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Two types of coronaelektrets discharge characteristics

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Photodischarge characteristics of coronaelectrets were investigated. It proposed a simple model of photocondactive coronaelectrets relaxation. This model is based on the assumption of internal opposite-EMF formation. The expression for geometrical parameter of opposite-EMF was obtained. On the base of obtained experimental data, the electrical field strength and thickness dependencies of free charge carriers lifetime was calculated. It was corroborated that in riched on structural defects anthracene crystals the transport of holes attributed by their moving along nonbasic edge dislocations.

Изучены фоторазрядные характеристики короноэлектретов. Предложена простая модель релаксации фотопроводящих короноэлектретов. Эта модель основана на предположении о формировании внутренней противо-ЭДС. Получено выражение для геометрического параметра, описывающего противо-ЭДС. На основании экспериментальных данных рассчитаны электрополевые и толщинные зависимости времени жизни свободных носителей заряда. Подтверждено, что в богатых структурными дефектами кристаллах антрацена транспорт дырок обусловлен их движением вдоль небазисных краевых дислокаций.

Coronaelectrets is used in many types of electronic and optoelectronic equipment. They apply as active elements of electret microphons, sensors of pressure, electromechanical transdusers, air filters, dosimeters. Different kinds of xerography are based on the photodischarge of inorganic (Se, ZnO_2) and organic (polyvinylcarbazole — PVC, anthracene) coronaelectret layers. On the other hand, method of xerography is very suitable to study photoelectrical properties of high-resistence materials at the limiting high, up to $2 \cdot 10^8$ V/m, electrical fields [1].

Therefore, it is very important to develop new procedures for investigation of coronaelectrets electrophysical properties and photo- and thermoelectrets connected with them. Such research is suitable to carry out on the model systems using well known materials, namely anthracene or PVC.

Properties of coronaelectrets with plane-parallel configuration (Fig. 1) is usually studied by measuring of time dependence of electret potential difference $V(t) = V_t$. The value of V_t is an integral characteristic, and it doesn't explain the processes in electret unambigously. Therefore, V_t data needs in additional information that can be received by the measuring of thermo- or photostimulated depolarization currents,sectionalization and et al. Factually, these methods destroy electret state.

In the process of electret state relaxation the displacement of nonequilibrium and equilibrium carriers leads to the partial neutralization of surface charges σ_0 introduced by electricity. The other part of carriers is trapped by deep levels in the volume of samples with formation of the persistent internal polarization — PIP. The last is characterized by the value of internal opposite electromotives force-opposite-EMF

$$E_t = (1/\varepsilon_0\varepsilon)\int_0^D x\rho(x)dx, \qquad (1)$$

where $\rho(x) = \rho_n(x) + \rho_p(x)$ — the total distribution of localizated electrons $\rho_n(x)$ and holes $\rho_p(x)$. The separation between "centroids" of this distribution $(d_f)_t$ allows to describe PIP by simple model, in which

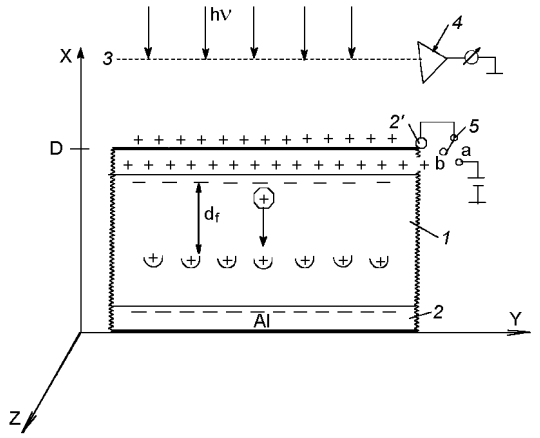

Fig. 1. Schematic diagram of experiment: *1* — photosemiconductor; *2* — graunded electrod; *2'* — upper electrode; *3* — semitransporant vibrating-reed probe; *4* — amplifier-recording system; *5* — switch: electrization — "a", measurment — "b".

