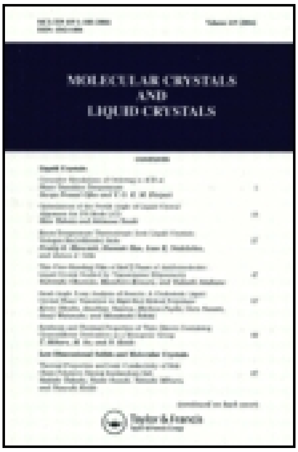

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DIPOLE RELAXATION DURING CHARGE TRANSPORT IN POLYMERIC PHOTOCONDUCTORS

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Abstract The photoinduced current measured without external electric field is caused not only by charge transit through the sample but also by relaxation of the molecular dipoles. This dipole relaxation changes the current direction. Measurements of the photocurrent were carried out after laser flash on poly(N-vinylcarbazole) with trinitrofluorene (PVK/TNF) and on polysiloxane with carbazole side groups (PS). The mobility of charge carriers, the coupling factor between dipole polarization and electric field and the relaxation time of molecular dipoles can be discussed by using a theoretical model of charge transit and dipole relaxation.

INTRODUCTION

The application of polymeric photoconductors, e.g. in laser printers, is connected with a photoinduced decharging without external electric field. Firstly, the polymeric layer is charged, e.g. by a corona, to generate a surface charge on the layer. This surface charge causes an electric field in the photoconductor. If there are movable molecular dipoles in the material a partial orientation of this dipoles follows the electric field of the surface charges. After light flash the charges transit through the layer, the electric field decreases and the dipoles relax in this decreasing electric field. The transit time of charges and the time constant of dipole relaxation strongly determine the shape of the photo-current. So the dipole relaxation causes a change of polarity of the photo-current if the relaxation time exeeds the transit time of the charges.[1-3]

This change of polarity and the following anormalous current were measured in the systems PVK/TNF and PS because of the strong molecular dipoles of the carbazole group.

THEORETICAL MODEL

The photoinduced current shows firstly a decay caused mainly by the charge transit. After this the current changes its polarity followed by a so called anomalous current. To fit the time dependence of this anomalous current the theoretical model contains

- the electrical field caused by the surface charges and the partially polarized dipoles characterized by the coupling factor α,
- the local dependence of the intensity of the laser flash at time t=0 and
- the charge carrier transit through the layer with a mobility μ followed by the reduction of the electrical field and the relaxation of the molecular dipoles with the relaxation time τ.

The electric field E(t,x) can be calculated by the discrete equation

$$E(t,x=n\Delta x) = E(t,x=0) + \\ + \frac{\Delta x}{2A\epsilon_o}\left[l(t,x=0) + 2\sum_{m=1}^{N-1} l(t,m\Delta x) + l(t,x)\right] - \\ - \frac{1}{\epsilon_o}[P(t,x) - P(t,x=0)]$$

with $\Delta x = N/L$, N are the number of steps in x direction and L is the sample thickness. $l(t,x)$ is the charge density and $P(t,x)$ characterizes the polarization. A and ϵ_o are the sample area and the dielectric constant, respectively. The second Kirchhoff' law, the definition of the capacity, the Poisson equation and the variation of the dielectric displacement are included in the equation for E(t,x).

An example for the variation of the electric field is given in the following figure 1.

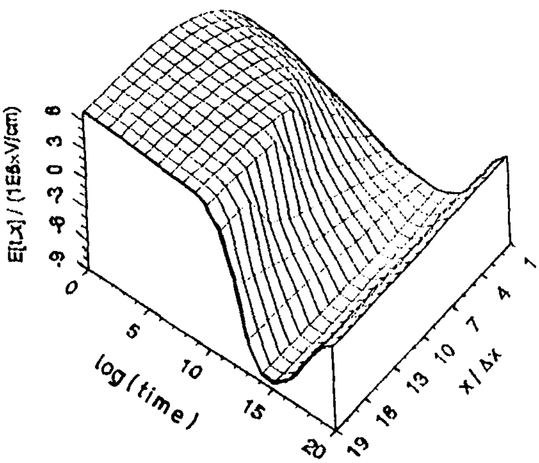

FIGURE 1 Calculated electric field E(t,x) parameter of the curves is the logarithmic time

The photoinduced current follows the integral over the electric field

$$I(t=Z\Delta t) = -\frac{\epsilon_o A\Delta x}{2s}\frac{d}{dt}\left[E(t,0) + 2\sum_{m=1}^{N-1} E(t,m\Delta x) + E(t,L)\right]$$

were s is the distance between the polymeric layer and the electrode. The time is digitized in steps of Δt.
In figure 2 an experimental time dependence of the photoinduced currend is given together with an theoretical fit. A relative good approximation of the experimental time dependence can be seen by the theoretical one.

DISCUSSION

Samoć and coworkers[4] discussed a charge accumulation on the backelectrode. This charge accumulation should cause an alternate of the current direction also. Hence the thickness dependence of the photoinduced current and the

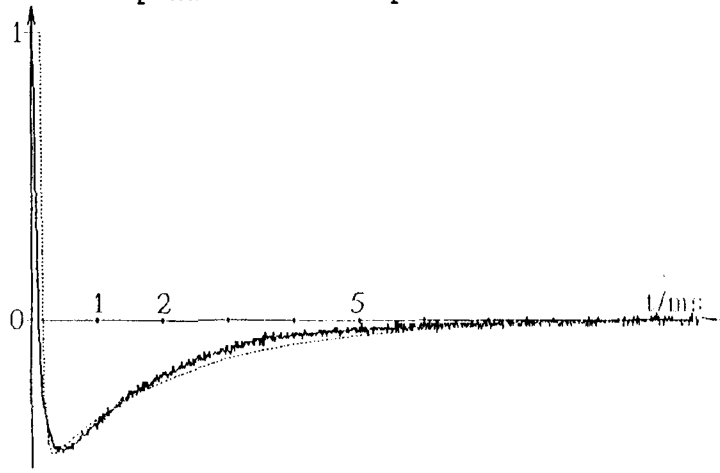

FIGURE 2: ———— measured current
········ calculated current

backelectrode material were varied to check the influence of the polymer surface on the time dependence of the anomalous photoinduced current. The variation of the anomalous current with the layer thickness shows the behaviour expected by the theoretical model with dipole relaxation. So the anomalous current is an volume effect. The variation of the electrode material doesn't vary the current significantly for iron, aluminium, silver, gold and platinum. Hence the charge accumulation can not be the reason for the anomalous current.

The fit of the experimental curves with the theoretical one gives us the possibility to calculate the coupling factor a, a mean mobility of the charge carriers μ and a mean relaxation time of the molecular dipoles τ. These parameters are given for several temperatures in the following table for the system PVK/TNF:

T / °C	30	40	50	60	70	80
a / 10^{-13} As/Vm	2.0	1.9	1.9	1.8	1.8	1.7
μ / 10^{-6} cm^2/Vs	1.9	2.1	2.4	2.9	3.3	3.9
τ / ms	6.3	5.4	6.0	5.0	5.7	5.1

We got analogous results for the polymer PS but with stronger temperature dependence of the dipole relaxation time τ.

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