The Thermal Impedance Spectroscopy on Li-Ion Batteries Using Heat-Pulse Response Analysis

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ABSTRACT

Novel characterization of thermal properties of a battery has been introduced by defining its frequency-dependent thermal impedance function. Such approach was employed before in different areas [1 - 3]. Thermal impedance function can be approximated as a thermal impedance spectrum by analyzing experimental temperature transient, which is related to the thermal impedance function through Laplace transformation.

In order to obtain temperature transient, a process has been devised to generate external heat pulse with heating wire and to measure the response of battery. This process is used to study several commercial Li-ion batteries of cylindrical type. The thermal impedance measurements have been performed using potentionstat/galvanostate controlled by digital signal processor, which is more commonly available than flow-meter conventionally applied for thermal property measurements. Thermal impedance spectrum of Panasonic battery is shown in Fig. 1.

Thermal impedance spectra obtained for batteries made by different manufactures are found to differ considerably, as can be seen in Fig.2. Comparison of spectra at different states of charge indicates independence of thermal impedance on charging state of battery. It is shown that thermal impedance spectrum can be used to obtain simultaneously thermal capacity and thermal conductivity of battery by non-linear complex least-square fit of the spectrum to thermal-impedance model.

Obtained data in combination with electrochemical impedance data were used to create non-linear equivalent circuit representing electrochemical-thermal model of battery, usable for simulation of voltage and temperature profiles at arbitrary load. This approach is an extension of our previous model, which was not considering thermal components [4]. In simulation of battery discharge we found that temperature inside the battery is by one-third larger that on its surface, as can be seen in Fig.3. This observation has to be considered to prevent damage by overheating.

Comparison of calculated voltage and temperature profiles with experimental ones indicate good capabilities of used model to predict electric and thermal battery performance.

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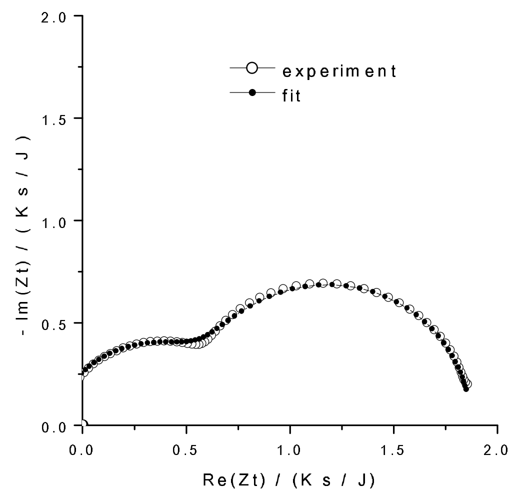

Fig.1 *Thermal impedance spectrum of the Panasonic 18650-size Li-ion of battery in fully charged state, measured between 0.1Hz and 100µHz.*

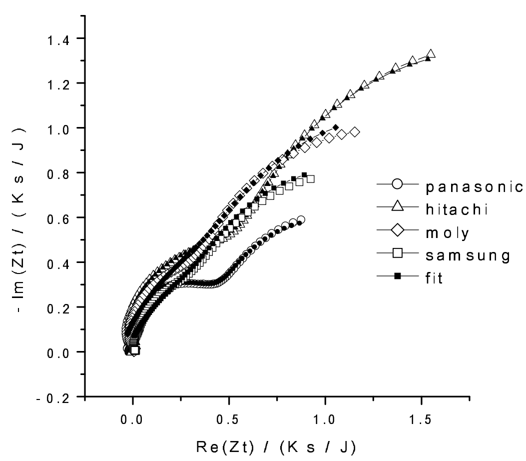

Fig.2 *Comparison of thermal impedance spectra of Panasonic, Moly Energy, Hitachi, and Samsung 18650-size Li-ion batteries measured between 0.1Hz and 1mHz.*

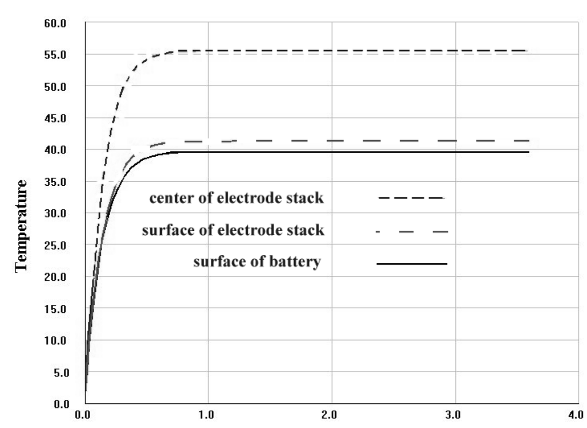

Fig.3 *Temperature response of Panasonic Li-ion battery to 20W internal heating pulse under circulation cooling conditions.*