Insulation properties of XLPE by adding Cross-linking Agent and Cross-linking Co-agent

가교제와 가교조제 함량에 따른 XLPE의 절연특성

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Abstract

We studied about electrical, chemical and mechanical characteristics of XLPE by dicumyl peroxide(DCP) and trimethylolpropane triacrylate(TMPTA) content ratio. DCP content was changed from 1.0 to 2.5phr increasing 0.5phr. TMPTA content was changed 0.5 to 1.5phr increasing 0.5phr. Thermal analysis (DSC) was carried out in order to observe tendency of Tg according to DCP and TMPTA content. Tensile strength was measured in order to observe mechanical strength. In experimental results, content DCP 2.0phr and TMPTA 1.0phr has highest breakdown strength. Content DCP 2.0phr and TMPTA 0.5phr has lowest dielectric constant. Tendency of Tg did not affected by DCP and TMPTA content. Breakdown strength and Specific inductive capacity was measured.

Key Wards(중요용어) : DCP, TMPTA, Breakdown strength and Specific inductive capacity, DSC

1. Introduction

Polyethylene (PE) has excellent electrical properties, such as low conductivity and low tan . It is widely used for the insulating materials of the power cable. However, polyethylene, despite of its excellent physical and chemical properties, is known to exhibit structural degradation when submitted to a continuous AC stress in humid environment, which may lead to a breakdown of the polymer [1~2]. In order to develop superior polyethylene insulation system and to design the new insulating materials, which stand under an even much higher electric stress and has a better reliability, it needs to improve the electrical properties inherent to materials [3].

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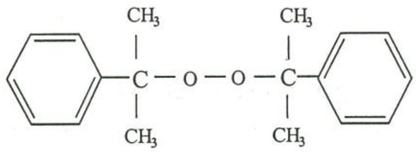
In the late 1960s Dow corning introduced technology has been applied to manufacturing crosslinked PE pipe and power cables. Crosslinked polyethylene (XLPE) has been playing a main role in solid dielectric insulated power cables, which has much merit such as high electrical strength easy handling in·laying and jointing, simple maintenance, etc [3~5]. And dry curing process has been developed to substitute steams curing, in order to reduce microvoids [6~7].

In this work, we investigated electrical and chemical properties by followed test; AC breakdown strength, specific inductive capacity and differential scanning calorimetry.

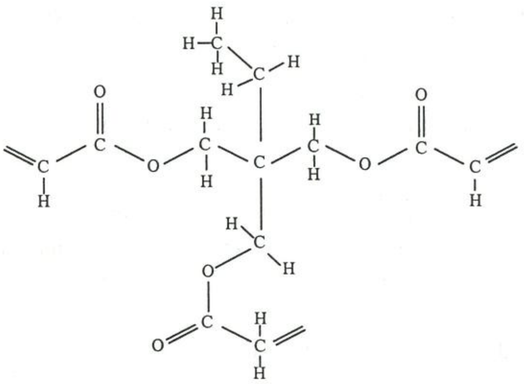
2. Experimental

2.1 Preparation of specimen.

Low-density polyethylene (LDPE, 0.920g/cm^3) was used as a starting material. It was blended with Trimethylopropane triacrylate (TMPTA) and dicumylperoxide (DCP) using roller mill, and it was crosslinked by hot press. Specimens were prepared by change of weight ratio of DCP and TMPTA. Table 1 is the classify of specimens and Fig. 1 is the structure of DCP and TMPTA.



(a)



(b)

Fig. 1 Structure of dicumyl peroxide and trimethylolpropane triacrylate.

Table 1. Specimens classification by DCP and TMPTA content ratio

TMPTA \ DCP	1.0 phr	1.5 phr	2.0 phr	2.5 phr
0.5 phr	A	D	G	J
1.0 phr	B	E	H	K
1.5 phr	C	F	I	L

2.2 Thermal analysis

In order to investigate thermal stability by change of DCP and TMPTA content ratio, the thermal properties of XLPE was investigated by using differential scanning calorimetry (DSC, Model 910S, Dupont Co.) in the range of 25~300 ℃, heating rate was 10 ℃/min.

2.3 AC breakdown test

Using AC breakdown test set, we made an experiment to elevate AC voltage rate of 1[kV/sec] by calculate AC breakdown field strength. Size of specimens were made to 30×30×0.3[mm] and it was located between ball and ball electrode. Fig. 2 is the AC breakdown test set and breakdown strength was calculated by formula (1)

We also tested tanδ value of specimen (10.9cm^2) using 4194A Impedance analyzer (Hewlett Packard Co.). Permit voltage was 1kV. The value was calculated by formula (2)

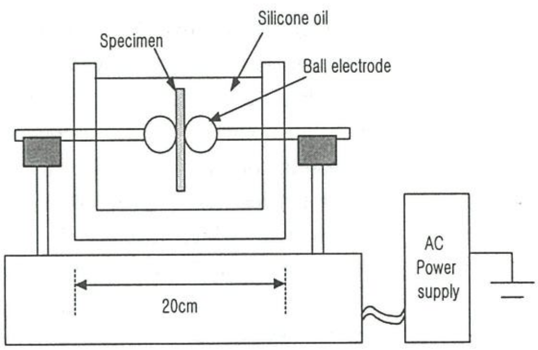


Fig. 2 Schematic diagram for AC breakdown test set.

