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An analysis of electrical characterization on LTO batteries based on electrochemical method

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ABSTRACT

In this paper, electrical and electrochemical analysis are derived through an electrochemical method. Detailed analyses of the characteristics of the LTO($Li_4Ti_5O_{12}$) battery is detailed through various electrochemical and electrical analysis methods. By default, study the LTO($Li_4Ti_5O_{12}$) battery using a method such as EIS (electrochemical impedance spectroscopy), CV(cyclic voltammetry), GITT(galvanostatic intermittent titration technique), PITT(potentiostatic intermittent titration technique), etc. Here, detailed analyses of electrical characteristics and subsequent changes in the electrochemical changes are analyzed. Based on the preceding parameters of the characteristics of the LTO($Li_4Ti_5O_{12}$) battery, the calibration can be performed on the SOC(state-of-charge) and SOH(state-of-health) estimation algorithms.

1. INTRODUCTION

These days, It is recommended to reduce fossil fuels due to environmental degradation caused by indiscriminate use of fossil fuels. Therefore, interest and research on renewable energy are actively being carried out. Among renewable energy sources, lithium-ion batteries are used in many applications. Representatively, electric vehicle(EV) and hybrid electric vehicle(HEV), satellite, space launch vehicle, energy storage system(ESS), tram as shown in Fig. 1.

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Fig. 1 Application of high power Li-ion cells

The lithium-ion battery can monitor and control the capacity information and internal status of the battery such as state-of-charge(SOC) and state-of-health(SOH) through the battery management system(BMS). The accuracy of off-line parameters is important to improve BMS. Electrical, electrochemical, and mechanical processes must be performed for the complete analysis of the battery. This paper, The 18650 LTO($Li_4Ti_5O_{12}$) battery is analyzed through one of the electrochemical methods.

Generally, the battery is divided to the cathode material. But this experiment use LTO instead of graphite in the anode material. LTO batteries have a wide range of temperature, rapid charging, stability, long life and high output characteristics in lithium ion battery series.

2. Electrochemical method

Fig. 2 Elctrochemical and electrical set for test of Li-ion cells

Electrochemical methods include cyclic voltammetry(CV), electrochemical impedance spectroscopy(EIS), galvanostatic intermittent titration technique(GITT), potentiostatic intermittent titration technique(PITT). In this paper, LTO($Li_4Ti_5O_{12}$) battery characteristics are analyzed using EIS and GITT methods. The LTO battery used in the experiment is a battery manufactured by YJpower.

2.1 EIS(Electrochemical Impedance Spectroscopy)

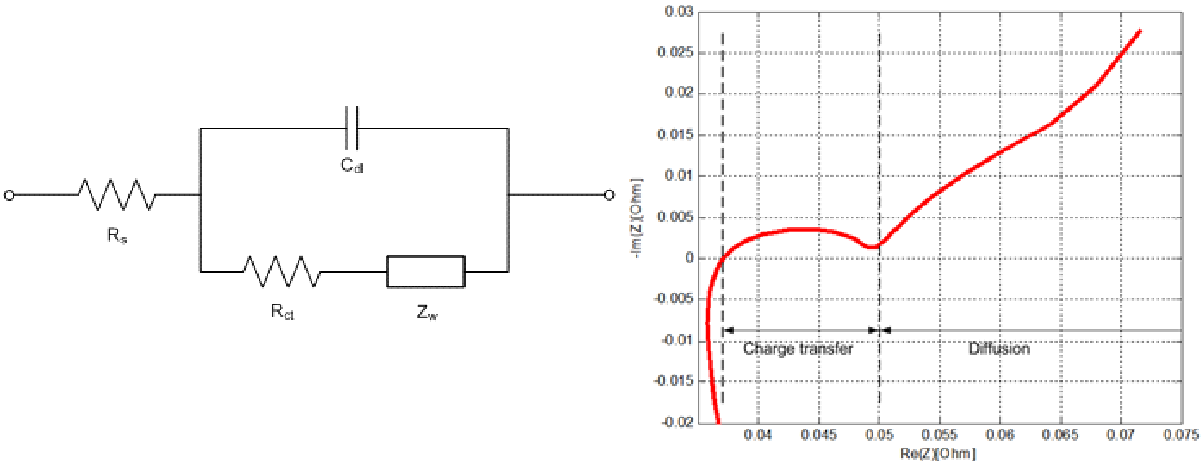

Fig. 3 Equivalent circuit based on Randles model

After measuring the 18650 LTO battery discharged capacity(1213.5mAh), measure the internal impedance of the battery using electrochemical impedance spectroscopy(EIS) equipment. In this experiment, we can see the internal impedance of the battery in the frequency range from high frequency to low frequency(1kHz~1mHz). Nyquist curves from EIS are represented in the battery by electrochemical modeling shown in Fig. 3. R_{ct} is the charge transfer resistance, which is the voltage drop component generate on the surface of the electrode. It can be represented by Butler-Volmer equation as shown in Eq. (1). C_{dl} is the double layer capacitance, instead of constant phase element(CPE) commonly used in batteries.

