LAAN-A-AG-E001

SHIMADZU

Application News

Material Testing System No.i229

Multi-Faceted Approach for Evaluating Lithium-Ion Battery Separators

Lithium-ion secondary batteries (in this report, simply referred to as "lithium-ion batteries") are widely used as power sources in cell phones, information devices and other small electronic devices because of their high energy density and high cell voltage. In recent years, the development of hybrid vehicles and electric vehicles has been proceeding at an accelerated rate, fueled by a heightening awareness for environmental conservation. Lithium-ion batteries are vital for their power systems, too. Moreover, a demand has emerged for large-capacity secondary batteries as a flexible response to the demand for power even in the field of natural energy usage (solar cells and wind power generation).

On the other hand, however, short-circuiting, overcharging, physical impact, and other factors sometimes cause lithium-ion batteries to become unstable. So, various evaluations and measures for ensuring safety are being performed also at battery component level.

This Application News introduces some attempts as examples of physical evaluation of separators, one of the component parts of lithium-ion batteries whose increased application is anticipated for the above reasons. Separators perform a dual role of preventing short-circuiting between the plus and minus electrodes and allowing lithium-ions to pass through smoothly. They also have a function for shutting off current when heat is generated, for example, by short-circuiting of the battery. Currently, polyolefin (PE) micro-porous film is generally used as the separator film. PE has a shutdown mechanism that functions when the battery heats up, whereby the porous structure closes near the melting point of the material to prevent ions from passing through.

■ Specimens

The specimens used for this evaluation were three separators (specimens A to C) removed from lithium-ion batteries (commercially available batteries were obtained, with Fig. 1 showing an internal observation image of a general battery product taken by X-ray CT) used in small electronic devices. All of these specimens use polyolefin as their main material. Furthermore, a general polyolefin film (simply called "specimen PE" from here on) also was evaluated for comparison.

Table 1 summarizes a list of these specimens.

Table 1 Specimens

Specimen	Lithium Battery Separator			General-Purpose Polyolefin Film
Specimen Name	A	B	C	PE
Thickness (µm)	20	20	10	13

By way of reference for internal structure, Fig. 1 shows an X-ray CT image of a typical lithium-ion cell for a small electronic device (a commercially available battery for a cell phone was obtained). A structure immersed in electrolyte with electrodes (plus and minus) separated by a separator wound around it can be seen. (The Shimadzu industrial X-ray CT system inspeXio SMX-225CT was used as the observation instrument.)

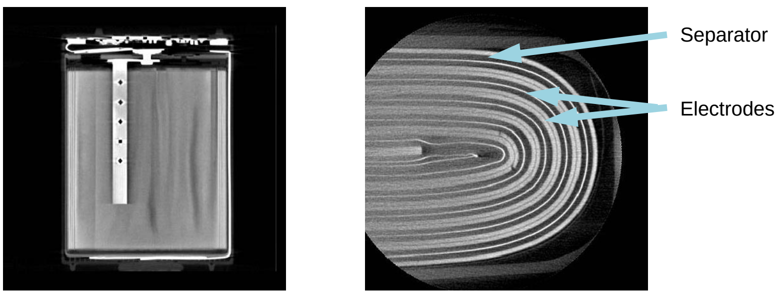


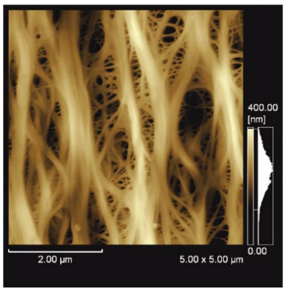
Fig. 1 Observed CT Image of Lithium Battery by X-Rays

■ Test Results

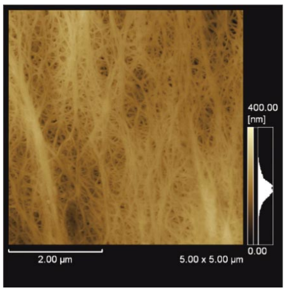
Here, observation of the surface by a probe microscope, measurement of pores by a mercury porosimeter and physical strength testing (i.e. tensile testing) were conducted to evaluate the physical properties of specimens.

