Application Note AN-BAT-003

リチウムイオン電池におけるガルバノスタティック間欠滴定法(GITT)

ガルバノスタティック間欠滴定法(GITT)は、電池材料の反応速度論および熱力学的特性を評価するために広く用いられている、強力な電気化学的手法です。

GITT は、リチウムイオン(Li-ion)電池に対して主に以下の3つの用途があります。すなわち、拡散係数の算出、開回路電圧(OCV)の解析、および 過電圧/内部抵抗の解析です。本手法により、実際の動作条件下における材料の電気化学的挙動に関する有用な知見が得られるため、電池の開発および最適化に携わる研究者や技術者にとって不可欠なツールとなっています。

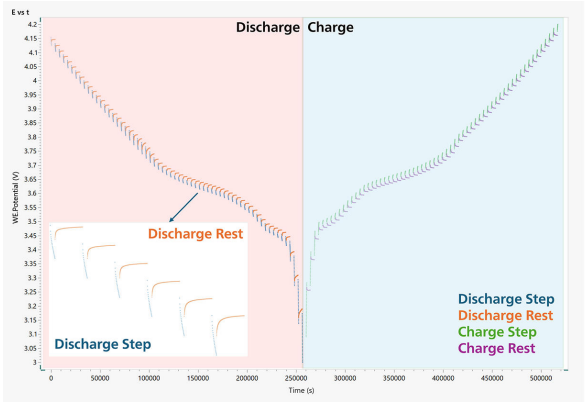
この技術資料では、エネルギー貯蔵分野における GITT の原理、測定手順、および応用について概説します。続く章では、測定方法およびデータ解析について説明し、さらに INTELLO と、その電池用途向けに最適化された強力なコマンド群を紹介します。

GITT C GITT

C C/10 C/20 5~30
1~2 10

1 GITT 2121**()()**

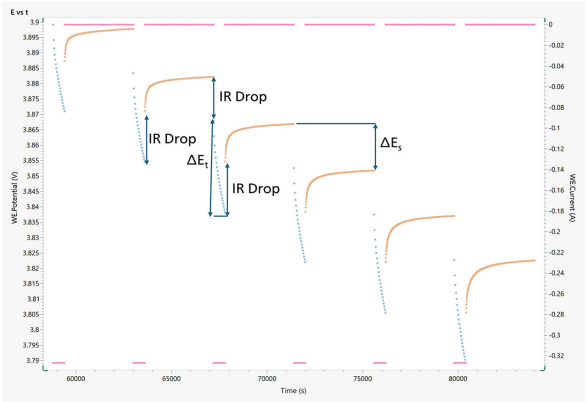
GITT 1 (E)



1. 10 60 GITT

iR R Ru RCT
() *iR* (*dE/dt 0*)(OCP)

25*iR Et*() *Es* GITT



2. 5iR

GITT ()[1–3]

$$D = \frac{4}{\pi}\left(\frac{iV_m}{z_A FS}\right)^2 \left[\left(dE/d\delta\right) \Big/ \left(dE/d\sqrt{t}\right)\right]^2$$

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i(A)*Vm*(cm3/mol)*za F* (96485 C/mol)*S*(cm2)*dE/d* (:C/20)(:10)*dE/dt*
dE/dt 1

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

(s)*nm*(mol)*Vm*(cm3/mol)*S*(cm2)*Es*(V)()*Et*(V)(*iR*) (SOC)

Open Circuit Potential, OCP

GITT (SOC) OCP [1] OCP ()

$$V(x) = \frac{\mu_{Li}^{Cathode}(x) - \mu_{Li}^{Anode}(x)}{e}$$

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x e SOC

OCP (*E*meas)(*E*e)[1]

$$\eta = \left| E_{meas} - E_{eq} \right|$$

SOC OCP

$$Internal\ Resistance\ (\Omega) = \frac{\eta}{i_{applied}}$$

1.

		/ mAh
1	2	3270
2	3	4150

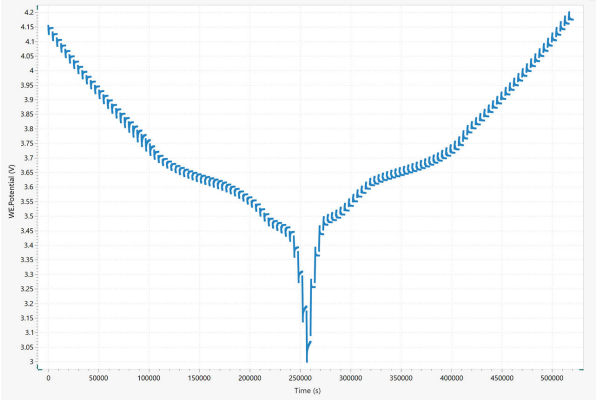
GITT INTELLO VIONIC 2INTELLO GITT 2 INTELLO Autolab NOVA
C ()**–(S2)** WE.potential

2.

