Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Electric Field Influence on Holes Transport in High-Ohmic Organic Semiconductors

Roman N. Kuzmin [a], Vladimir G. Syromyatnikov [a], Ludmila N. Fedorova [a] & Valeriy M.(N.) Yashchuk [b]

[a] Faculty of Chemistry, Kyiv Taras Shevchenko University, 60, Volodymirska St., 01033, Kyiv, Ukraine

[b] Faculty of Physics Kyiv T. Shevchenko University, Academica Glushkova St., 6, 03022, Kyiv, Ukraine

Version of record first published: 24 Sep 2006

To cite this article: Roman N. Kuzmin, Vladimir G. Syromyatnikov, Ludmila N. Fedorova & Valeriy M.(N.) Yashchuk (2001): Electric Field Influence on Holes Transport in High-Ohmic Organic Semiconductors, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 361:1, 113-118

To link to this article: http://dx.doi.org/10.1080/10587250108025727

Mol. Cryst. and Liq. Cryst., 2001, Vol. 361, pp. 113-118
Reprints available directly from the publisher
Photocopying permitted by license only

Electric Field Influence on Holes Transport in High-Ohmic Organic Semiconductors

ROMAN N. KUZMIN[a], VLADIMIR G. SYROMYATNIKOV[a], LUDMILA N. FEDOROVA[a] and VALERIY M.(N.) YASHCHUK[b]

[a]*Faculty of Chemistry, Kyiv Taras Shevchenko University, 60, Volodymirska St., 01033 Kyiv, Ukraine and* [b]*Faculty of Physics Kyiv T. Shevchenko University, Academica Glushkova St., 6, 03022 Kyiv, Ukraine*

The xerographic discharge method has been used to study holes transport in anthracene crystals. The accumulation of holes by their capture on deep traps was taken into account. Some properties of holes transport may be explained by the concentration of the electric current along nonbasis dislocation lines.

Keywords: anthracene; holes; conductivity; capture; dislocation

INTRODUCTION

Presently scientific and technological community witnesses a rapid expansion of the region of applied investigation, which is motivated by the design of the efficient organic electroluminescent systems (LED) [1,2]. Emission from the luminescent centers in these systems are related with the electrical charge carrier transport. Therefore, a thorough knowledge of the particular features of the charge carrier transport is important for design and manufacture of LED systems.

A xerographic discharge method is widely used in the investigation of photoelectric properties of high-ohmic semiconductor materials[3-5]. The quantum efficiency of photogeneration is calculated by the formula

$$B=(\varepsilon\varepsilon_o/eIL)\dot{V}_t, \qquad 1)$$

where I is the radiation intensity, L is the sample size alone field strength direction. This formula can be applied if "Shcubveg" λ is more than the thickness of the sample. However, if $\lambda<L$ then expression (1) should be corrected.

EXPERIMENTAL

Anthracene crystals have been grown by two different ways. The crystals of first type were prepared from the solution[6]. For these crystals the delayed fluorescence life-time was rather short ($\sim 4\cdot10^{-3}$ s). The other type of crystals was obtained by the zone refining of the anthracene melt. Increase of the delayed fluorescence life-time up to $1{,}8\cdot10^{-2}$ s confirms the higher purity of this kind of crystals. The quality of crystalline structure was estimated by counting the number of etch pits on the surface parallel to the plane of the crystal. These pits correspond to the points of nonbasic edge dislocations on the crystal surface. The density of etch pits D for the samples obtained from the solution is equal to $\sim10^5$ cm^{-2}, and D $\sim10^7 \div 10^9$ cm^{-2} for crystals grown from melt. In accordance with the conditions of surface electrization, the direction of electric field coincided with the C' axis of the crystal. The xerographic discharge of the samples was performed by photoinjection of holes from the positively charged free surface under illumination by UV radiation.

Let us consider the sample in plane-parallel configuration. Potential change rate $\dot{V}_{t\,o}$ is equal to the integral of the partial derivative $\partial F(x,t)/\partial x$ (where x is the coordinate along field direction). At the open circuit condition

$$\partial F(x,t)/\partial t = (\varepsilon\varepsilon_0)^{-1}\cdot\mu_h\cdot\rho_h(x,t)\cdot F(x,t), \qquad (2)$$

where μ_h is the hole mobility, $\rho_h(x,t)$ is the density of free holes, $\rho_h(x,t)=j(0,t)\cdot\exp(-x/\lambda)/(\mu_h\cdot F(x,t))$, where $j(0,t)$ is the photocurrent density on surface radiated. Thus,

$$\partial F(x,t)/\partial t = (\varepsilon\varepsilon_0)^{-1} \cdot j(0,t) \cdot \exp(-x/\lambda). \quad (3)$$

Substituting (3) to (1) and carrying out the integration we found the photocurrent in the generation region

$$j(0,t)=\varepsilon\cdot\varepsilon_0\,(dV/dt)/\lambda\,(1-\exp(-L/\lambda)). \quad (4)$$

The denominator in this expression is the "centroid" of the spatial distribution of the captured carriers $\bar{x} = \lambda\,(1-\exp(L/\lambda))$[7]. Electric field strength $F(0,t)=V(t)/L$ on the sample free surface depends on irradiation time, so the quantum efficiency $\eta(F)=j(0,t)/eI$ of the photogeneration of carriers, which depends on $F(0,t)$, is also a time dependent. Taking into account (4) we obtained in contrast to (1)

$$\eta=(\varepsilon\varepsilon_o/eI\bar{x})V_t. \quad (5)$$

So, the value of $\eta(F)$ describes only the processes of free carriers generation and does not dependent on their transport and capture. Value of η is defined by the processes of initial separating of electrons and holes in the near-surface region of the sample (~0,1 μm) and, therefore, determines the quantum efficiency true value.

