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A Study on Impedance Change Trend and Battery Life Analysis through Battery Performance Deterioration Factors

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Abstract

Although the use of batteries is rapidly increasing worldwide to improve carbon neutrality and energy efficiency, performance degradation due to the increase in the number of uses is inevitable as it is a finite resource that can be applied according to capacity and specifications. Deterioration and failure of batteries are recognized as important problems in various applications using batteries, including electric vehicles. In order to solve these problems, a diagnostic technology capable of accurately predicting battery life and grasping state information is required, but it is difficult in a non-linear form due to internal structure or chemical change.

In this paper, the factors that generally cause battery performance change are directly applied to check whether there are external changes and impedance changes in the battery, and to analyze whether they affect battery life. Impedance change trends and result values were confirmed using a universal impedance spectroscopy method and a self-developed internal impedance measurement method. The results did not significantly affect the impedance change trend. It was confirmed that the increase in the number of times of battery use was prominent in the impedance change trend.

Keywords: *Impedance, electric vehicles, Lithium-Ion Battery, Variation Factor, Prediction*

1. Introduction

As markets for electric vehicles and energy storage devices expand domestically and internationally, battery performance degradation and failure are recognized as important problems in various application fields using batteries, including electric vehicles. In order to solve this problem, a diagnostic technique capable of identifying accurate battery state information is required, so various battery diagnostic techniques have been developed recently, and a diagnostic method through impedance is common [1].

Impedance can be interpreted as a cause that hinders electrical transmission when a chemical (oxidation-reduction) reaction occurs in an electrode. Impact, short circuit, and damage can be cited as the causes of the increase in impedance, which is considered to be internal damage of the battery. The Electrical Impedance

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Spectroscopy (EIS) method for determining the degree of disturbance of the battery's electrical transmission uses a method of identifying the impedance characteristics that change depending on the battery condition by frequency by applying a small amount of power to perform accurately and quickly. The internal impedance measurement method (BTR) through an equivalent circuit is measured using microvoltage and current [2].

2. Design of Impedance

Impedance for determining the degree of disturbance of electricity transmission of a battery refers to the ratio of current and voltage in an AC circuit, and is usually expressed as Z. The impedance of an AC circuit is divided into impedance due to resistance (ZR), impedance due to capacitance (ZC), and impedance due to inductance (ZL). impedance (ZR) due to resistance is not different from DC resistance, but it hinders current flow and consumes power. Impedance due to capacitance (ZC) and impedance due to inductance (ZL) show completely different behavior in an AC circuit from that in a DC circuit, and have a characteristic that the size varies depending on the frequency. As described above, impedance is largely composed of three elements, and it can be seen that capacitance and inductance among them are changed according to frequency due to their characteristics. It is common to express the characteristics of each frequency and the factors of change according to the influence in complex numbers so that it can be seen at a glance. Impedance is expressed as a combination of resistance, capacitance, and inductance, and is divided into resistance and reactance according to phase change. Impedance Z is expressed using a complex number when expressing the magnitude and phase, and can be represented by the real part R and the imaginary part jX [3].

In the imaginary part, the fluid reactance XL and the capacitive reactance 1/XC can be defined as in the following equation (2-1).

$$Z = R + jX = R + \frac{1}{jwC} + jwL \qquad (2\text{-}1)$$

3. Test Configuration for Impedance Variation Factors

Figure 1 shows the battery tester (Hioki BT3563A) of the electrical impedance spectroscopy (EIS) method and the battery tester (BTR) of the internal impedance diagnosis method through an equivalent circuit. Measure and compare the results and pattern changes according to impedance change factors using diagnostic equipment with different impedance calculation and measurement methods [4].

Test Battery Specifications: Li-ion 4850mAh, 3.64V

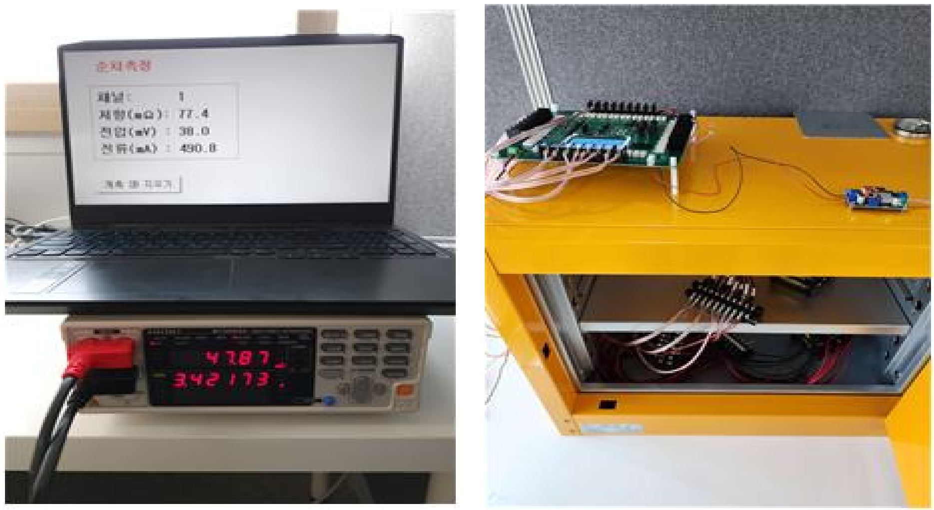

Figure 1. TEST of BT3563A & BTR

4. Test Conditions for Impedance Variation Factors

In Figure 2, the reliability of the measured values of the equipment to be measured could not be guaranteed, so the result value was first confirmed by connecting a simple resistor. The reliability and calibration of the equipment were confirmed through the measurement results through the battery jig board and the output ratio of the result values according to the wiring.

