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Application News

Microfocus X-Ray CT System inspeXio™ SMX™-225CT FPD HR Plus

Analysis of the Cylindrical Lithium-Ion Battery by X- Ray CT System and Introduction to the Charge/Discharge Device Attached System

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User Benefits

- Microfocus X-ray CT system enables the observation of internal structure in lithium-ion batteries.
- The distance between the electrodes can be measured, and the junction of the positive/negative terminal leads can be observed.
- The charge/discharge device attached system*1 enables changes in the internal structure of the battery to be observed after charging and discharging.

■ Introduction

Lithium-ion batteries (LIB) are secondary batteries in which Li ions move between the cathode and anode to charge/discharge, and are classified into three types, cylindrical, square, and laminated, depending on the shape of the cell. Especially, the cylindrical LIB is widely used in mobile batteries, notebook computers, etc. because of its low manufacturing cost and high energy density. In recent years development for electric vehicles has been remarkable, and research and development is progressing in pursuit of higher performance such as higher output and large capacity.

On the other hand, LIBs may have manufacturing defects such as short circuits due to foreign matter mixed in the electrodes and unwinding, and such defects may result in combustion and explosion accidents. Therefore setting the manufacturing conditions for development prototypes and their inspection are important. The X-ray CT system (Fig. 1) is an effective tool for analyzing the inside of batteries non-destructively.

This article introduces analyses of a cylindrical LIB using an X-ray CT system and the charge/discharge device attached system.

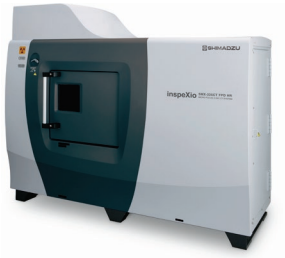

Fig. 1 Microfocus X-Ray CT System inspeXio™ SMX™-225CT FPD HR Plus

■ Fluoroscopy of the Cylindrical LIB

Fig. 2 shows a fluoroscopic image of a 21700*2 type LIB cell. The contrast in a fluoroscopic image is determined by the relative difference of X-ray absorption of the materials. Fluoroscopy is used for simple inspection because it can be observed in short time. As shown in Fig. 3, electrodes are composed of cathodes, anodes, and separators, which are arranged alternately.

Fig. 2 Fluoroscopic Image of the Positive Terminal in a 21700 Type LIB Cell

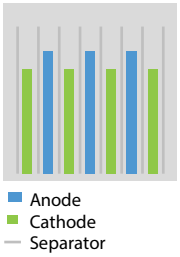

Fig. 3 Schematic Diagram of the Electrode Structure in a LIB

■ X-Ray CT Scan of a Cylindrical LIB

The X-ray CT scan is effective when more detailed observation/analysis is required. Fig. 4 shows a cross-sectional image of the 21700 type LIB cell, and Fig. 5 shows its three-dimensional image.

In the cross-sectional image, cathodes and anodes and the current collector tab, which are overlapped in fluoroscopic images, are clearly distinguished. In addition, a three-dimensional image can be displayed by stacking cross-sectional images, and the internal structure is observed by partially cutting or selectively displaying only specific materials.

