ELECTRICAL PROPERTIES OF HIGHLY ELONGATED POLYETHYLENE
고연신폴리에칠렌의 전기적 특성

PARK Dae-Hee* GoldStar Cable Co., Research Lab.
박 대 희* 금성전선(주) 연구소

Park Dae-Hee Goldstar Cable Co., Research Lab.

본보고는 전기절연재료로 사용되고 있는 폴리에칠렌의 전기적특성의 연신효과에 관한 연구 결과이다. 전기적 특성으로서는 전기전도, 이동도, 절연파괴의 온도의존성을 파악한 것이다.

Introduction

The electrical property of polyethylene has attracted much attention from both the practical and fundamental standpoints, because this polymer has been used widely as insulating material in high voltage machines and cables and also it's molecular structure is the simplest among various polymers. However, there still exist many unsolved properties. Recently, it has been recognized that a morphology of polymer has strong influence on it's property.

In this paper, electrical properties like conductivity, mobility and breakdown, in high density polyethylene are investigated as a function of elongation ratio.

Experimental

By applying a roll elongation method to additive free high density polyethylene at 114°C, films with the elongation ratio of 500%, 700% and 900% were prepared. The sample was around 25um in thickness and was washed in ethanol under ultrasonic radiation for 10 minutes. Evapored gold on bath surfaces of the specimen surved as the electrode.

Electrical conductivity of the sample was measured by a vibration - reed electrometer(TR-84M).

The carrier mobility was evaluated by a time of flight method utilizing a N_2 laser of 5 nsec pulse width as a light source. In this case, thin evaporated selenium layer on the polymer film served as the carrier - generating region. Details of a time of flight method and the procedure for mobility evaluation was already reported in our previous papers 1) 2) 3).

The breakdown strength was measured by applying voltage pulse of 6) usec width(rise time is 0.1 usec) to the specimen immersed in the appropriate liquid ; silicone oil (300 - 400K), dry icemethanol(200K), liquid nitrigen (77K) and liquid helium(4.2K) also. Detailed procedures of the study of breakdown were already reported in our previous paper 4).

Results and Discussion

1. Electrical Conductivity

Fig.1 indicates the relation between the electrical conductivity and the ratio of the elongation of the polyethylene film. As evident from this figure, the sample with higher elongation ratio indicated lower conductivity is determined by both the charge carrier density and the carrier mobility.

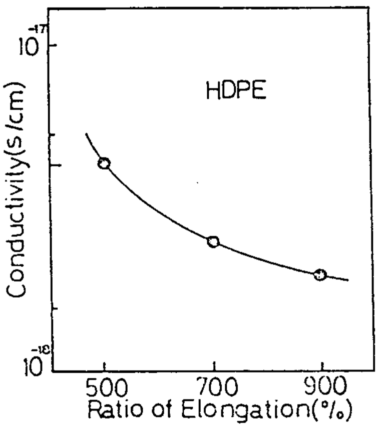

Fig.1 Dependence of electrical conductivity of high density polyethylene on the ratio of the elongation.

From the study of the photocoduction spectrum in ultraviolet and vacuum ultraviolet regions, the band gap of the polyethylene is found to be not influenced remarkably by elongation, which suggests the independence of the carrier density on elongation.

Details of photoconduction in elongated polyethylene will be reported in future.

2. Carrier Mobility

Then we have studied the carrier mobility in some of these polymer films. In the current signal which was obtained by differentiating the N_2 laser induced current signal graphically, any clear knee corresponding to the carrier transit between electrodes was not observed. In such a case, Scher - Montrall analysis 5), logarithmic plots of current i versus time t, has been used. In the present case, a clear knee was observed at time T_r in log i vs log t curve, from which carrier mobility u was evaluated by the relation of $u = d^2(VT_r)^{-1}$, where d and v are electrode distance and applied voltage.

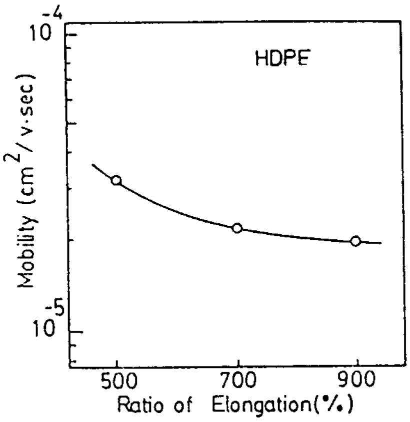

Fig.2 Dependence of carrier mobility of high density polyethylene on the ratio of the elongation.

Dependence of the observed carrier mobility on the ratio of the elongation is shown in Fig.2. As evident from this figure, with increasing elongation ratio the carrier mobility becomes smaller. The decrease of the carrier mobility should be explained either by the increased carrier scattering, though detailed origin of this center in not clear at this stage of experimenent. At least from these results the decrease of the carrier mobility should explain the decrease of the conductivity in the elongated films. By the elongation of polyethylene, re-orientation of lamella, unfolding of lamella, alignment of polymer chains and an arrangement of the amorphous part are considered to be induced, which should influence on the electron scattering.

3. Dielectric Breakdown

This difference of the carrier mobility by elongation should explain the breakdown characteristic in the elongated polyethylene films in Fig.3. the sample with the larger elongation ratio indicated higher breakdown strengths compared with those of the samples of lower elongation ratios. The temperature insensitive breakdown strength in the low temperature region seems to suggest an electronic breakdown process in these polymer films. This interpretation is also consistent with the high breakdown strength of highly elongated sample in which lower mobility was observed, because the energy input from electric field is reduced in the sample of lower mobility.

Conclusion

The carrier mobility decreases with increasing elongation ratio due to the increase of the carrier scattering or trap. Therefore, the increase of the breakdown strength by the elongation

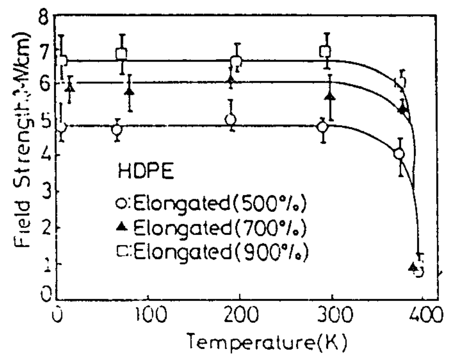

Fig.3 Temperature dependence of breakdown strength of the elongated high density polyethylene.

As evident from this figure, the breakdown strength in the elongated sample is almost independent of the temperature between 4.2K and 300K, but falls remarkably at higher temperature just as the case of the non-elongated sample. In the low temperature region, can be explained by the decrease of the carrier mobility by the elongation.

Reference

1) K.Hayashi, K.Yoshino and Y.Inuishi; Jpn.J.Appl.Phys.15(1976)931

2) K.Yoshino, J.Kyokane, T.Nishitatani and Y.Inuishi; J.Appl.Phys,49(1978)4849

3) M.S.Yun and K.Yoshino; J.Appl.Phys.58(1985)1950

4) K.Yoshino, S.H.Kim, K.Kaneto and Y.Inuishi; IEEE Trans. Elect.Insul.EI-20(1985)327

5) H.Scher and E.W.Motroll; Phys.Rev.B12(1975)2455