Data Acquisition and Performance Analysis on Discharge Process of Wide Temperature Resistant Battery

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Abstract. For lithium ion battery discharge performance of different problems in different ambient temperature, with a company of a new wide temperature resistant ternary lithium ion battery as test object, established a new method of testing, set up to −40 °C, −25 °C, 25 °C and 55 °C four different temperature conditions, with high and low temperature testing system for the ternary lithium battery charging and discharging 1 c to charge and discharge test, Recorded and processed data. The results show that the energy density of the battery reaches 244.12Wh/kg at room temperature of 25 °C. At −25 °C and −40 °C, the average energy density decreases to 77.47% and 50.24% of that at room temperature, respectively. The energy density decreases to 97.35% of the normal temperature condition after the high temperature charge retention and capacity recovery at 55 °C.

Keywords: Wide temperature resistant battery · Lithium ion battery · Energy density · The depth of discharge

1 Introduction

As a comprehensive battery system at present, lithium ion battery has the advantages of small volume, high specific energy, no memory effect, light weight, no pollution and high cycle life, and has been widely used in hybrid vehicles, information technology, aerospace and other aspects, with great demand. However, lithium-ion batteries are greatly affected by ambient temperature, and their optimal operating temperature range is generally 15–35 °C. When the temperature is below 0 °C, the performance of batteries will be greatly reduced [1–3]. Gao Chen et al. conducted discharge tests on lithium-ion batteries at low temperature and compared them with normal temperature. The results showed that the discharge performance of lithium-ion batteries decreased significantly at −15°C, and the capacity at 1C discharge was only 34.1% of that at normal temperature [4]. However, when the battery is in a high temperature environment, the side reaction rate in the battery will increase along with the decomposition of the electrolyte, affecting the service life of the battery [5].

In order to study the discharge characteristics of a new type of lithium-ion battery with wide temperature resistance at different temperatures, various comparative tests of the

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discharge depth and energy density of the lithium-ion battery were carried out at 55 °C, 25 °C, −25 °C and −40 °C, respectively, to investigate the influence of temperature on the discharge performance of the battery with wide temperature resistance.

2 Experimental Methods

This part introduces the test device and data acquisition platform, battery to be tested and test process respectively.

2.1 Test Device and Data Acquisition Platform

The structure of the high and low temperature charge and discharge test system is shown in Fig. 1. The battery charge and discharge test equipment in the figure is the energy recovery battery test system Chroma 17020, which can simultaneously test voltage, current, energy, capacity and temperature, etc., the highest voltage is 20 V, the maximum current is 400 A, the test accuracy is 0.001; The ultra-low temperature environment simulation test chamber is SDJ710FA high and low temperature humid heat chamber, the highest temperature is 150 °C, the lowest temperature is −70 °C, the accuracy is ±1 °C.

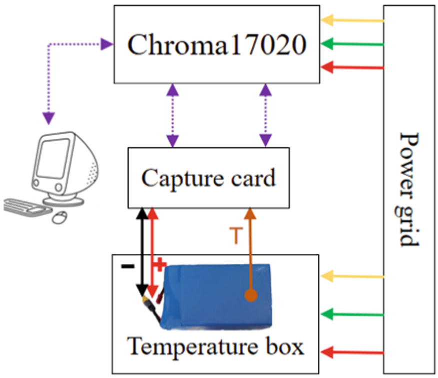

Fig. 1. Schematic diagram of high and low temperature test system

2.2 Test Data Collection Object

The experimental object is a new type of ternary lithium battery with width and temperature resistance, and its main technical parameters are shown in Table 1.

2.3 Test Process and Data Collection Content

The battery is connected to the test interface and sampling interface of the battery charge and discharge test equipment through the special battery fixture and sensor, and different

Table 1. Technical parameters

Project	Parameter
Nominal capacity	10.8 Ah
Nominal voltage	3.7 V
Mass	170 g ± 1 g
Charging cut-off voltage	4.4 V
Charging cut-off current	0.5 A
Maximum charge rate	1C
Discharge cut-off voltage	2.5 V

rates of discharge experiments are carried out in the high and low temperature humid heat chamber. The discharge voltage, charge and discharge current and battery temperature can be detected during the test.

Three identical batteries were selected for three tests of low temperature (−25 °C low temperature, −40 °C ultra-low temperature) and high temperature (55°C high temperature). The test process and data collection content are shown in Table 2 and Table 3.

