Dielectric Breakdown Characteristics in LDPE with Semiconductive Electrodes

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Abstract

Dielectric breakdown strength of LDPE films was investigated using metal electrodes and semiconductive electrodes respectively. In both of two cases, the results show that there are characteristics of dependence on thickness and dependence on temperature. However, there are some differences in both cases.

1. Introduction

Further increasing in the operating stress level of power cables, the interest has been concentrated on improving the quality of insulating materials, and many investigations on the estimation of insulating materials have been conducted. As one of test methods for estimating the electrical performance of insulating materials, electrical breakdown test has widely used up to now, mainly made under the metal electrodes.[1),2),3)] In fact, however, dielectric breakdown of high voltage power cables is occurred in insulation volume between inner semiconductive layer and outer semiconductive layer. Therefore, it is very important to compare the difference between the dielectric strength under metal electrodes and under semiconductive electrodes.

In this study we performed the AC dielectric strength tests for the low density polyethylene(LDPE) film with and without semiconductive electrodes, and also reports the dependent characteristics as a function of temperature.

2. Experimental method

The specimens used for this study are LDPE films which have 20, 40, 60, 80[μm] thickness respectively. The density is 0.92 [g/cm^3] and the melt index is 3.0 [g/10min], and the crystallinity is 34.1[%]. Fig. 1 shows the representative DSC chart for the LDPE film.

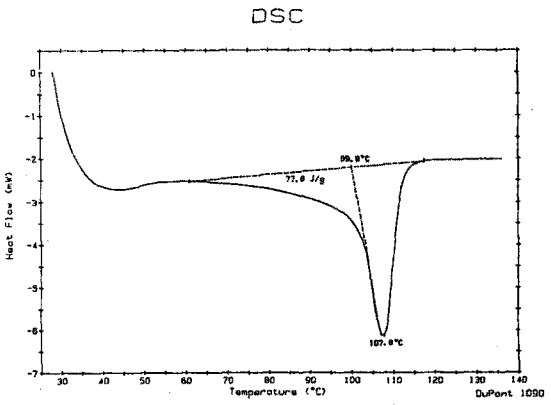

Fig.1 Representative DSC chart for LDPE films

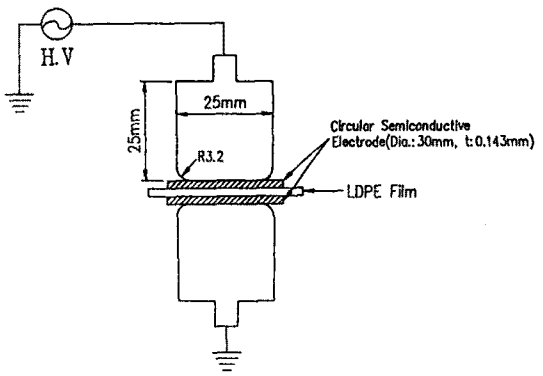

Fig.2 Specimen configuration and electrodes system

Attempts to dielectric breakdown tests have been made in LDPE films using both the metal electrodes according to the ASTM D149 standard test electrodes and the plane geometry with semiconductive electrodes. Fig. 2 shows the specimen configuration and electrodes system. The semiconductive electrodes used are of commercial products films which have 143[μm] thickness and below 10^3[Ω-cm] volume resistivity. The

specimens are cleaned before use and immersed in the insulation oil to prevent external discharge and flashover.

The applied alternating voltage(freq.:60[Hz]) is linearly increased at the rate of 0.5[kV/sec] until breakdown is occurred. The maintaining of the ambient oil temperature is obtained by putting the oil vessel on an electric heater(hot plate). The specimens were subjected to a breakdown test at room temperature(25℃), 50℃, 75℃ and 90℃ respectively.

The average breakdown voltage of each thickness of specimens was the average of ten measurements.

3. Experimental result and discussion

Tests were performed to find out the dielectric breakdown characteristics of LDPE films with the metal electrodes as well as the semiconductive electrodes.

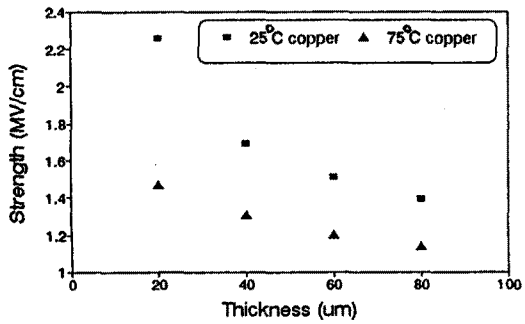

Fig. 3 Dependence on thickness-temperature of LDPE films under metal electrodes : 25℃ & 75℃

<3·1> Dependence on thickness

Fig. 3 shows the dependence on thickness of dielectric strength under the metal electrodes at the room temperature. Dielectric strength decreased with increasing the thickness of LDPE films, and the dependence on thickness for the dielectric strength decreased with increasing ambient temperature. These phenomena have been already known as thermal breakdown.[4),5)]