(1) Surface observation by probe microscope

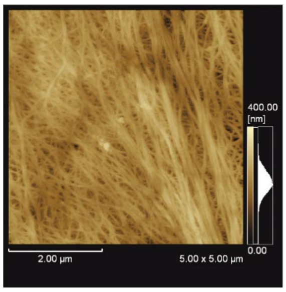
Fig. 2 shows surface observation images of separator specimens A to C and general-purpose polyolefin film specimen (PE) taken by the Shimadzu scanning probe microscope SPM-9600. In each of these images, the vertical direction corresponds to the longitudinal direction of the separator.
With each of the separator specimens, a characteristic multi-pore structure is observed. When looked at more closely, the pore diameter of specimen A apparently seems larger than that of specimens B and C, and a difference in the shape of the pores also can be seen when specimens B and C are compared. Whereas, with the general-purpose film specimen PE, pores such as those in separators are not apparent.



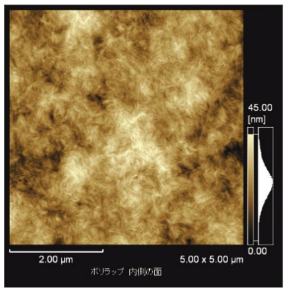
Specimen A



Specimen B



Specimen C



Specimen PE

Fig. 2 Surface Observation by Scanning Probe Microscope

(2) Measurement of pore size distribution by mercury porosimeter

Next, the pore size distribution in the separators observed in (1) was measured by the mercury porosimeter Auto Pore 9520 from Micromeritics Instrument Corporation (overview shown in Fig. 3) as a method for quantitatively evaluating the size of the pores. This instrument evaluates the pore size distribution of target specimens by mercury intrusion method. The results of measurement are shown in Fig. 4 and Table 2. According to these, it can be seen that the median diameter of the specimen pores is specimen A > specimen B > specimen C, which this matches the results obtained by microscope observation in (1). Also, the pore volume, which was measured at the same, of specimen B is characteristically larger than that of the other specimens. On the other hand, almost no pores were seen on the general-purpose film (specimen PE).

Fig. 3 Overview of Mercury Porosimeter

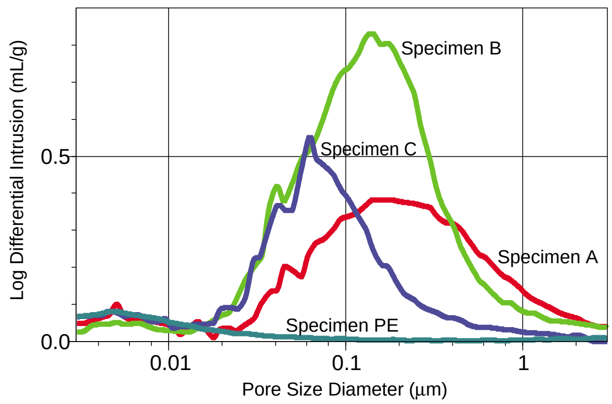


Fig. 4 Pore Size Distribution Measurement Results of Film Specimens

Table 2 Pore Size Distribution Measurement Results

Specimen	Lithium Battery Separator			General-Purpose Polyolefin Film
Specimen Name	A	B	C	PE
Pore Volume (ml/g)	0.50	0.80	0.41	0.07
Median Dia. (µm)	0.18	0.13	0.07	–

(3) Measurement of mechanical properties by precision universal testing machine

The separator in a lithium battery is in contact with the surface of the electrode, and is exposed to various mechanical and thermal fluctuations. Accordingly, evaluation of the mechanical properties (strength, etc.) of the separator is important in improving the reliability of the lithium-ion battery.
For this reason, the mechanical strength of the separator was evaluated by tensile test. For the tensile test, the Shimadzu precision universal testing machine Autograph AG-50NX and video type non-contact extensometer were used, and testing was performed up to breaking by crosshead speed of 50 mm/min. Since the video type non-contact extensometer does not contact the specimen and two cameras are used, measurement of minute elongation can be performed in the elastic region and elongation up to breaking can be measured continuously in subsequent regions. (Fig. 5 shows specimen and extensometer.)

