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저밀도 폴리에틸렌을 위한 고전계 파형의 필름 두께의존성에 관한 연구 동향

[1]정 성찬, [1]노 정현, [1]이 주홍, [2]황 종선, [1]최 용성, [1]이 경섭
[1]동신대학교, [2]전남도립 남도대학

A Research Trend on Film Thickness Dependence of Ac High Feld for Low Density Polyethylene

[1]Sung-Chan Jung, [1]Jung-Hyun Rho, [1]Joo-Hong Lee, [2]Jong-Sun Hwang, [1]Yong-Sung Choi, and [1]Kyung-Sup Lee
[1]Dongshin University, [2]Namdo Provincial College

Abstract - Polyethylene is widely used as the insulator for power cable. To investigate the conduction mechanism for power cable insulation under ac high field, it is very important to acquire the dissipation current under actual running field. Recently, we have developed the unique system, which make possible to observe the nonlinear dissipation current waveform. In this system, to observe the nonlinear properties with high accuracy, capacitive current component is canceled by using inverse capacitive current signal instead of using the bridge circuit for canceling it. We have already reported that the dissipation currents of 40 μm thick LDPE film at 10 kV/mm and over 140 Hz, it starts to show nonlinearity and odd number's harmonics were getting large. To investigate the conduction mechanis ms in this region, especially space charge effect, various kinds of estimation, such as time variations of instantaneous resistivity for one cycle, FFT spectra of dissipation current waveforms and so on, has been examined. As the results of these estimations, it was found that the dissipation current will depend on not only the instantaneous value of electric field but also the time differential of applied electric field due to taking a balance between applied field and internal field. Furthermore, two large peaks of dissipation current for each half cycle were observed under certain condition. In this paper, to clarify the reason why it shows two peaks for each half cycle, the film thickness dependences of dissipation current waveforms were observed by using the three different thickness LDPE films.

1. Introduction

It was reported the frequency dependences of dissipation current waveforms of LDPE 40 μm thick films at 10 and 15 kV/mm [1, 2]. Dissipation current waveforms show nonlinearity and the value itself is getting large with the increase of frequency above certain condition. In addition, in higher frequency, dissipation current waveform shows 2 peaks in each positive and negative half cycle. To understand this phenomenon, various kinds of estimations were carried out [5]. It is well known that the first peak of each half cycle may occur due to the injected homo space charge become hetero just after inverse of polarity under alternative electric field [6-9]. On the other hand, the second peak of each half cycle appears after the peak of applied field. In this region, applied electric field is getting small, so why it starts to increase again is hard to explain so far [5]. Injected homo space charge will make relief the electric field at vicinity of each electrode, however, these homo space charge make to enhance electric field in bulk instead. If this second peak may relate with carrier movement in bulk due to these homo space charge, it should show the film thickness dependence. To confirm this effect, various thickness LDPE films are prepared and examined.

It is well known that space charge effect is a time dominant phenomenon. Under ac field, not only the value of electric field but also the time differential of electric field is always varying and should affect the charge injection and space charge formation. In order to estimate this effect, high field triangle waveform application which makes the time differential constant with varying the value and includes polarity reversal, is carried out by using the latest dissipation current waveform observation system. Rectangular waveform is selected as the capacitive current canceling signal.

In this paper, the instantaneous internal electric field enhancement effect at the later part of each positive and negative half cycle which mentioned above and the effect of the time differential of electric field will be introduced. Electric field dependences of dissipation current waveforms observation were carried out by using three different thickness LDPE films to confirm the bulk effect. FFT analyses are employed to know the behavior of spectrum distributions, especially 3rd and 5th harmonics of the dissipation current. Furthermore, from the results of high field triangle waveforms application, the E-I properties in each case is discussed.

2. Experimental

LDPE films in three different thickness 37, 72 and 93 μm were used as the sample for sinusoidal waveform application and thickness 21.5 μm was used for triangle waveform application, respectively. Four same thickness film samples were prepared at the same time to confirm reproducibility. A three-terminal electrode system was employed. Here, these electrodes were formed by gold evaporation. This film sample was put into the sample holder. Then, to avoid the partial discharges, the holder was set in high-pressure N2 gas chamber (0.2 MPa).