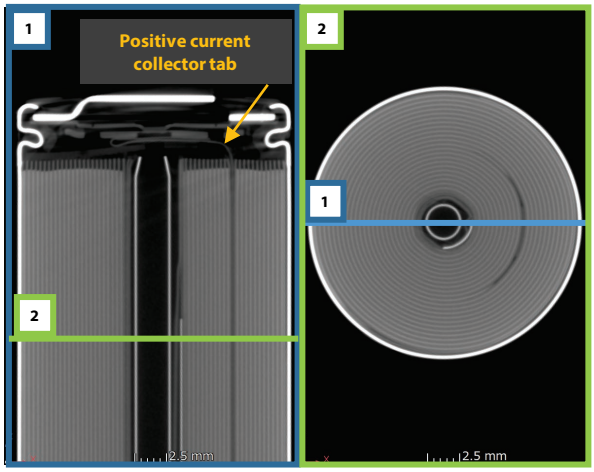

Fig. 4 Cross-Sectional Image of the 21700 LIB Cell

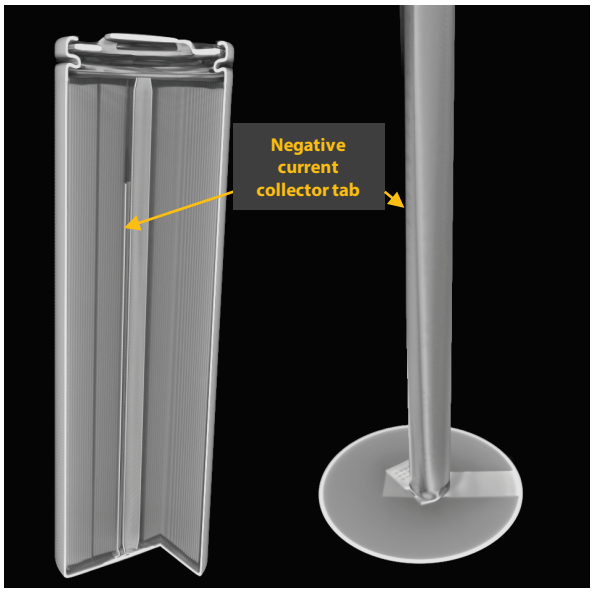

Fig. 5 Three-Dimensional Image of the 21700 LIB Cell

*1 The charging/discharging device must be provided by the customer.
*2 Battery model diameter : 21 mm, full length : 70 mm

Fig. 6 shows an image of the unrolled cylinder cross-sectional image of the 21700 type LIB cell. The unrolling position is indicated by the purple line in Fig. 6-A, and the unrolled cylinder cross-sectional image is shown in Fig. 6-B. Here, the current collector tab is shown, and by enlarging it the structure of its joint can be observed. In addition to vertical and horizontal cross-section observation, observation along a cylindrical surface is also possible, so, the electrodes can be observed as they were before they were rolled.

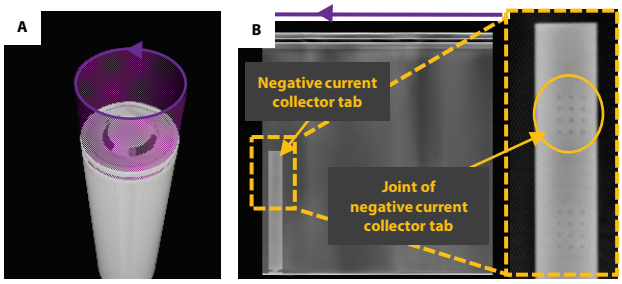

Fig. 6 Unrolled Cylinder Cross-Sectional Image of the 21700 LIB Cell
-A Indicates unrolling position -B Unrolled cross-sectional image

■ Distance Measurement between Electrodes

Fig. 7 and Table 1 show the results of distance measurement between electrodes. In addition to measuring lengths on the cross-sectional image, the pitch of the cathode and anode are also measured from the line profile of the gray value as shown in Fig. 8.

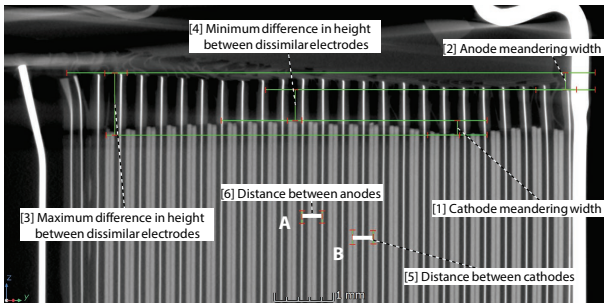

Fig. 7 Result of the Distance Measurement between Electrodes

Table 1 Result of the Height and Width Measurement between Electrodes

Measurement points	Result (mm)
[1] Cathode meandering width	0.248
[2] Anode meandering width	0.293
[3] Maximum difference in height between dissimilar electrodes	1.067
[4] Minimum difference in height between dissimilar electrodes	0.532
[5] Distance between cathodes	0.356
[6] Distance between anodes	0.348