RESULTS AND DISCUSSION

The dependence of potential decay initial rate on initial field strength for the crystals grown from solution is shown in Figure 1 (curve 1). The initial values of $\bar{x}_0$ which are found accordingly to[8] are shown by curve 2. Basing on data obtained and taking into consideration the expressions (4) and (5) the values of surface photogeneration current j_o and correspondent quantum yield η for the different initial values of F were calculated (Figure 1, curve 3, for j_o and η). The results for the crystals grown from the melt is presented in Figure 2. The changing of slope and saturation of decay rate are not associated with the processes of electron-hole pairs generation, but with the nature of free carriers transport in the volume of xerographic layer that follows from the electric field dependence of $\bar{x}_0$ (curve 2 in Figures 1 and 2).

The experimental results show that the dependence of $\bar{x}_0$ on F is determined mainly by the crystal structure perfection. For the crystals with higher density of structure defects (the nonbasis dislocations at this case) the change in positive carriers transport character occurs. For the elucidation of the physical nature of this change the dependence of holes effective shift on the electrical field strength will be useful to consider. The effective shift of carriers is determined by the expression: $\lambda=\mu_{c'c'}\tau_h F$, where $\mu_{c'c'}\approx 1$ cm^2/V·s is the hole mobility along C′ axis and τ_h is the free holes lifetime. Using this formula values of τ_h for different values of electric field strength were found. The results obtained are given in Fig.3. The decrease of τ_h with the increase of F gives an evidence of the quasi-onedimentional character of hole motion along C′

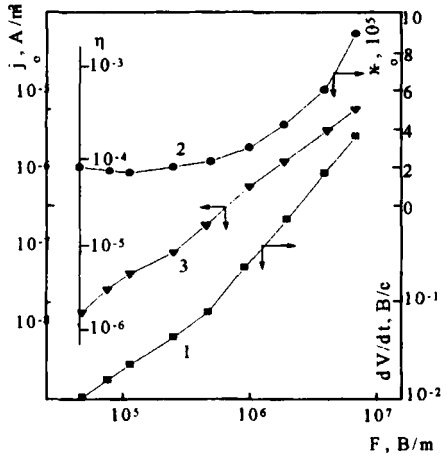

FIGURE 1. The electric field dependence of initial values of $(dV/dt)_o$, $\bar{x}_0$, and η for anthracene crystal grown from solution (D=10^{4}cm^{-2}, λ=392 nm, I=5·10^{12}photon/cm^2·s).

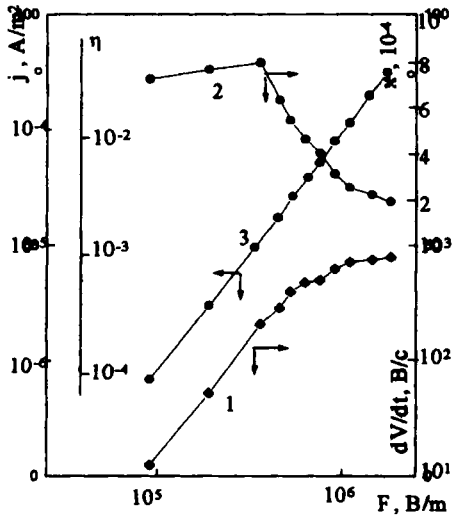

FIGURE 2. The electric field dependence of $(dV/dt)_o$, x_o, j_o, and η for anthracene crystal grown from the melt (L=1000 μm, $D=10^8$ cm^{-2}, λ=392 nm, $I=5\cdot10^{12}$ photon/cm^2s).

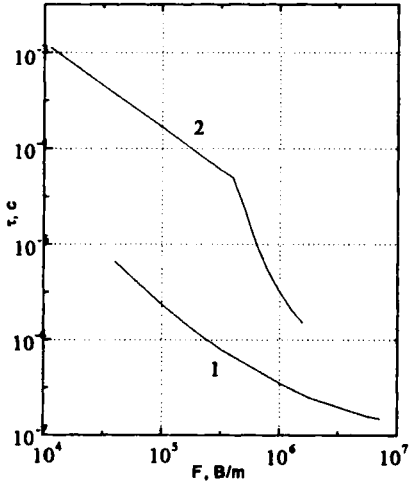

Figure 3. The electric field dependence of free holes life-time for crystals which was grown from solution - curve 1, and from the melt - curve 2, correspondingly.

axis. In our opinion this effect is caused by the creation of current "strings" along nonbasis dislocation lines, which, as it was shown in [9], can serve as highly conductive channels.

References

[1] Y. Yang, *MRS bulletin*, **22**, 6, 31–38, (1997).
[2] P. Burn, D.W. Sanmel, *Materials today*, **1**, 4, 3–5, (1998).
[3] S.G. Grenishin, *Electrophotography process*, Nauka, Moscow 1970.
[4] *Electrets*. Edited by Sesler G.M.-M: Mir. Moscow.1983.
[5] P.M. Borsenberger. *J. Appl. Phys.*, **7**, 49, (1978).
[6] H. Kallman, M. Pope, *Rev.* Sci. Instr., **29**, 993, (1958).
[7] M. Lampert, P. Mark, *Current injection in solids*, Mir, Moscow 1973.
[8] R.N. Kuzmin, *Izv. Vuzov SSSR, Physics*, 5, 58–61, (1987) [in Russian].
[9] V.U. Litvinenko, A.S. Pushkaryova, O.I. Kozhukhova, *Crystallography*, 4, 850, (1976). [in Russian].