Outlines of the dissipation current waveform observation system has been described else where [3]. Arbitrary Function Generator (Tektronix AFG320 / NF WF1946A) and Digital Phosphor Oscilloscope (Tektronix TDS3052) were connected to personal computer via GP-IB cable. Sinusoidal waveform signal was generated from AFG320, triangle waveform signal was generated from WF1946A, respectively. Here, to make the digital noise small, this signal has 12 bit vertical resolution and 16,384 data points by using edit function. Generated signal was amplified at high voltage amplifier (Trek Model 610C) and applied to the sample in the chamber. Here, this amplifier's slew rate is 20 V/μs.). It is enough to apply the exact sinusoidal waveforms up to 200 Hz for 100 μm thick film sample (Here, in the case of the experiment at 200 Hz and 15 kV/mm, the sample thickness 100 μm, the expected maximum slew rate value will be around 2.0 V/μs.). Furthermore, the output of the amplifier has been experimentally confirmed that there was no distortion on the applied ac high voltage waveform when the ac high voltage at 200 Hz, 15 kV/mm was applied to the 100 μm thickness LDPE film sample. During applying ac high voltage to the sample, simultaneously, a canceling signal (cosine waveform / rectangular waveform) was generated from another Arbitrary Function Generator (Tektronix AFG310 / NF WF1946A) and connected to the main electrode via serial resistor RS. Only the dissipation current component and un-canceled capacitive

current flowed the detecting resistor RD. The detected voltage signal was amplified by an operational amplifier and was stored by TDS3052.

3. Results and Discussion

Dissipation current waveforms at 6 and 15 kV/mm, room temperature, which results were obtained from different thickness film samples, is shown in Fig. 1. In this figure, at 6 kV/mm, dissipation current waveform is almost sinusoidal and there are no film thickness dependence. The dissipation current waveform of all film samples had four peaks for one ac cycle at 15 kV/mm. Here, each peaks are named P1, P2, P3 and P4 as shown in Fig.1. Amplitude of peaks P1 and P3 are almost same between each sample and appeared at 60o and 240o, respectively. As these peaks appeared just after the polarity reversal and showed no film thickness dependence, it is considered that charge injection from the electrode is mainly occurred in this phase.

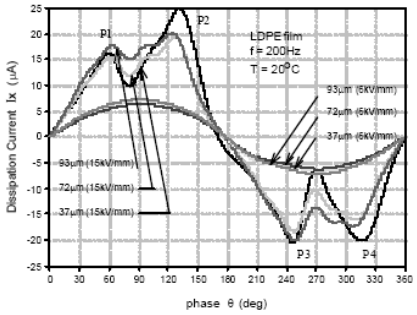

Fig. 1. Dissipation current waveforms obtained from different thickness film samples.

On the other hand, the values for P2 and P4 peaks which appeared at ~130o and ~310o, respectively, showed the film thickness dependence. Variation of dissipation current after each peaks P1 and P3 is also differ with the film thickness. Thinner film sample's variation is larger than thicker one. As peaks P2 and P4 showed the film thickness dependence, it seems to consider that the conduction mechanism in this region will be related on the charge movement in bulk.

Fig. 2 is electric field dependence of 3rd and 5th harmonics for different thickness film samples. These data were deduced from the results of electric field dependence of dissipation current waveform by using FFT analysis. As shown in Fig.2, up to 6 kV/mm, 3rd and 5th harmonics are quite small and there are no film thickness dependence. Over 7 kV/mm, both 3rd and 5th harmonics starts to increase and 5th harmonics show the relatively small peak first. Then, 3rd harmonics show the large peak. Over 10 kV/mm, 5th harmonics start to increase again. These results indicate that the time variation of dissipation current is getting rapid with the electric field increment. As shown in Fig. 2, once the 3rd and 5th harmonics appeared, then the film thickness dependence also were observed.

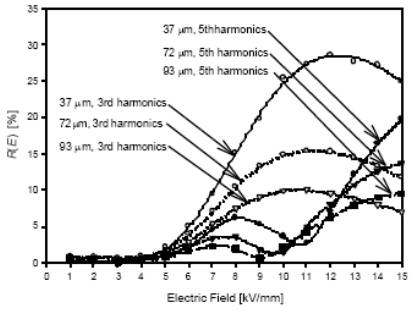

Fig. 2. Electric field dependences of 3rd and 5th harmonic component for different thickness film samples.

4. Conclusion

In order to study the charge behavior under ac high field, by using the latest observation system, dissipation current waveform under ac high field and under triangle waveform application are carried out and the film thickness dependence of dissipation current waveform and the effect of time differential of applied electric field are discussed. As the results of these experiments, where the dissipation current waveform show the nonlinearity, peaks P2 and P4 showed the film thickness dependence. It is also confirmed that the time differential of applied electric field affect the conduction under ac high field.

Acknowledgement

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