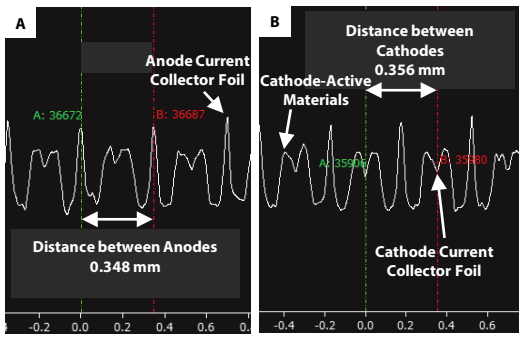

Fig. 8 Result of Distance Measurement with Line Profile of Gray-Value
-A Line profile of line A –B Line profile of line B

■ Charge/Discharge Device Attached System

It is known that the electrodes expand and contract during charging and discharging of LIBs, and the battery deteriorates due to volume changes and chemical changes. In deterioration evaluation and development for longevity, there is an increasing need to observe the internal structure of the battery when charging and discharging are repeated.

This system enables CT scanning while charging and discharging the lithium-ion battery inside the device*3 (Fig. 9). It can be connected to a charge/discharge device prepared by the customer.

*3 The main specifications of the X-ray CT are the same as those of the standard inspeXio SMX-225CT FPD HR Plus.

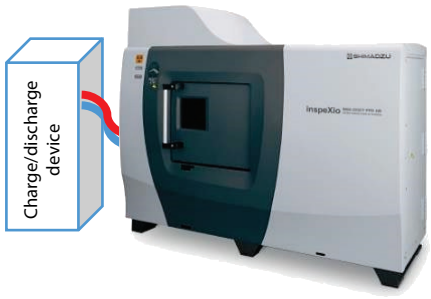

Fig. 9 inspeXio™ SMX™-225CT FPD HR Plus
with Charge/Discharge Attached System (Illustration)

Fig. 10 shows a cross-sectional image of a 18650 type LIB cell before and after the charge/discharge test. In this cross-sectional image after the test, deformation of the electrodes can be seen in the part indicated by the red frame. Even if the battery has no problem in appearance, the internal electrodes may be deformed. It is possible to observe the inside non-destructively by using the X-ray CT system.

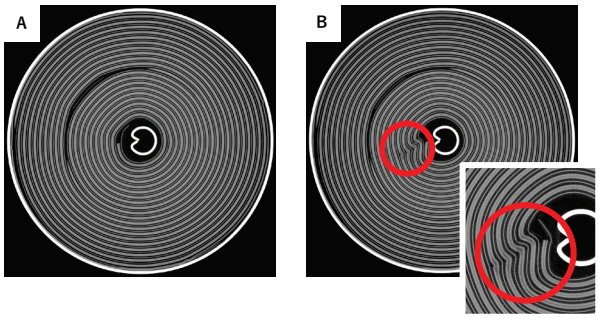

Fig. 10 Cross-Sectional Image of a 18650 Type LIB Cell
-A before charge/discharge -B after charge/discharge

■ Conclusion

This article introduces analyses of a cylindrical LIB using an X-ray CT system and a charge/discharge device attached system. X-ray fluoroscopy is suitable for simple observation and inspection in a short time, but X-ray CT is effective for more detailed observation and analyses. By using the X-ray CT system, it is possible to measure the distance between electrodes and observe the joint of current collector tab. In addition, by using the custom product charge/discharge device attached system, deformation of electrodes can be observed in-situ.

In this way, the CT system can be used in situations such as setting manufacturing conditions for development prototypes and sampling inspection of manufactured products.

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