	C-rate	Pulse duration / min	Rest duration /min
1	C/10	10	60
2	C/10	10	10

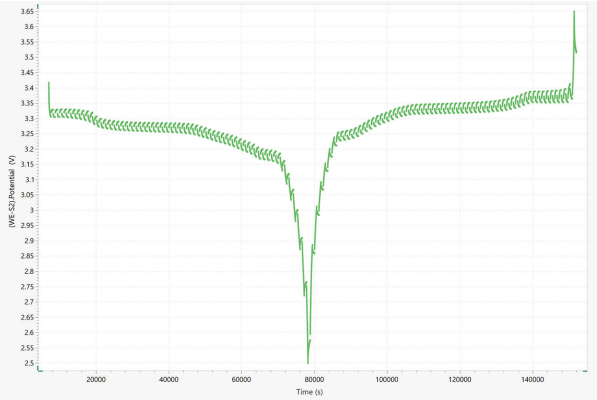
GITT 0.5C 1 4.2 V 3.0 V 4.2 V 23.65 V 2.5 V 3.65 V

1() GITT 3OCP SOC



3. 3270 mAh 1 GITT

2 GITT 4INTELLO WE.potentialS2.potentialWE-S2.potential 3WE+S CE+S2 RE WE.potential(S–R) S2.potential(S2–R) S2.potential WE.potential WE-S2 GITT WE-S2 (t) WE-RE S2-RE



4. 4150 mAh 2 GITT

1. Kim, J.; Park, S.; Hwang, S.; et al. Principles and Applications of Galvanostatic Intermittent Titration Technique for Lithium-Ion Batteries. *J. Electrochem. Sci. Technol* **2021**, *13* (1), 19–31. DOI:10.33961/jecst.2021.00836
2. Shen, Z.; Cao, L.; Rahn, C. D.; et al. Least Squares Galvanostatic Intermittent Titration Technique (LS-GITT) for Accurate Solid Phase Diffusivity Measurement. *J. Electrochem. Soc.* **2013**, *160* (10), A1842. DOI:10.1149/2.084310jes
3. Zhu, Y.; Wang, C. Galvanostatic Intermittent Titration Technique for Phase-Transformation Electrodes. *J. Phys. Chem. C* **2010**, *114* (6), 2830–2841. DOI:10.1021/jp9113333

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装置紹介

Autolab PGSTAT302N

This high end, high current potentiostat/galvanostat, with a compliance voltage of 30 V and a bandwidth of 1 MHz, combined with our FRA32M module, is specially designed for electrochemical impedance spectroscopy.The PGSTAT302N is the successor of the popular PGSTAT30. The maximum current is 2 A, the current range can be extended to 20 A with the BOOSTER20A, the current resolution is 30 fA at a current range of 10 nA.

Autolab DuoCoin Cell Holder

The Autolab DuoCoin Cell Holder has 4-point Kelvin gold-plated contacts to assure the highest precision measurements for your battery research. A versatile accessory that can accommodate all standard cells sizes with capacity for smaller and larger non-standard cells and two cells can be processed at one time.Autolab DuoCoin Cell Holder gold plated contacts and gold plated PCB provide protection from corrosion and damage to the accessory in your busy laboratory.Experimental set up is simplified with the Autolab DuoCoin Cell Holder with visible electrode labels and cable connections that correspond to the Autolab potentionstat/galvanostat cable colors. Autolab's attention to detail is reflected in the silicon surface grippers on the bottom of the Autolab DuoCoin Cell Holder to provide stability in a complex experiment set up.

Advanced software for electrochemical research

NOVA is the package designed to control all the Autolab instruments with USB interface.Designed by electrochemists for electrochemists and integrating over two decades of user experience and the latest .NET software technology, NOVA brings more power and more flexibility to your Autolab potentiostat/galvanostat.NOVA offers the following unique features:Powerful and flexible procedure editor; Clear overview of relevant real-time data; Powerful data analysis and plotting tools; Integrated control for external devices like Metrohm Liquid Handling devices; Download the latest version of NOVA

Autolab PGSTAT204

The PGSTAT204 combines the small footprint with a modular design. The instrument includes a base potentiostat/galvanostat with a compliance voltage of 20 V and a maximum current of 400 mA or 10 A in combination with the BOOSTER10A. The potentiostat can be expanded at any time with one additional module, for example the FRA32M electrochemical impedance spectroscopy (EIS) module.The PGSTAT204 is an affordable instrument which can be located anywhere in the lab. Analog and digital inputs/outputs are available to control Autolab accessories and external devices are available. The PGSTAT204 includes a built-in analog integrator. In combination with the powerful NOVA software it can be used for most of the standard electrochemical techniques.