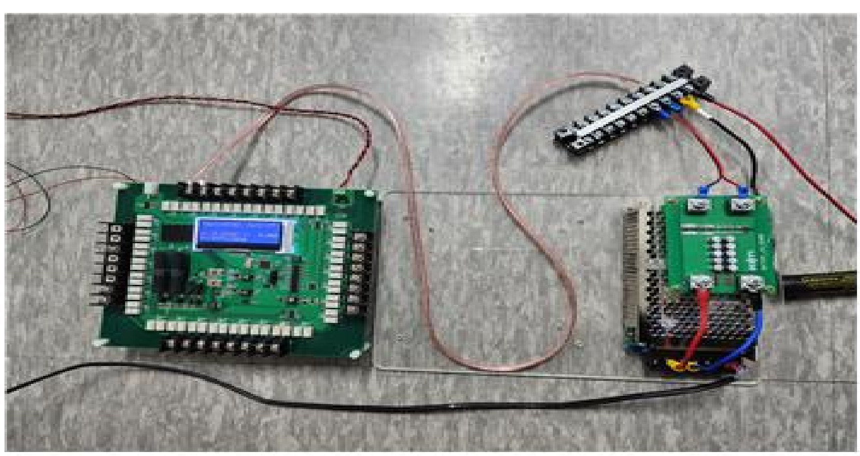

Figure 2. Battery JiG Board and Connector Wiring

As a result of checking the measurement results in Table 1, there was a difference in the direct measurement values of the two equipments, but the change in values for the measurement conditions showed the same pattern. . It was decided to confirm and compare the results according to the impedance change condition through partial correction of the result values [5].

Table 1. Measurement results

Impedance Factor		Battery JIG Board	Con 1	Con 2	Con 3
BT3564A	result	27.7	38.5	178.5	189.3
	ratio	**0.15**	**0.20**	**0.94**	**1.00**
BTR	result	6.6	8.1	25.3	26
	ratio	**0.25**	**0.31**	**0.97**	**1.00**

As shown in Table 2, the measurement method tried to confirm the battery change and impedance change that occurred when the following four conditions were applied.

Table 2. TEST Condition

TEST Condition	1	2	3	4
Battery Test Conditions:	Measure after applying 10 impacts with a hammer 10 times	Measure after generating short circuit for 10 seconds/5 times	Normal battery condition	Measure after inducing damage using a 1.0~2.0mm drill
Cell No.	#1 ~ #8	#9 ~ #16	#17 ~ #24	#25 ~ #30
Picture				
Fire condition	x	x	x	o

5. Test Results for Impedance Variation Factors.

Table 2 shows the test results for the factors of impedance change. In the impact test, the external appearance of the battery was deformed, but the impedance value did not change significantly. In the short-circuit test, external deformation did not show much, but the impedance value showed a difference for each cell. A normal battery was able to confirm certain data, and in the damage test, 50% of the fire occurred, and leakage and impedance change due to external damage could be confirmed [6].

Table 3. TEST Result

Cell	BT3564A		BTR		Test Conditions:
	Con 1	Con 1+2	Con 1	Con 1+2	
1	51.8	211.02	15.9	28.7	Impact TEST (hammer)
2	45.5	201.81	14.8	28.2	
3	47.2	199.38	14.5	28.2	
4	46.5	199.88	13.9	28.0	
5	48.88	202.50	14.5	28.2	
6	47.23	204.80	14	28.3	
7	51.8	211.23	14	28.6	
8	46.0	202.59	14.2	28.8	
9	48.0	218.12	14.6	29.3	Short-Circuit Withstand TEST
10	49.3	210.55	14.4	28.9	
11	44.7	195.01	14.2	28.2	
12	43.6	200.52	14.5	28.7	
13	49.7	203.04	14.4	28.6	
14	48.1	201.25	14.3	28.6	
15	40.5	197.91	14.3	28.5	
16	42.6	200.27	14.6	28.7	
17	46.9	200.60	14.7	28.6	Normal
18	50.1	203.80	14.3	28.6	
19	44.7	200.87	13.8	28.5	
20	45.6	199.89	14.2	28.1	
21	45.5	204.49	14.2	27.5	
22	48.1	206.24	14.7	27.9	
23	45.8	198.72	14.9	27.2	
24	45.9	197.24	15.6	26.5	
25	40.3	200.77	16.4	28.7	Damage TEST

Therefore, the degree of external damage is the most critical for safe battery operation, and a process of minimizing damage to battery use is essential. In particular, in the case of electric vehicles, it seems necessary to add methods to reduce battery damage due to accidental collisions and flooding.

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