Table 2. Test process and data collection content (low temperature)

Steps	Temperature	Experiment content	Data acquisition
1	25 °C	1C Discharge to 2.5 V, then stand for 1h	—
2		1C Charge to 4.4 V, then charge at constant voltage to 0.05C and stand for 1 h	Voltage, current, temperature
3		1C Discharge to 2.5 V, then stand for 1 h	Voltage, current, temperature
4		1C Charge to 4.4 V, then charge at constant voltage to 0.05C and stand for 1 h	Voltage, current, temperature
5	−25 °C/−40 °C	Stand for 12 h	temperature
6		1C Discharge to 2.5 V, then stand for 1 h	Voltage, current, temperature
7		1C Charge to 4.4V, then charge at constant voltage to 0.05C and stand for 1h	Voltage, current, temperature
8		1C Discharge to 2.5 V	Voltage, current, temperature

Table 3. Test process and data collection content (high temperature)

Steps	Temperature	Experiment content	Data acquisition
1	25°C	1C Discharge to 2.5 V, then stand for 1 h	—
2		1C Charge to 4.4 V, then charge at constant voltage to 0.05C and stand for 1 h	Voltage, current, temperature
3		1C Discharge to 2.5 V, then stand for 1 h	Voltage, current, temperature
4		1C Charge to 4.4 V, then charge at constant voltage to 0.05C and stand for 1 h	Voltage, current, temperature
5	55°C	Charge retention at high temperature for 7d	temperature
6	25°C	stand for 1 h	temperature
7		1C Discharge to 2.5 V, then stand for 1 h	Voltage, current, temperature
8		1C Charge to 4.4 V, then charge at constant voltage to 0.05C and stand for 1 h	Voltage, current, temperature
9		1C Discharge to 2.5 V	Voltage, current, temperature

3 Data Processing and Analysis

In order to study the effect of charging and discharging temperature for the depth of discharge, the experiment system, we use Fig. 1 respectively according to low temperature and ultra-low temperature and high temperature testing conditions for battery charging and discharging test, and in the process of test data collection and analysis, the condition of different charge and discharge and temperature was obtained to devolve power voltage and discharge depth, the relationship between the low temperature set by shown in Fig. 2.

3.1 Discharge Performance Data Processing and Analysis of Batteries at Low Temperature

According to the charge and discharge curve at room temperature, when the battery is discharged at room temperature, the discharge voltage will experience three stages: rapid decline at first, steady decline at last, and rapid decline at last. However, under the conditions of low charge and ultra-low charge, there is a phenomenon of voltage rise and then decrease between the two stages of rapid decline and gradual decline of discharge voltage, while the phenomenon of low temperature charge and discharge is small. Among them, the discharge voltage of normal temperature charge and ultra low temperature discharge has the largest rebound range, up to 0.36 V.

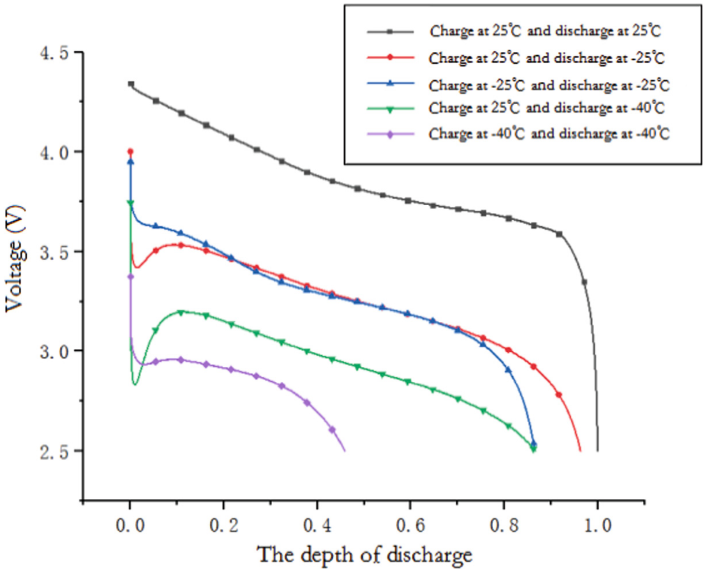

Fig. 2. Relationship between discharge depth and discharge voltage at different low temperature and charging and discharging conditions

The reason for this phenomenon is mainly related to the utilization rate of active substances inside the battery [6–8]. Due to the low temperature discharge of the battery, the internal active substances can not be fully used, the electrode polarization is serious, the battery internal resistance is large, so the initial discharge voltage of the battery drops rapidly. With the discharge, due to the large internal resistance of the battery, a lot of heat is generated inside the battery, so that the battery temperature rises rapidly, so that the active substance of the battery is activated, so the battery discharge voltage begins to rise. As the temperature of the battery rises, the internal resistance of the battery starts to fall, and the heat generated decreases, and the rate of temperature rise decreases, resulting in a decrease in the discharge voltage of the battery. As the charge at normal temperature is greater than that at (ultra) low temperature, the initial value of discharge voltage, voltage drop range and voltage rebound range of normal temperature charge and (ultra) low temperature discharge are all greater than that of (ultra) low temperature charge and discharge.

3.2 Discharge Performance Data Processing and Analysis of Battery Under High Temperature Conditions

Since the treatment method of high temperature condition is different from that of low temperature condition in the test, it is discussed separately, and the battery charge and discharge test is still carried out with the experimental system in Fig. 1 and data collection is carried out. The relationship between battery energy density before and after high temperature treatment is obtained, as shown in Fig. 3.

