STUDY ON THE EFFECTS OF SPACE CHARGE AND CONDUCTION CURRENT BY PVDF/PZT(PIEZO SENSOR)

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Abstract: In this study, we have investigated the effects of space charge on the conduction current with the variation of applied time of electric field in polymer insulators. Until now, most of established measuring systems for space charge distribution in polymer insulators are intended to measure space charge profile only. However, we have successfully measured both space charge distribution and conduction current simultaneously by modifying the PEA method. Such a simultaneous measurement system can reduce the problems which may be happened due to infinitesimal change of interface conditions when measuring both separately. Besides, this system has advantages in analyzing the effects of preformed space charge on electrical characteristics directly and in investigating the direct correlation between space charge and conduction characteristics under various times. Also, we tried an experiment to use piezoelectric sensor named PZT($PbZrTiO_3$) to improve the signal of space charge in this measurement system. From this experiment, we have known the variation of conduction current characteristic due to the existence of space charge in XLPE.

1. INTRODUCTION

Increase of recent electricity consumption and the information age require high reliability for electric devices, and expectation for reliability in terms of electric devices, especially long term reliability towards electric transmitting cables is increasing. So, DC XLPE electric cable with high reliability is demanded and is rapidly extended along with undergrounding of power distribution lines [1]. However, it is well known that electric cables are driven in long term and during this stage electric conductivity of polymer insulators and space charge is increased due to the degradation of insulating materials under DC high stress. But, the precise physical mechanism about it is not yet sufficiently understood. In general, space charge distorts the electrode-insulator interface field and internal field to impact conduction properties of insulator and carrier capturing processes [1-2]. Therefore, it is very important to grasp the effects electricity conduction characteristics within polymer insulators and the preformed space charge on the electric conductivity, in order to enhance insulation performance and achieve highly reliable insulation design.[3] In this research, based on such a background, we have investigated the relation between the distribution of space charge and the conduction current over time by the simultaneous measurement system of space charge and conduction current under DC high voltage, which was improved the PEA (Pulsed Electro-Acoustic) method. The PEA method is one of the famous space charge measurement methods. We reinforced the switching part of our system because of the danger of high voltage short-circuit when switching from conducting current measurement to space charge. We have also corrected the experimental results of space charge by means of deconvolution process [4].

2. ECPERIMENT METHOD AND DESIGN

The conventional PEA method developed by the Takada and the Cooke has only its purpose on space charge distribution measurement in the insulation. However, our system in this paper has been improved to enable simultaneously both space charge distribution and conduction current by installing a guard electrode and a contact switch at the lower electrode. We also mounted a knob for convenient control of switching between them safely, as shown in Figure 1. We have simultaneously measured the space charge distribution and conduction current in the same sample with the variation of applied time and filed. Such a system is very useful tool for investigating the (preformed) space charge effect on the conduction current of insulators [5-6].

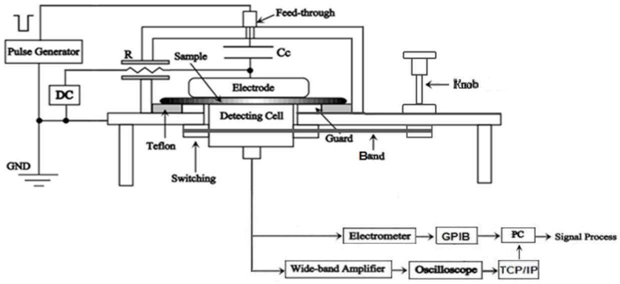


Fig.1 Draft of the measurement system under direct current voltage

The experiments were carried out using the electrode structure as Figure 2. The diameter of the lower electrode is 2cm, the gap between the guard electrode and lower electrode is 1mm. Input pulse is -4kV of height and ~ 20ns of width as negative voltage. According to the applied input pulse, acoustic waves were generated at the bulk of the insulator and both electrodes, and passed through the delay-line (Al). The acoustic signal was detected as a voltage signal at the detecting cell installed at the lower part of lower electrode. The detected signal was amplified with AU-1332 (band width: 1KHz ~ 500MHz, Gain: 51db, Ra: 50Ω) broadband amplifier and measured by a digital oscilloscope (TDS3054B). The piezoelectric materials used in our experiments were 28μm PVDF of thickness and 2μm PZT thickness, respectively. A polymer of PE class was also used as an absorber for acoustic waves to prevent a ringing phenomenon. To improve the S/N ratio of the output signal, averaging of 512 times was implemented at the oscilloscope. We have conducted S/W filtering and deconvolution process to calibrate space charge distribution as to the measured signal by LabVIEW S/W. We have constructed a communication interface with PC via GPIB for data acquisition. We also measured the conduction current using a high precision digital multi-meter (Keithley 6517A). The conduction current was measured with the period of 0.1 sec during 18 minutes after charging and discharge. The system circuit for short pulse (~20ns) should be treated as a distribution circuit. The impedance matching between the measuring cell and a pulse generator are very important for proper bypass of the input pulse to the ground. Due to such a reason, in this research, we installed a feed-through with a characteristic impedance of 50Ω (5W) at the inlet of the measuring cell. It is also important to reduce the contact resistance as much as possible, which was a potential noise source in measuring space charge. Therefore, we made double shielding the cables of the detection part. Additionally, we made the switching knob for safety when manipulating a section switch.