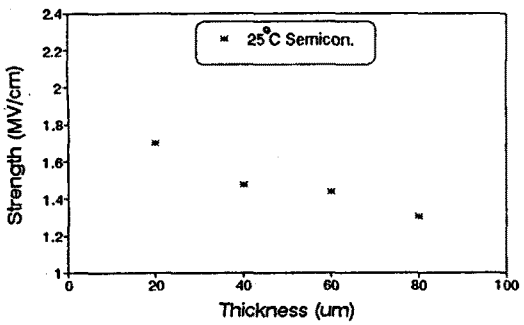

Fig. 4 Dependence on thickness at 25℃ under semi-conductive electrodes

The thickness dependence of dielectric strength under the semiconductive electrodes is shown in Fig. 4, and dielectric strength under semiconductive electrodes tends to be less dependent on thickness than in metal electrodes. That seems to be interesting phenomena, and it may be concerned that dielectric breakdown in this experiments was caused by thermal electrons emitted from semiconductive electrodes.

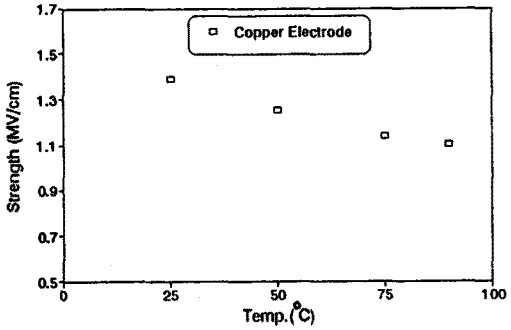

Fig. 5 Dependence on temperature using metal electrodes with 80 μm film

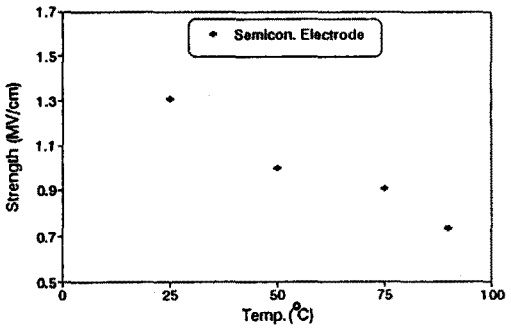

Fig. 6 Dependence on temperature using semiconductive electrodes with 80 μm film

<3·2> Dependence on Temperature

Fig. 5 shows the results of experiments which are to observe the characteristics of dielectric strength dependent on temperature using metal electrodes with 80[μm] LDPE films. Dielectric strength decreased with increasing temperature. It is well known as thermal breakdown.[4),5)]

Experiments using semiconductive electrodes and the same thickness of LDPE films were performed and the result is shown in Fig. 6. The tendency of decrease in dielectric strength appeared almost same as using metal electrodes. It appeared to be rapidly lowered at 90℃ especially. Wherever, the decreasing rate of Fig. 6 is more rapid than that of Fig. 5. Such rapidity of decrease under semiconductive electrodes is concerned that, with increase of temperature, there could be thermal electron injection or acceleration caused by vibration of thermal lattice

4. Conclusion

In this experiments, we have tried to compare the dielectric strength characteristics between semiconductive electrodes and metal electrodes. It was found that the dielectric strength of LDPE films using semiconductive electrodes is lower than using metal electrodes. In case of semiconductive electrodes, the dependence on temperature and/or thickness for the dielectric strength is also revealed. However, the rapid decrease in dielectric strength under semiconductive electrodes appeared with increase of temperature.

Thus, there could be a conclusion on possibilities that semiconductive layers made dielectric strength lower while play a good role in the homogeneous electric field in the power cable.

By the way, more work will be performed to clarify the phenomena of lower dielectric strength under the semiconductive electrodes than under the metal electrodes.

REFERENCES

(1) M.Hikita, I.Kanno and M.Ieda, "Electrical Breakdown of Ethylene Copolymers", IEEE Trans. on Elec. Ins. Vol. EI-22 No. 2, pp.175-180, 1987

(2) Edward F. Cuddihy, "A Concept for the Intrinsic Dielectric Strength of Electrical Insulation Materials", IEEE Trans. on Elec. Ins. Vol. EI-22 No.5, pp.573-589, 1987

(3) N.Yoshifuji, et al., "Development of The New Polymer Insul- ating Materials for HVDC Cable", IEEE Tran. on Power Delivery, Vol. 7 No. 3, pp. 1053-1059, 1992

(4) T. Mizutani, "High Field Conduction and Breakdown in Insulating Polymers", T. IEE Japan, Vol. 112-A No. 3, 1991

(5) H. Fröhlich, "On the Theory of Dielectric Breakdown in Solids", Proc. Roy. Soc., A 188, 521, 1947