Introduction

The lithium-ion battery is widely used as a power supply for portable electronic devices. It is believed that its future applications will be even further expanded to include electric vehicles and large-scale equipment. A fine porous polyolefin film is generally used as the separator in a lithium-ion battery, and serves to isolate the anode and cathode while preventing electrons from flowing directly between the anode and cathode, as well as to allow the electrolyte or ions to pass through. Accordingly, these properties are important with respect to the lithium-ion battery's performance as well as safety. Here we introduce the physical properties test results using both DSC and TMA measurement.

Measurement by DSC

The separators were removed from three different kinds of lithium-ion batteries for cellular phone, and were measured by DSC. An endothermic peak caused by the melting of polyethylene was measured in the region of 100 – 150 °C for all separators. The melting peak temperature becomes higher in the order of \(1 < 2 < 3\). It is believed that the separator contracts at around this temperature, but when the battery generates an abnormal amount of heat, it is obviously preferable from the standpoint of safety that contraction of the separator occurs at a higher, rather than lower temperature. A small peak is observed at around 160 °C in sample 2, which may be caused by the melting of polypropylene at trace levels in this separator. Since the heat of fusion is proportional to the degree of crystallinity, the degree of crystallinity of these separators increases in the order of \(1 < 2 < 3\).
**Measurement by TMA**

The changes in dimension that occurred when heating the separators were measured by TMA. (① and ② correspond to the same samples as those in DSC measurement.) Fig. 2 shows the results of film measured by TMA in elongation mode in the MD direction; 1 g force of tensile load was applied during heating to keep the film straightened. It is clear that each sample begins to contract at around 100 ºC, and exhibits expansion beyond 150 ºC. When separator film begins to melt, it contracts. This corresponds to the fact that when the film stretches during the film forming process, it crystallizes. By comparing the results for samples ① and ②, it is seen that sample contracts at a higher temperature, which agrees with the DSC measurement results.

Fig. 3 shows the results of film measured by TMA in elongation mode in the TD direction. Both samples exhibit contraction, although the amount of contraction is less than that in the MD direction, and sample ① shows less contraction than sample ②. From the standpoint of safety, it is a drawback that ① contracts at a lower temperature. Yet this is offset by the advantage that its amount of contraction in the TD direction is smaller than that of sample ②.

**Measurement by Testing Machine**

We compared the tensile strength of separators ① and ② using the AG-X universal testing machine. Fig. 4 and Fig. 5 show the results of measurement in the MD and TD direction, respectively. The results for the MD direction were ① 175.6 N/mm² and ② 129.5 N/mm², and in the TD direction, ① 36.9 N/mm² and ② 78.2 N/mm². Higher tensile strength is seen for ① in the MD direction, and ② in the TD direction. In the TD direction, sample ① shows higher strain up to the point of breaking and higher elasticity. This, together with the smaller amount of contraction seen during heating in the TMA testing of Fig 3, leads to the expectation that elongation of ① will be smaller in the TD direction during forming of the film than sample ②.