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EFFECTS OF VOLTAGE AGEING OF POLYESTER FOIL DETECTED BY TSDC METHOD

1. Introduction

The application of polyethylene-terephatalate foil in insulating systems results in changes of partial discharge characteristics because of the charge trapping in solid dielectric [1,2]. Such a result is important for the test-and measurement procedure of insulating system, the results of which can be missinterpreted. Particularly the p.d. inception voltage and $tg\delta$ vs. test voltage are influenced by the formation of space charge in solid dielectric [3].

In the research presented in this paper the time characteristics of overvoltage acting were investigated using the method of thermally stimulated depolarisation current (TSDC).

2. Program and results

As the investigated material the polyethylene-terephtalate foil, Estrofol, 10 μm thickness have been used [4]. The scope of the research program is as follows:

- the acting of special determined periodically repeated overvoltages in gas space contacting to the tested foil; their values and time of activity were the parameters of this program [4],
- the TSDC-measurements to detect the electrical effects of overvoltages.

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The parameters of overvoltages were as follows: overvoltage duration - 1 s, normal voltage operation - 10 s; overvoltage value was taken as triple of the initial p.d. inception voltage U_0 (at t = 0) while the normal operating voltage was taken lower than U_0.

The TSDC- measurements were carried out in the open circuit, 0,3 mm air space, with the rate of temperature increase of 8 deg per minute, in the temperature range from the ambient temperature up to 410 K [5,8].

The typical form of the TSDC thermogramm on the material before the overvoltage acting is presented in the Fig 1. The depolarisation peaks being the consequence of the natural polarisation after the technological process are seen.

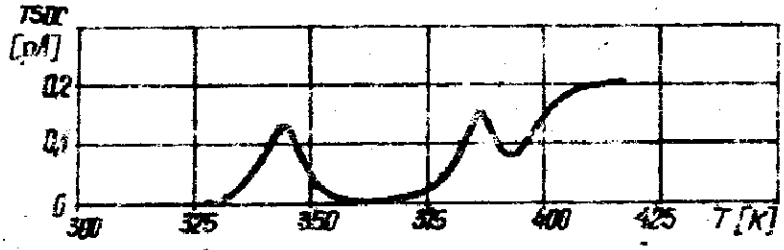

Fig.1. TSDC thermogramm of PET foil in natural stage

The typical TSDC-thermogramms measured after different time of voltage duration are presented in the Figures 2, 3 and 4.

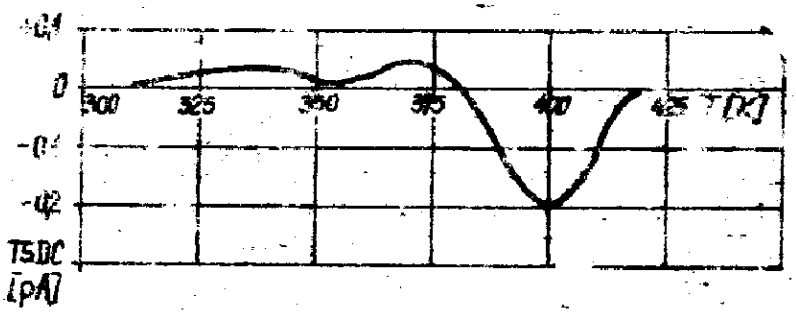

Fig.2. TSDC thermogramm after 10 min. of voltage ageing

The measured results are the basis for calculation of the values of depolarisation charge values (DC). If we consider only this part of the thermogramm which depends on the influence of p.d. acting i.e. in the temperature range from about 350 up to 400 K, the calculated depolarisation charges measured after different ageing duration can be presented in the form of

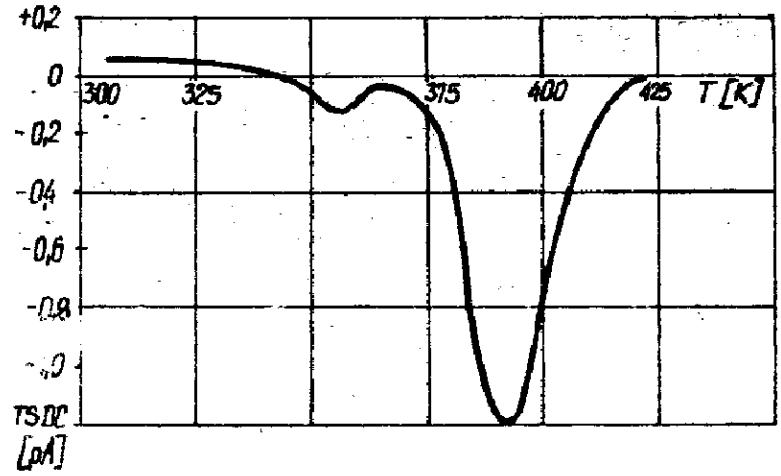

Fig.3. TSDC thermogramm after 2,5 h of voltage ageing

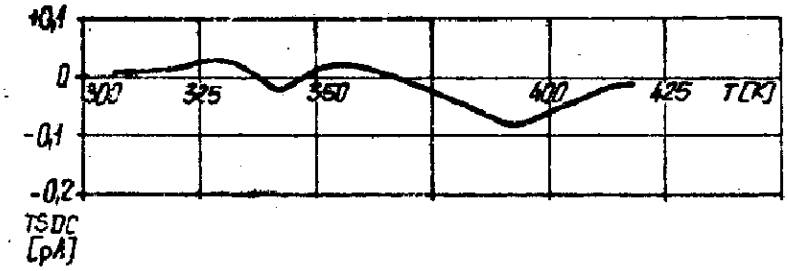

Fig.4. TSDC thermogramm after 28 h of voltage ageing

the relation of charge value vs. time. The typical form of such a time relation is given in the Fig.5.