$\rho_n(x)$ and $\rho_p(x)$ is represented by two thin negative and positive charge layers σ_f^- and σ_f^+ placed on distance d_f from one to other. It is assumed the existing of two infinit thin surface spaced closely locking layers. So all relaxetion process can be described by E_t development. Then, according to electroneutrality conditions $|\sigma_f^-| = |\sigma_f^+| = \sigma_f$ the value of opposite-EMF may be expressed as

$$E_t = (1/\varepsilon_0\varepsilon)(d_f)_t(\sigma_f)_t. \qquad (2)$$

Electret potential difference changes as

$$V_t = V_{0i} + E_t, \qquad (3)$$

where $V_{0i} = (1/\varepsilon\varepsilon_0)D\sigma_{0i}$ — initial potential after i-th electrization.

The value of potential change velocity at the process of relaxation

$$V_t' = (1/\varepsilon_0\varepsilon)\left((d_f)_t(d\sigma_f)_t' + (\sigma_f)_t(d_f)_t'\right) \qquad (4)$$

is proportional to the total internal current in electret. High-resistance photosemiconductores are usually used in xerography. So at room temperature we can ignore the currents of equilibrium carriers.

To different initial potentials V_{oi} the different initial velocities of it changing $(V_t')_{oi}$ is conformed (Fig. 2b, curve 1). On the other hand, to each moment of exitation on the sample after i-th electrization the definitivies values of potential V_t and velocity of it changing V_t' are corresponded (Fig. 2b,

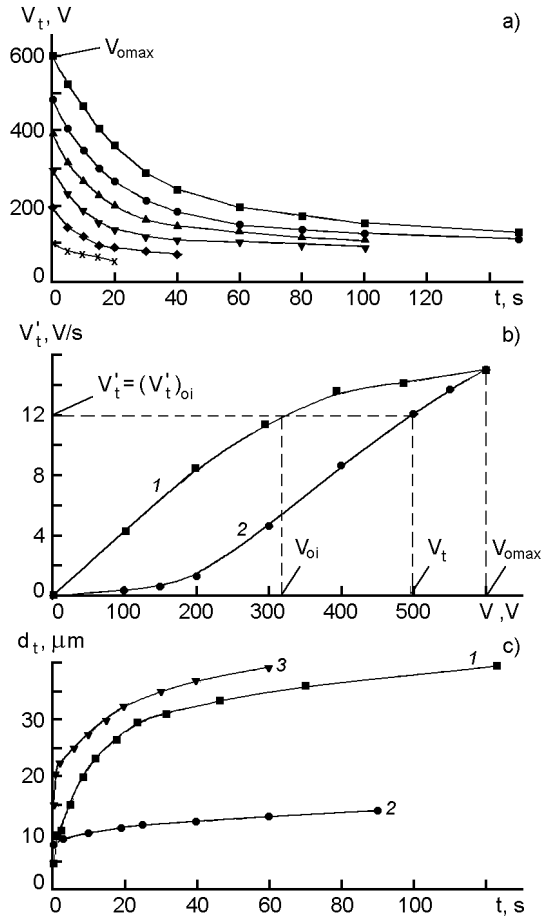

Fig. 2. Photoelektret characteristics of melt grown anthracene crystal. Positive charged, free surface illuminated (D = 50 μm, λ = 392 nm, $k = 10^5$ cm^{-1}, $I = 10^{16}$ photon/m^{2}s^{-1}): a — the family of volt decay carves $(V_t)_I$ at the different initial potentials V_{0i} ; b — initial points $(V_t')_{0i}$ from the all elements of volt decay family — *1*, continuous differentiation of decay curve from the largest initial potential V_{0max}= 600V — *2;* c — kinetics of polarizations geometrical parameter $(d_f)t$ behavior. Newly made crystal at initial fields F_0=1,2·10^{7}V/m and 6·10^{6}V/m measured - curves 1 and 2, respectively. Crystal after annealing, F_0=1,2·10^{7}V/m — *3*.

curve 2). Consequently to each of specific V_t' two magnitudes of potential are corresponded

$$V_{oi} = (D/\varepsilon_0\varepsilon)\sigma_{oi} \qquad (5)$$

and

$$(V_t)_i = (1/\varepsilon_0\varepsilon)(D\sigma_{oi} + d_{ft}\sigma_{ft}). \qquad (6)$$

Since the photocurrents is similar in both cases. The fields in the space of carrier generation and transport is similar to.

$$\sigma_{oi} = \sigma_{omax} + \sigma_{ft}. \quad (7)$$

From (1)–(7) the following relationship

$$(d_f)_t / D = (V_{omax} - V_t)/(V_{omax} - V_{oi}) \quad (8)$$

allows to determine the value of geometrical parameter in the process of continuous exposure by photoactive radiation on the sample.