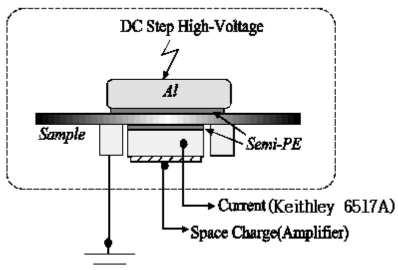
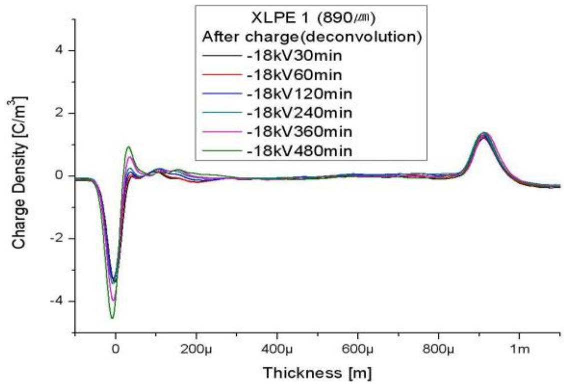


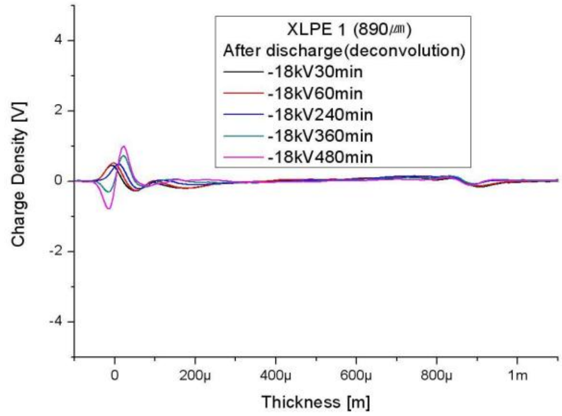
Fig. 2 Schematic of electrode structure

3. EXPERIMENT RESULT AND ANALYSIS

This experiment was carried out to measure the variation of the space charge distribution according to the time of applied voltage. We have applied voltages (-16kV, -18kV) at room temperature and prepared the samples of XLPE which was manufactured by cable company. XLPE 1 (thickness ~890μm) and 2 (~825μm) was made with different compounds for survey.



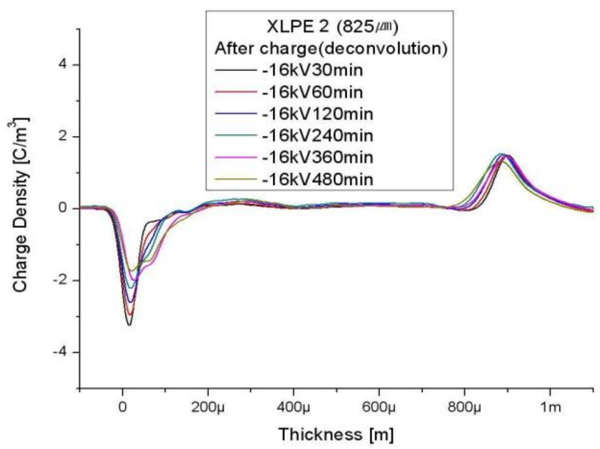
(a)



(b)

Fig. 3 Distribution of space charge within XLPE 1 over time (Sample thickness about 890μm)

Figure 3(a) shows the measured distribution of space charge in XLPE1 after applying (-) DC voltage (18KV) according to time (30, 60, 120, 240, 360 and 480 minutes), respectively. (b) show the signals after discharging the XLPE 1 for 10 minutes. The deconvolution process was applied for both of them by LabVIEW S/W. We found from the results that the positive space charge was accumulated near the negative electrode while the negative space charge nears the positive one. The quantity of space charge was increased as the voltage was increased. Such hetero charges were moved gradually into the bulk of the specimen with increasing the time of applied voltage. We also found that most of space charge was remained after discharging for 10 minutes, which means that space charge was trapped at deep trap sites, relatively. The accumulation of hetero charge is generally known to increase the electric field of the electrode-specimens interface, and thus increase the carrier injection from electrodes.