Although EIS takes a long time, but I focused on the superiority of estimation ability.

$$i = i_0(\exp(\alpha \frac{nF}{RT}\eta) - \exp(-(1-\alpha \frac{nF}{RT}\eta)) \quad (1)$$

$$R_{ct} = \frac{RT}{nFi_0}$$

After discharging for 6 minutes at a current of 1C-rate, the battery internal impedance was measured in a stabilized state with sufficient rest. SOC was measured from 90% to 10% as shown in Fig. 4. Because the impedance of the line can not be ignored during the experiment, the accuracy of the impedance data is improved by removing the line impedance from the battery impedance. The part touching the real axis represents the series resistance part with R_s and the semicircle end point is R_{ct}. The sum of R_s and R_{ct} represents the internal resistance of the battery. The lower the SOC, the increase the internal impedance as shown in Table. 1.

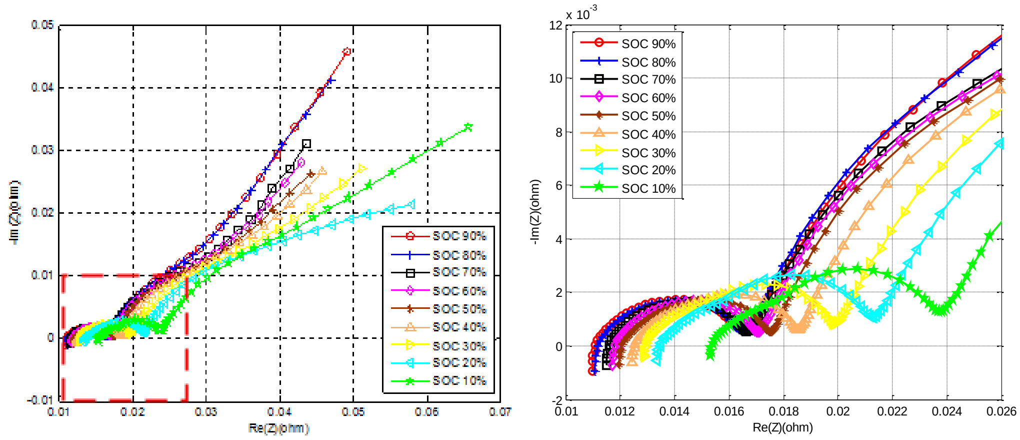

Fig. 4 Nyquist curves for LTO battery

SOC[%]	90	80	70	60	50	40	30	20	10
$R_s[\Omega]$	0.0111	0.1117	0.1162	0.1182	0.0121	0.0126	0.013	0.0114	0.0154
$R_s + R_{ct}[\Omega]$	0.0165	0.0165	0.0166	0.0171	0.0175	0.0185	0.0199	0.0213	0.0237

Table. 1 LTO battery internal impedance for each SOC

2.2 GITT(Galvanostatic Intermittent Titration Technique)

The GITT method is one of the most precise methods because it can measure the current and time most accurately. In addition, the GITT method is useful for finding thermodynamic and kinetic parameters. Thermodynamic and diffusion coefficient information can be obtained through this method. The method of obtaining the diffusion coefficient can be found from Eq. (2). n_m is mol, V_m is the molar volume of the electrode, S is the contact area between the electrode and the electrolyte. ΔE_s is voltage change in steady state, ΔE_t is voltage change during pulse.

$$D = \frac{4}{\pi\tau}\left(\frac{n_m V_m}{S^2}\right)^2\left(\frac{\Delta E_s}{\Delta E_t}\right)^2 \qquad (2)$$