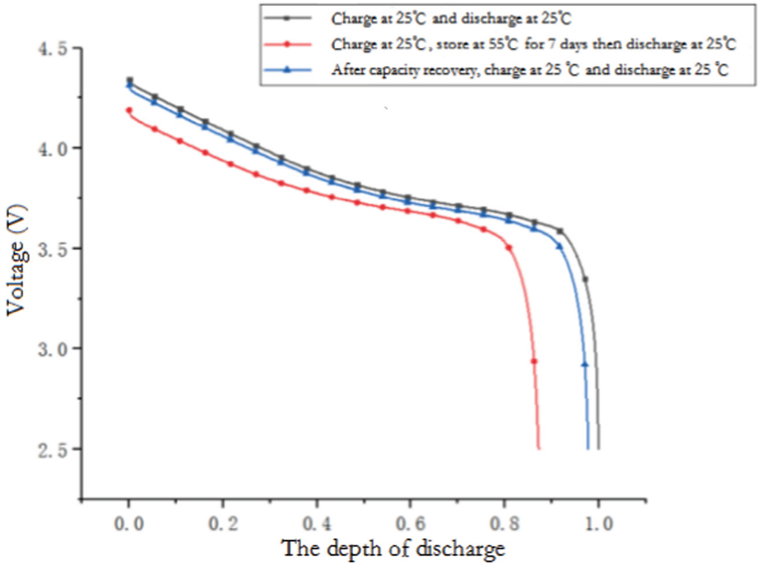

Fig. 3. Relationship between discharge voltage and discharge depth before and after high temperature treatment

The experimental results show that the charge retention rate and capacity recovery rate of the battery are 87.20% and 97.78%, respectively. The reason for the difference between the values of charge retention curve and capacity recovery curve is that during the storage at 55 °C for 7 days, the battery not only suffers from permanent loss due to high temperature, but also has self-discharge phenomenon, which leads to the reduction of electric quantity and the reduction of initial discharge voltage and discharge depth during subsequent discharge at room temperature. The difference between the capacity recovery curve and the original state is the permanent loss of battery capacity caused by high temperature of 55 °C [9–11].

3.3 Processing and Analysis of Energy Density Data

In order to study the influence of different temperatures and charging and discharging conditions on battery energy density, the experimental system in Fig. 1 was used to test the energy density under the above different conditions, and the energy density under different temperatures and charging and discharging conditions was obtained, as shown in Fig. 4.

The experimental results shown that both high temperature and low temperature reduce the energy density. When the low temperature test was conducted, the lower the temperature, the lower the energy density was, and the energy density of normal temperature charge and (ultra) low discharge was higher than that of (ultra) low temperature charge and discharge. The energy density of normal temperature charge and low temperature discharge was reduced by 19.04%, 26.02%, 33.74% and 65.78%, respectively,

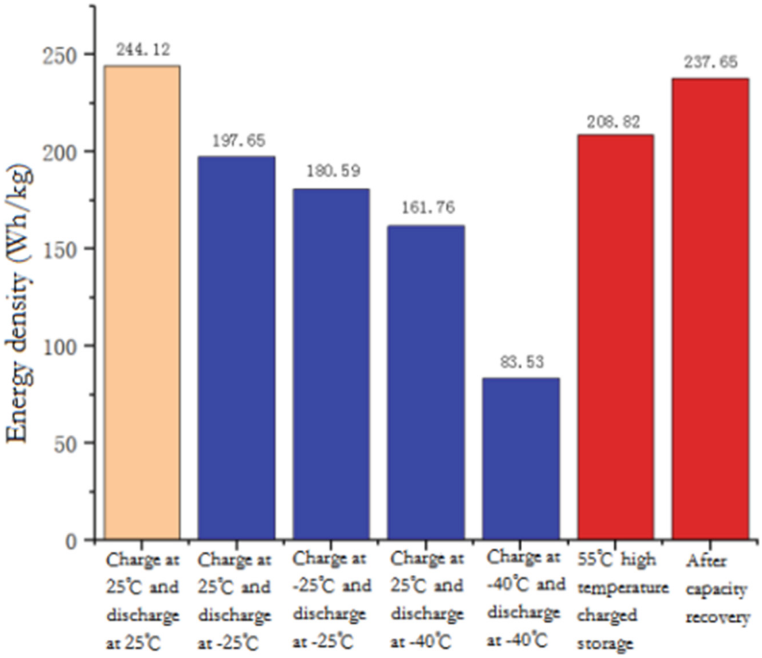

Fig. 4. Energy density under different temperature and charging and discharging conditions

compared with that of normal temperature charge and low temperature discharge. During the high temperature test, the energy density after charging and discharging at high temperature is reduced by 14.46% compared with that at normal temperature, and the energy density after capacity recovery is reduced by 2.65%.

4 Conclusion

Based on the above analysis of the battery discharge data, it can be seen that: At low temperature, the discharge depth and energy density decrease with the decrease of temperature, and the decrease is relatively gentle, only in the ultra-low temperature charge and discharge test, the discharge depth and energy density will decrease significantly compared with the conventional lithium ion battery at −15 °C, the low temperature tolerance of this battery is improved significantly. After 7 days of high temperature charge retention and capacity recovery, the charge retention rate and capacity recovery rate of the battery are 87.20% and 97.78%, and the loss is less. Overall good tolerance to wide temperature conditions.

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