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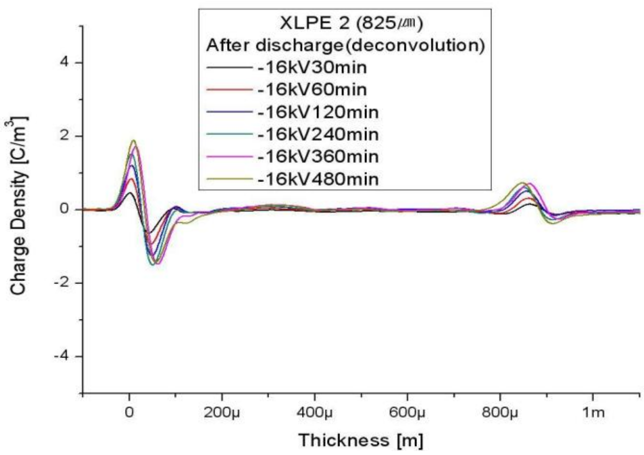

(b)

Fig. 4 Distribution of space charge within XLPE 2 over time (Sample thickness about 825μm)

Figure 4(a) shows the measured distribution of space charge in XLPE 2 after applying (-) DC voltage (16kV) according to time (30, 60, 120, 240, 360, 480), respectively. (b) Show the signals after discharging the XLPE 2 for 10 minutes. Such homo charges were moved gradually into the bulk of the specimen with increasing the electric field of applied value of space charge. As a result of research, formation of space charge is very important. So we think this systematic research achievement will be valuable in the future.

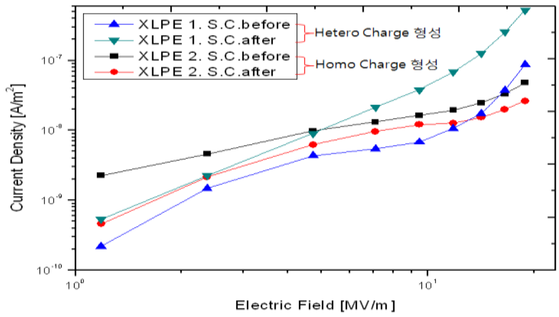

Fig. 5 Current density as to voltage

Figure 5 shows the time dependence of conducting current which after the formation of space charge, applying (-) DC voltage (2, 4, 6, 8, 10, 12, 14, 16kV) during 18minute. XLPE 2 inside which homo charge were formed. It showed almost a constant value when compared with the conducting current before and after the formation of space charge, XLPE hetero charge were formed at XLPE 1, it tended to increase over time comparing to XLPE 2. We could also investigate that as which showed electric field dependence of conduction current, it increased in XLPE 1 comparing to XLPE 2, and that space charge gave a great influence to conduction characteristics. And it was considered that such a characteristic would give a great influence to the insulting characteristic of a polymer insulator, especially in long term reliability. We also used another PZT sample for the experiment. It was manufactured and experimented and its manufacture process is as follows.

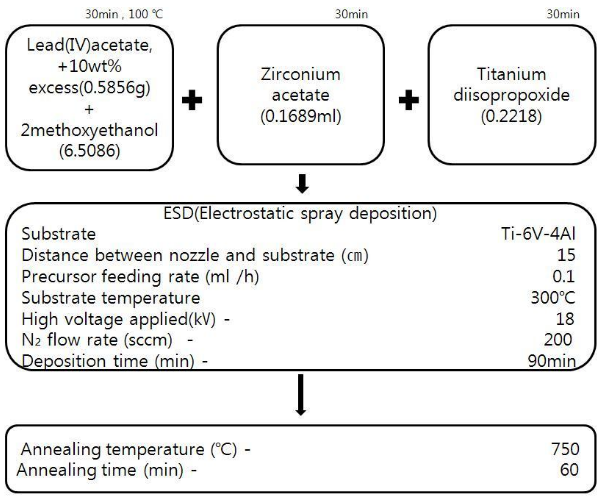

Fig. 6 PZT Manufacturing flowchart

15cm distance from the Ti-6V-4Al circuit board, Zirconium solution with 18kV voltage imposed for 90 minutes was sprayed at 0.1ml per hour and heat process of 750℃ for 60 minutes was implemented to manufacture.

4. CONCLUSION

This research is about the measurement method of space charge within solid polymer material. Through PEA method, we have successfully implemented the simultaneous measurement of space charge distribution and conduction current. We have analyzed the effects influencing the conductivity characteristic of a polymer insulator under direct current voltage. Furthermore, we could tell that the characteristic of high electric field conductivity of an XLPE, the formation of space charge is according to time and it remained even after discharge. As to the 2 types of XLPE 1 and XLPE 2 those are used as a conventional insulator for ultra-high voltage power cable, by measuring the space charge and conduction current at the same time. We could verify that time dependence of conduction current had a very close relationship with space charge. And in this experiment, we used the new Piezoelectric (PZT) to improve signal acquisition of the space charge. However too many noise was detected when measuring the space charge signal. We have know important things that coating time and heat treatment for the core component plays a crucial role in the surface polishing process of a Titanium component when making a PZT cell. For this reason we will research to improve space charge signal.

5. ACKNOWLEDGMENTS

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