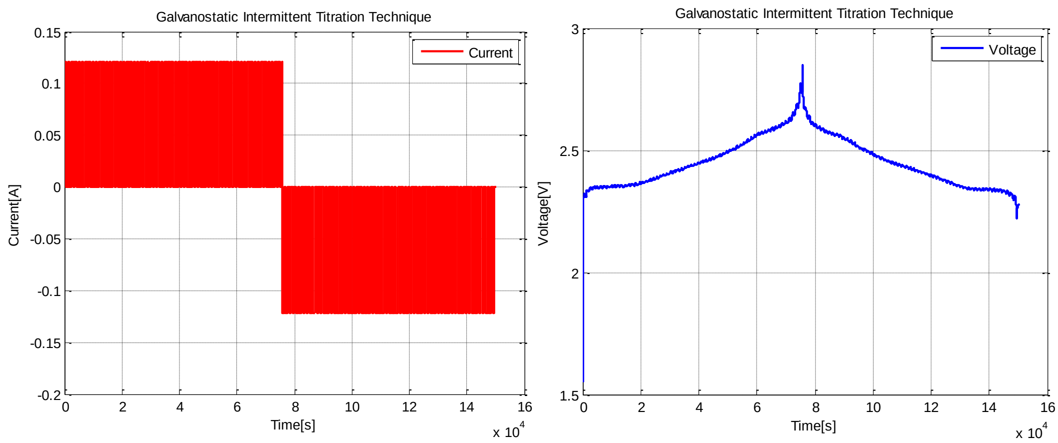

Fig. 5 GITT method profile current and voltage

In the case of the GITT method, the charge and discharge segments were combined into one cycle. In this experiment, the current was controlled at 100 mA. It is charged with pulse current of 10 minutes and fully charged up to 2.85V of charging voltage, and then discharged with a pulse current of 10 minutes interval to fully discharge to 1.5V of cut-off voltage as shown Fig. 5.

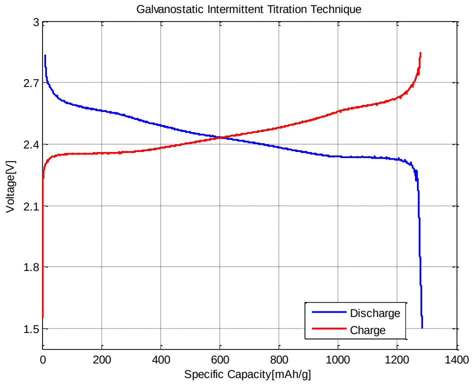

Fig. 6 Voltage versus differential capacity of LTO battery

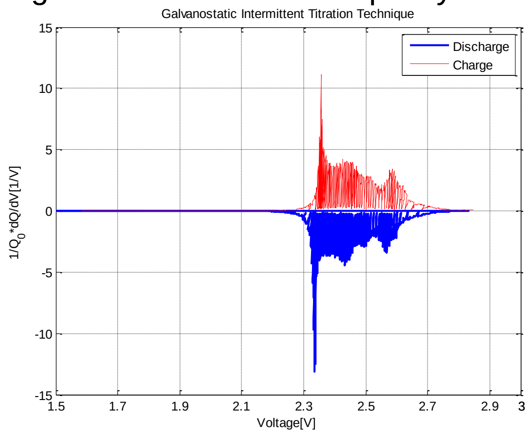

Fig. 7 Specific capacity versus voltage of LTO battery

The specific capacity versus voltage indicates the aging of the LTO battery Fig. 6. It can be seen that the differential capacity is high near the nominal voltage range of 2.4V shown Fig. 7.

3. CONCLUSIONS

In this paper, the internal characteristics of the LTO($Li_4Ti_5O_{12}$) battery were evalu -ated using the electrochemical methods of electrochemical impedance spectroscopy (EIS) and galvanostatic intermittent titration technique(GITT). The resistance parameters were separated by 10% state-of-charge(SOC) using the EIS method and the internal differential capacity according to the battery voltage was obtained through the GITT method. It is expected that the accuracy of the estimation performance will be improved by substituting the battery parameters from the electrochemical method into the SOC and SOH estimation algorithms.

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REFERENCE

Jung-Eui Hong, Rye-Gyeong Oh, and Kwang-Sun Ryu. (2015), “$Li_4Ti_5O_{12}/Co_3O_4$ Composite for Improved Performance in Lithium-Ion Batteries”, Journal of the Electrochemical Society 162: A1978-A1983.

Tsuyoshi Sasaki, Yoshio Ukyo, Petr Novák. (2013), “Memory effect in a lithium-ion battery”, Nature Materials 12, 569–575 doi:10.1038/nmat3623

April.Möller, Alexander. (2014),"Study of the mechanism of lithium insertion and depletion in lithium iron phosphate thin films."

Zhu, Yujie, and Chunsheng Wang. (2010),"Galvanostatic intermittent titration technique for phase-transformation electrodes." The Journal of Physical Chemistry C 114.6 2830-2841.