Micro-Structural Enhancement of XLPE Insulation Using Additive Diffusion Method

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Abstract : With the aim of developing XLPE insulation for extra high voltage cable, we investigated the morphology of cross-linked polyethylene. We used a kind of base materials and additives, and controlled curing condition and amount of additives. The effect of addition of additives on morphology of XLPE such as lamellar density, orientation and additive layer were analyzed using TEM analysis. We applied this result to diffused additive amount was analyzed using FT-IR analysis, and the change of microstructure as the degree of additive diffusion was analyzed using TEM analysis.

Key words : XLPE insulation, additive, TEM, FT-IR, Weibull.

1. INTRODUCTION

Improvement of XLPE cable insulation has been characterized by reduction of contaminants by clean insulation process, voids by application of dry type curing methods, and protrusions by the triple layer simultaneous extrusion method. Further improvement is needed for reduction in insulation thickness especially for extra high voltage cables, and this has been a research subject for many researchers. Reduction of insulation thickness has been desired for cost reduction in transport and construction of extruded XLPE cable as extra high voltage underground line. Reduction of insulation thickness would be beneficial not only for increasing transportable cable length but also would improve its thermal performance. For this purpose, additives are diffused from semi-conductive layer into the XLPE insulation during curing process such as cross-linking process of XLPE power cable and these diffused additives could stimulate crystallization of XLPE by playing a role as nucleus. It is well known that lamellar structures originating from the crystallization could increase the dielectric strength of XLPE insulation.

We tried to control the lamellar density of XLPE by using specific additives We observed these morphological characteristics such as the density and orientation of lamellarin XLPE according to additive using transmission microscope (TEM). And the amount of diffused additive was analyzed using FT-IR analysis. This paper describes the effects of additives (lamellar density at the interface between semi-conducting and XLPE insulation layer).

2. EXPERIMENTAL

We used ethylene affiliation(E.A.) resin as a base material and used conventional low molecular additive as an additive. Identification of sample material used showed in Table 1.

Table 1. Identifications of sample material used

Identification	Description
E.A.	Basic semi-conducting material
E.A. + 0.5	EBA + 0.5C additive
E.A. + 1	EBA + 1.0C additive
E.A. + 3	EBA + 3.0C additive
E.A. + 5	EBA + 5.0C additeve

For simulated cable sample, we referred to the manufacturing process of test sample by other researchers [1]. Electrode of semi-conducting material in a semi-spherical shape was molded at 130?for 10 min and its thickness was 4.5◆0.1mm. Rounded XLPE pieces with a spherical pit at the center, 22mm in diameter, was molded at 130?and for 10 min. Both semi-conductive electrode and XLPE insulating piece were cured at 170? and for 20 min. (Fig. 1)

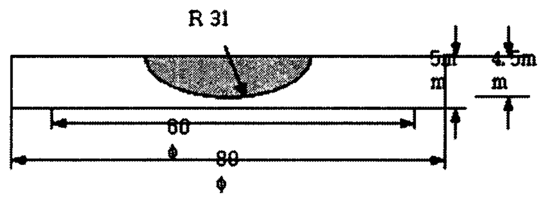


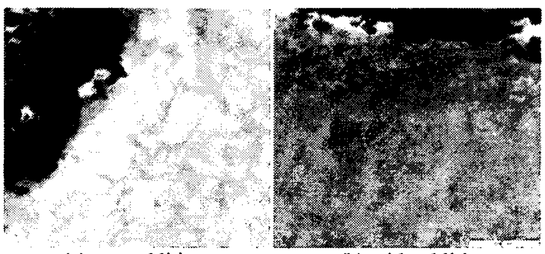
Fig 1. Simulated cable sample for measuring the dielectric breakdown strength

Morphological characteristics were observed by imaging thin sections with Transmission Electron Microscope (LEO 912 Omega, Carl Zeiss, Germany, Installed at Korea Basic Science Institute) The crystalline phase (lamella) can be clearly distinguished on the TEM after staining with RuO4(ruthenium tetra oxide)solution. All samples were prepared by staining with RuO4 solution to increase the contrast between amorphous and crystalline region. Staining was performed in 2 wt% RuO4 solution for 24 hours at room temperature. After removal from the solution, the samples were cut with ultra-microtome to approximately 80nm in thickness and collected on a mesh grid.

The samples were then examined in EF-TEM at a magnification of 10,000. Samples(with 0.5C, 1C, 2C additive) for FT-IR analysis to verify amounts of additive diffusion were made using roll-miller.

3. EXPERIMENTAL TEST RESULTS

Fig. 1 shows the micrographs of TEM observations for cables. It was found that the density of lamellar structure increases with adding additives. Tanaka et al. found that insulation characteristics near the interface can be improved by the addition of some additives on the basis of the interfacial diffusion method. Additives would increase lamellar density and modify the growth of PE crystal nuclei to orient the lamellar in a certain direction.



(a) non additive (b) with additive

Fig 1. .Examples of TEM photograph near the interface between semiconducting and XLPE insulating material

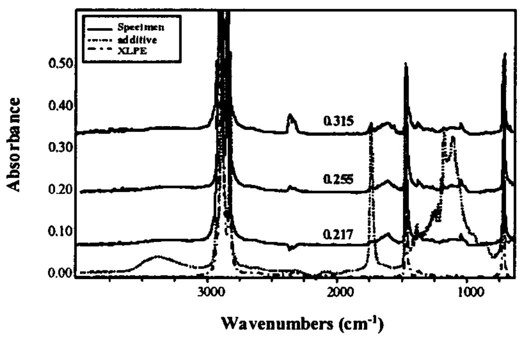


Fig 2. FT-IR analysis of XLPE, Additive and Model cable

Fig. 2 shows the FT-IR spectrum of additive-free XLPE, additive itself and molded XLPE specimens which include additive of different concentration. And Fig.3 shows the calibration curve as the amount of additives. The amount of diffused additive of 3.0C added specimen can be calculated as about 0.5C from the calibration curve of FT-IR intensity.

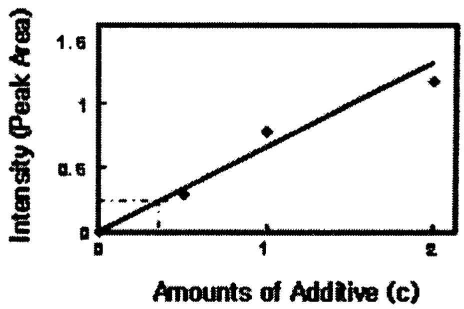


Fig 3. Calibration Curve and Change of Intensity by Amounts of Additive

4. DISCUSSION

This study was carried out to investigate the effect of additives and cooling rate on XLPE dielectric strength. Experimental samples are basically composed of semiconductive compound with additives. In addition, the effect of cooling rate on breakdown strength was conducted. We obtained the following results from the results of breakdown strength test, TEM analysis.

- The lamellar crystalline density of XLPE insulation is increased by adding additives in semi-conducting material.
- It was verified that diffusion amount of additive can be calculated using FT-IR analysis and adequate amount of additive addition can be designed to control lamellar density.

REFERENCES

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