The initial increase of the depolarisation charge value followed by its further decrease can be observed as the typical relation obtained during the p.d. ageing in overvoltage cycles on PET foil.

3. Interpretation and conclusions

The p.d. acting in the gaseous phase can be treated as the source of

charges which are injected into the solid dielectric. The charges are trapped within it. The depths of trapps in polymeric materials differ in relatively wide range 0,1 - 0,5 eV and more, even up to some eV [6,7] depending on the material and its crystal and amorphous structure.

Such a time relationship of the measured depolarisation charge is the result of space charge in solid dielectric. Assuming that the charge transport into the dielectric is limited by this space charge, the charged layer of the depth r is formed within it.

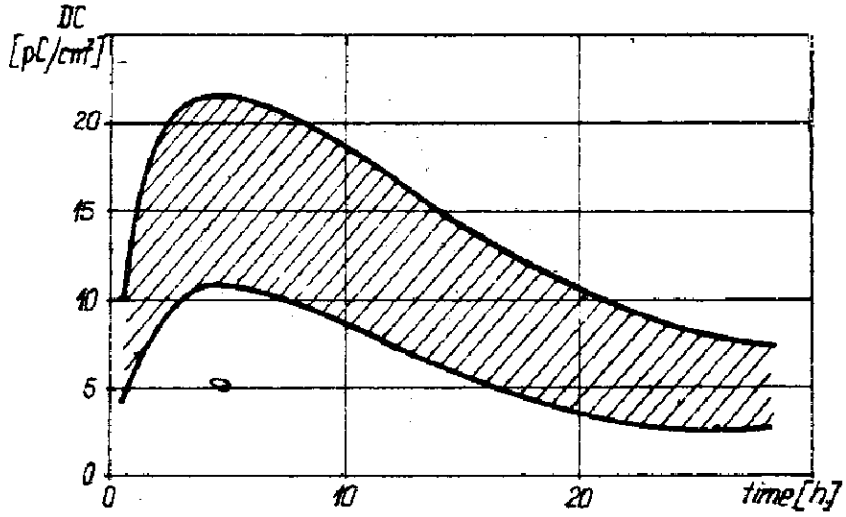

Fig.5. Typical change of depolarisation charge density

The r value depends on the duration of charge injection time, i.e. on the effective time of partial discharge action: $r = f(t)$. The depolarisation charge DC which is detected and measured in the TSDC is thus influenced by the depth of the charged layer related to the thickness of dielectric. Neglecting the conductive-and diffusion components of the current across the dielectric the following formula for the relative DC value can be taken [6]:

$$\frac{DC}{Q_o} = -\frac{r}{2d}\left\{1 - \frac{d^2}{r^2} \cdot \exp\left[2\left(1 - \frac{d}{r}\right)\right]\right\} \qquad (1)$$

where: r - thickness of the charged layer,

d - dielectric thickness,

$Q_o = \rho_o \cdot r$

ρ_o - charge density in the r-layer.

The theoretical relation $\frac{DC}{Q_o} = f(r)$ reaches its maximum at $r \cong 0{,}6 \cdot d$.

The real conditions existing in the dielectric as intrinsic conductivity, diffusion current component and AC field influence the resulting time relation $r = f(t)$. Thus the formula for the effective $\frac{DC}{Q_o}$ value is more complicated than (1) and is now the object of investigations but its experimentally obtained results can be interpreted qualitatively as above. It should be noted that the relationship $\frac{DC}{Q_o} = f(t)$, where t is the ageing time, has the similar form as (1).

The described characteristics of TSDC during the process of overvoltage operation present the electrical effects of p.d. acting in polyethylene terephtalate foil. They can be used to explain the observed change of p.d. characteristics [4] which are thus treated as the result of charge trapping in the dielectric.

References

1. Florkowska B., Syrek W., Włodek R.: Badanie mechanizmu samowygaszania za pomocą pomiarów prądów termicznie stymulowanych. IV Symp."Problemy wyładowań niezupełnych w układach elektroizolacyjnych" AGH 1983.
2. Florkowska B., Syrek W., Włodek R.: Influence of Solid Dielectric on Charge Trapping and Intensity of Partial Discharges. IX Symp. on Electrical Discharges in Gases. TU, Warszawa 1985.
3. Florkowska B., Włodek R.: Influence of Solid Dielectric on Partial Discharges. Int. Conf. on Insulation Problems in Power Transformers.Łódź 1984.
4. Florkowska B.: Partial Discharge Characteristics in Voltage Ageing of PET Foil, V Symp. "Ageing Phenomena in Insulating Materials and Systems" AGH 1986.
5. Włodek et a.: Zastosowanie badań wyładowań niezupełnych do oceny technologii układów izolacyjnych. Sprawozdanie R.I. 13 MNiSzW, AGH 1983.
6. Sessler B.: Physics of Electrets. Springer Verlag 1980.
7. Rohl P.: Electronic Hopping Transport Mechanism in Polyethylene. IEEE Int. Symp. on El. Insul., 1984.
8. Syrek W.: The Application of the Thermo-Stimulated Depolarisation TSD Method for the Evaluation of the Partial Discharge Acting at the Polyester Foil. V Symp. "Ageing Phenomena in Insulating Materials and Systems" AGH 1986.