$$Breakdownstrength = \frac{Breakdown\ Voltage(kV)}{Specimen\ Thickness(mm)} \quad \text{.......................}(1)$$

$$\varepsilon_0 = \frac{C \times d}{\varepsilon_0 \times A} \quad \text{.......................}(2)$$

ε_0= dielectric constant of vacuum (8.8510-12pF)
A= Area (cm2)
d= thickness (mm)
C= Electrostatic capacity (pF)

3. Results and discussion

3.1. Change of glass transition temperature

In order to observe tendency of Tg according to DCP content, we analyzed them by differential scanning calorimetry (DSC, Model 910S, Dupont Co.). TMPTA of all specimens was fixed 1.5 phr. Fig. 3 shows it's results. DCP content 2.0phr has the highest value. It is indicate the increase bonding energy of molecular until DCP 2.0phr.
Also, The tendency of Tg according to TMPTA content was measured. DCP of all specimens was fixed 1.5 phr. Fig. 4 shows Tg of specimens according to TMPTA content. TMPTA content 0.5phr has the highest value. Tg of XLPE decreased as content of TMPTA increase

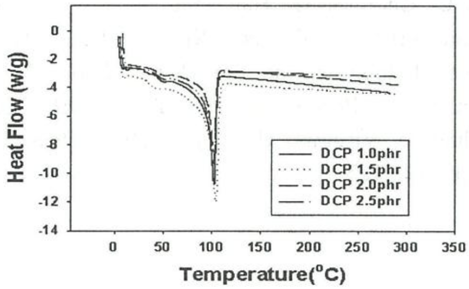


Fig. 3 DSC curves of XLPE by increasing of DCP content

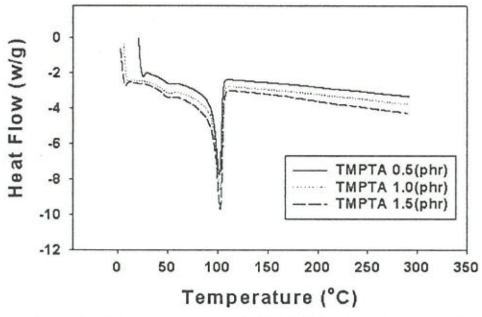


Fig. 4 DSC curves of XLPE by increasing of TMPTA content

3.2. AC Breakdown strength

The results of AC breakdown by change of DCP and TMPTA weight ratio are shown in Fig. 5. Breakdown strength of specimen 3 (DCP 2.0phr, TMPTA 1.0phr) was highest. Specimens, Which content DCP 1.5phr and DCP 2.0phr shows good breakdown strength at initial, but they decrease by increase of TMPTA content.

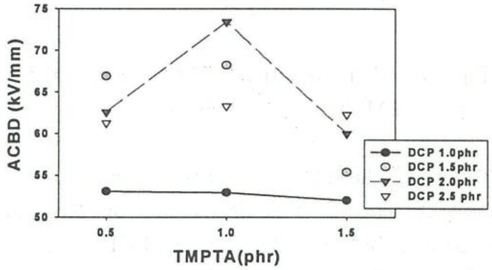


Fig. 5 Breakdown strength by DCP and TMPTA ratio

3.3 Specific inductive capacity

Fig. 6 is the results of specific induntive capacity measurement by change of DCP and TMPTA content ratio. Specific inductive capacity defines ratio of electrostatic capacity, which substitute substance and electrostatic capacity, which substitute vacuum. We predicted the increase of specific induntive capacity value by adding DCP and TMPTA, but only specimen 3 (DCP 2.0phr) increased. This is due to difference from cross-linked state by DCP and TMPTA content ratio.

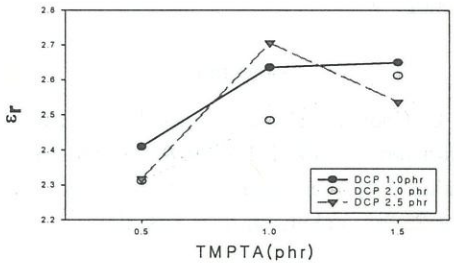


Fig. 6. Characteristics of ε_r according to DCP and TMPTA content ratio

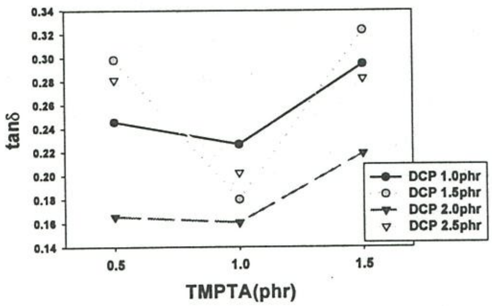


Fig. 7. Characteristics of tan by DCP and TMPTA content ratio

Tan δ is dielectric loss angle that is ratio of charge current. This is determined by property of dielectric substance. In Fig. 7, DCP 2.0phr and TMPTA 1.0phr sample has lowest value.

4. Conclusion

In thermal analysis by DSC, Specimen H, Which content DCP 2.0phr and TMPTA 0.5phr has the highest value. Breakdown strength of specimen H (DCP 2.0phr, TMPTA 1.0phr) has the highest and specific inductive capacity was very high. It is due to difference from cross-linked state by DCP and TMPTA content ratio.

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