Discharge capacity was 2.95Ah.

Continuous development to increase the energy density of the18650 cell will be done with not only the introduction of new chemistries but also with the improvement of cell manufacturing processes with tighter tolerances and mechanical designs of each component while still balancing the safety characteristics of the cell. Currently, EAS is working towards a 3.4Ah, 270Wh/kg 18650 cell using established ZeroVolt™ technology for an industry leading energy-rich and stable cell.

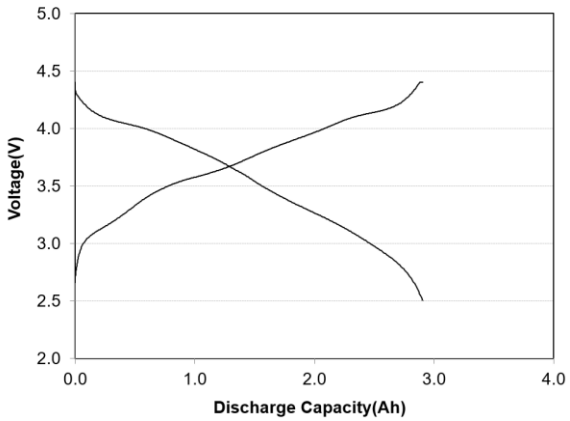

Fig. 8 Charge and discharge curves of 3Ah-class 18650 prototype cell

Summary

EAS 18650 cells (QL1500A and QL1500A-ZV) patented technology have been validated for aerospace applications. ZeroVolt™ technology was characterized extensively at lower temperatures for future deep space explorations. In addition, EAS has developed 2.5Ah cell in these 18650-cell product line which design is also validated in space mission currently. The continuous improvement on increasing energy density will be carried out to respond the high demands from the industries.

Reference

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