Ac impedance analysis on commercial Li ion battery

Toshiyuki Momma[a)], Kenji Tsuchiya[b)],
Tetsuya Osaka[a, b)]

a)Kagami Memorial Laboratory for Materials Science and Technology, Waseda University
b)Department of Applied Chemistry, Waseda University
Shinjuku, Tokyo 169-8555, Japan

In recent years, investigation on the mechanism of loosing energy density of the battery during the charging-discharging is required. The ac impedance spectroscopy is known as one of the effective methods to get the information of the electrochemical systems without destroying the system. Up to now, the enough understanding for the analysis of the impedance spectra of Li ion batteries is not achieved. In the present study, we designed the equivalent circuit to analyze the commercial Li ion battery and applied to analyze the ac impedance spectra of the commercial lithium ion battery to understand the change of inner conditions during the charging and discharging cycling.

The equivalent circuit was designed with considering 1) inner structure of battery, 2) two electrochemical systems for both of cathode and anode, and 3) un-homogeneity of diffusion condition in electrode. Commercial prismatic Li ion battery has a structure of wound sheet of electrodes, separators and current collectors inside the battery case. This structure causes inductive response[1)]. Complicated electrochemical reactions of cathode and anode respond as superimposed multi-semicircles. Non uniform diffusion due to the distribution of particle size in the active material are taking account to the design of equivalent circuit. With these considerations, the equivalent circuit was designed as shown in Fig. 1.

Figure 2 shows the impedance spectrum obtained for prismatic Li ion battery(Panasonic CGP34506, 85m mAh). Also the calculated curve with the curve fitting of each parameter of the equivalent circuit was shown in the same figure. The calculated curve shows well-agreement with the loci obtained by the impedance spectroscopy. This fact suggests that the proposed equivalent circuit would be the suitable one to analyze commercial prismatic Li ion batteries.

With analyzing a series of impedance spectra of the battery obtained with varying the charged state and, each component in the equivalent circuit was assigned to the reaction of electrodes. The tracking of each parameter of the fully charged battery during consequent charge-discharge cycles of charge-discharge revealed the change both of the electrode capacity and of the contribution of each resistance in inner resistance of whole battery as shown in Fig. 3 and Fig. 4.

From the analysis, the fading mechanism of battery capacity during the charge-discharge cycle was indicated.

Reference
[1] F.C.Laman, M.W.Matsen, J.A.R.Stiles, *J.Electrochem. Soc.*, **133**, 2441 (1986).

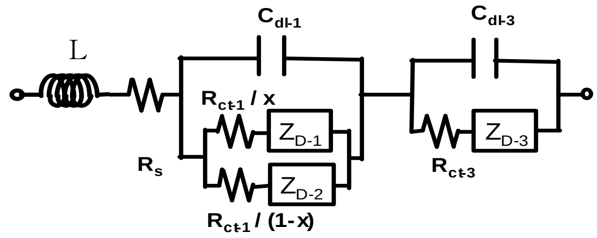

Fig. 1 Equivalent circuit for analysis.
L: Inductance component
R_s: Resistance of electrolyte
R_{ct-1},R_{ct-3}: Charge transfer resistance
C_{dl-1} , C_{dl-3}:Electric Double Layer capacitance
Z_{D-1}, Z_{D-2} , Z_{D-3} :Diffusion impedance

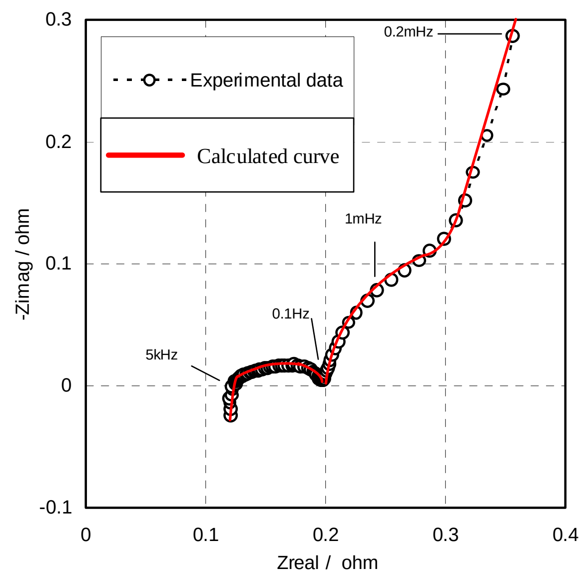

Fig. 2 Ac impedance spectrum of Li ion battery and fitting curve calculated by the equivalent circuit.

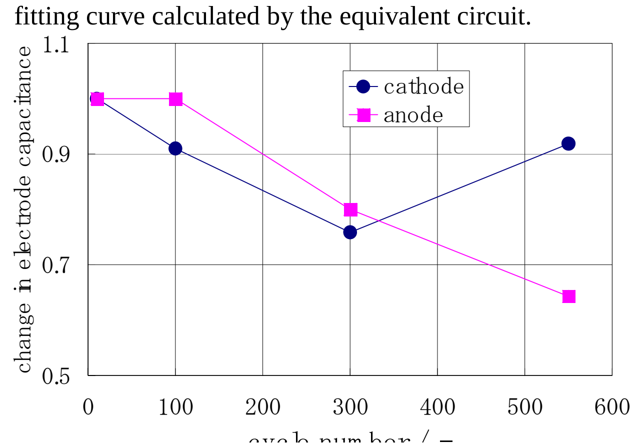

Fig. 3 Calculated electrode capacitance of the Li ion battery during charge-discharge cycle.

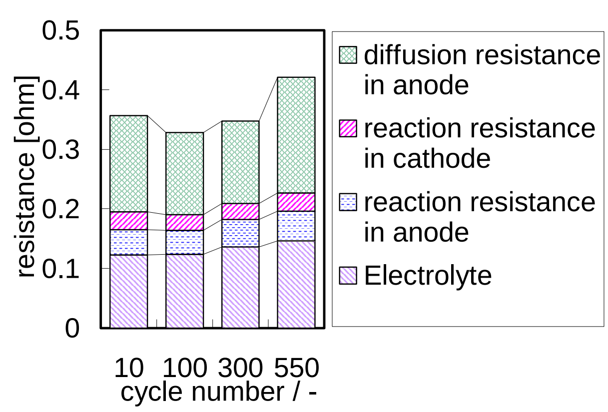

Fig. 4 Estimated components of inner resistance of the Li ion battery during charge-discharge cycle.