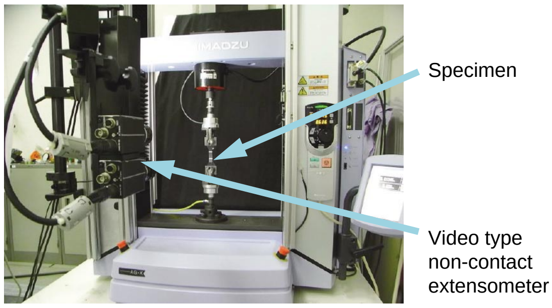


Fig. 5 Specimen and Extensometer

Fig. 6 shows the results of the tensile test as a relationship between stress (value obtained by dividing test force by the cross-sectional area of the specimen) and strain (value obtained by dividing elongation by gauge length. Table 3 summarizes the elastic modulus, tensile strength (maximum stress) and break point strain calculated from this data.

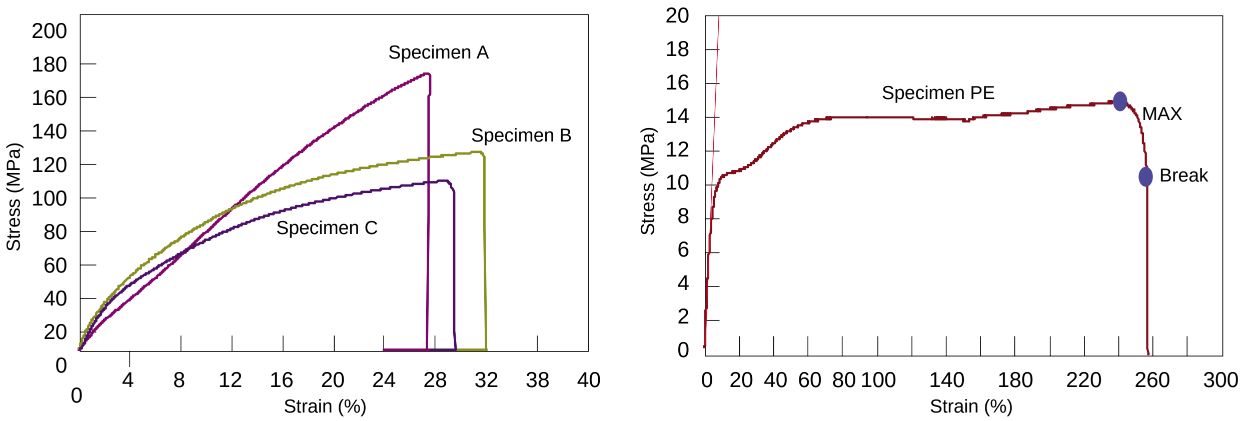


Fig. 6 Tensile Test Results

Table 3 Tensile Test Results

Specimen	Lithium Battery Separator			General-Purpose Polyolefin Film
Specimen Name	A	B	C	PE
Elastic Modulus (MPa)	902	1856	1378	265
Tensile Strength (MPa)	165	118	101	15
Break Point Strain (%)	27.6	31.7	29.1	255

As can be seen from these results, it can be inferred that each of the separators (specimens A to C) have a tensile strength one digit higher than that of general-purpose film (specimen PE), and that stretching and other processing has been performed for improving mechanical strength and controlling pores in their manufacturing processes.

NOTES:
*This Application News has been produced and edited using information that was available when the data was acquired for each article. This Application News is subject to revision without prior notice.

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