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폴리이미드 박막의 공간전하현상에 관한 연구 동향

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A Research Trend on High Density Polyethylene Electrical Strength

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Abstract - Polyimide is widely used as a high-temperature insulating material. Space charge distributions in polyimide (PI) films strongly depend upon electric field, temperature, water content and so on. We observed space charge distributions in PI films with various water contents. When a dc field was applied to as-received PI films or water-treated PI films, positive and negative homo space charges were observed near the respective electrodes at 333 K. In dried PI films, the homo space charges were much reduced, and positive and negative hetero space charges in the bulk were clearly observed. The space charge amounts in water-treated PI films were smaller than in as-received ones, while the current density in water-treated PI film was larger than that in as-received one by two or more orders of magnitude. These suggest not only that the charge injection from the electrode is enhanced by absorbed water but also that absorbed water makes carriers mobile. The decay of space charge was also faster in water-treated PI than in as-received or dried one. This also supports the enhancement of apparent mobilities of carriers in PI by absorbed water.

1. Introduction

Polyimide (PI) is widely used as a high-temperature insulating material because of its good insulating, mechanical and thermo stable properties. Although the electrical properties of PI were investigated by many researchers, the results were scattered depending upon the experimental conditions such as temperature, sample thickness, electrode materials, humidity, etc [1-4]. Various conduction models such as ionic hopping conduction [1-3], thermally activated injections [l, 3, 4] and thermally assisted tunneling were proposed. The high field properties, however, are not so clear still now. Positive and negative charge carriers are injected from the electrodes, and homo space charges are formed in a PI film. When the applied field was higher than 30 MVm-1, positive and negative hetero space charges were also observed, especially in dried PI. The injections of negative and positive carriers were reduced by removing absorbed water, but the hetero space charges seemed not to be affected by water content. In this paper, we ntroduced the space charge distributions under dc high fields and the effect of water or moisture content.

2. Experimental

The sample was Kapton 500H film with thickness of ca. 125 μm, which were kept in a desiccator more than one week before pretreatment or measurement. We call them as-received PI. Moisture controlled samples were also prepared. A water-treated PI was immersed in water for a week at room temperature and then water on the film surface was removed. A dried PI was kept at 423 K (150℃) for 24 hours and then the current or space charge was measured. The water content was estimated from the change in the weight. The space charge distributions were measured by the pulsed electro-acoustic (PEA) method [10]. The charging and discharging currents were also measured. The electrodes were the grounded Al plate and the semi-conductive (SC) layer connected to a high-voltage dc source. The measurements were carried out under dc fields for 90 minutes and after short-circuiting for 90 minutes at 333 K (60℃). The applied field strengths were 10, 20, 30, 40 and 50 MVm-1.

3. Results and Discussion

Figure 1 shows the field dependences of negative homo space charge for three kinds of PI films. As-received PI films had the largest amounts of homo space charges among the three types of samples. It almost linearly increased with increasing field. The amounts of homo space charge in water-treated or dried PI film seemed to be saturated around 20 MVm-1.

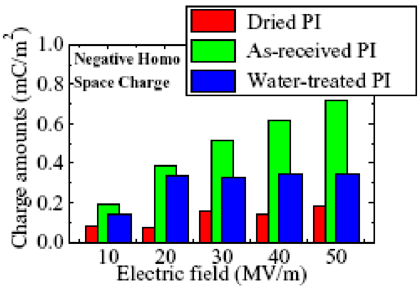

Fig. 1. Field dependence of negative homo space charge at 333 K.

Figure 2 shows charging and discharging current densities of water-treated, as-received and dried PI films at 50 MVm-1 and at 333 K, whose water contents were 3.2, 0.9 and 0 wt.%, respectively. The charging current density of water-treated PI was larger than that of as-received one by two orders or more of magnitude. That of dried PI was about a fourth of as-received one as shown in Fig. 2 (a). Figure 3 shows the current densities with respect to the water content at 90 minutes under 50 MVm-1. This result supports the enhancements of carrier injections and carrier mobilities by absorbed water.

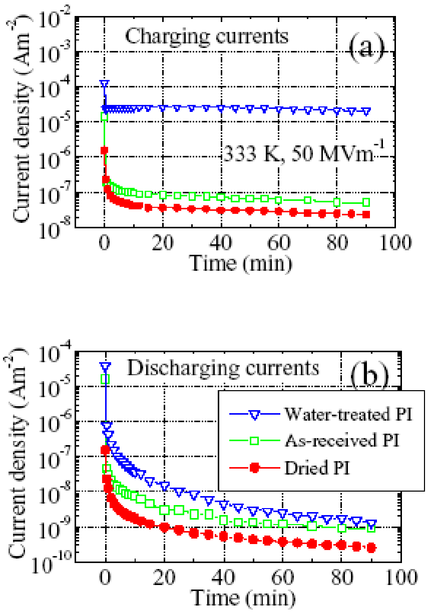

Fig. 2. Transient current densities in PI films with different water contents (a) under 50 MVm-1 and (b) after short-circuiting at 333 K.

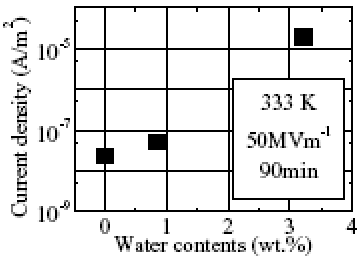

Fig. 3. Current densities with respect to water contents; charging time is 90 minutes, applied filed 50 MVm-1 at 333 K.

4. Conclusion

Space charge distributions and current densities were introduced on PI films with different water contents. Absorbed water largely enhanced current densities. The results of space charge revealed that both charge injection and carrier mobility were enhanced by absorbed water. Homo space charges were the largest in as-received PI films due to balance of charge injection and migration. For further discussions on the effect of absorbed water on carrier injection and transport, the effects of electrode material, temperature and so on should be studied.

Acknowledgement

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