Schematic diagram of experiment showed on Fig. 1. The "natatorial" electrode 2′ is used a device with tritium ionizer [2], that allows to deposit the closely measured amounts of produced ions on free surface (switch 5 in position "a") of the sample. Only in few cases the scorotron with needle electrode was used. Determination of potential difference between the sides of system was implemented by induction method with vibrating-reed probe 3 (switch 5 in position "b") [1] and recording equipment 4. The capacity between vibrating-reed probe and free surface of the system much lesser than capacity of the sample in all cases. Due to this fact the field in the sample does not perturb, practically.

As model system we have used the monocrystals of anthracene (high degree of the pure — lifetime of delayed fluorescence $\tau_{df} \approx 1.8 \cdot 10^{-2}$ s, that was grown from the melt; and low puring — $\tau_{df} \approx 4 \cdot 10^{-3}$ s, obtained from the solution). The crystals of second type have more perfect structure. In first case the density of nonbasic edge dislocations that are parallel to **c**′ axis of the crystal, was approximely 10^9 cm^{-2} with out annealing (373 K, 60 min) and order $5 \cdot 10^7$ cm^{-2} after it. In the second case the density is to approximately $2 \cdot 10^5$ cm^{-2}. Direction of electric field coincides with **c**′ axis of the crystal. To surfaces paralleling to **ab** plane thin nonphotoconductive insulator spacers (Maylar, 1.2μ, on Fig. 1 non highlight) was fitted snuggly. These spacers are the blocing layers, that prevent undesirable injection from electrode into the photoconductor. On one of the spacers aluminium thin layer was evaporated (lower earthed electrode). Another spacer was free. The "natatorial" electrode is interacted with it or semitransparent vibrating-reed probe was located at the measurments of potential.

On Fig. 2a the family of relaxation curves of electret potential difference V_t was shown. That results are obtained on the melt grown anthracene crystal before annealing at irradiation by strong absorbable (depth of penetration ≈0.1 μm) nonpolarized

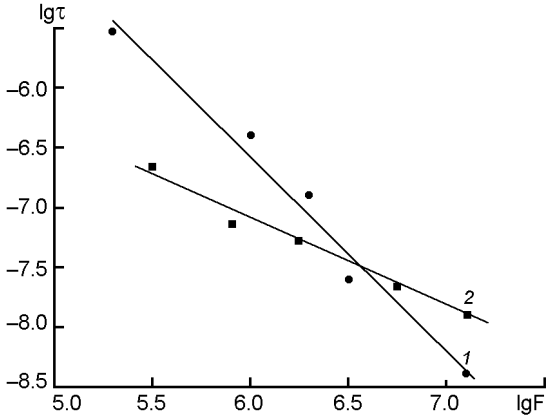

Fig. 3. Dependence of free carriers lifetime on electrical field strength F_0=1,2•10^{7}V/m. Newly made crystal - curve *1*; crystal after annealing — *2*.

light of positive charged free surface. Dependences $(V_t')_{oi}$ from V_{oi} and V_t' from V_t obtained from data on Fig. 2a, are represented by curves 1 and 2, correspondingly, on Fig. 2b. The magnitudes of $(d_f)_t/D$ relation calculated by formula (8) show the change of geometrical parameter polarisation at time of sample illumination for initial potentials V_o = 600 V ($F_o = 1.2 \cdot 10^7$ V/m) and V_o = 295 V ($F_o = 6 \cdot 10^6$ V/m) they are presented on Fig. 2b (curves 1 and 2, respectively).

In this experiment photogeneration of free charge carriers is attributed by nonown mechanism of the interaction between singlet exitons and surface additions centers (anthracence photooxides, predominantly). When holes move to negative, graunded electrode, under influence of external charges σ_{oi} field electrons remain at the boundary of anthracene-maylar separation. Part of them is captured on deep traps. Further they don't have own contribution in general potential V_t changing. For initial moment the mean value of carrier displasment up to a capture coincide with geometrical parameter of PIP

$$D_{fo} = \mu_c \tau_p F_o, \quad (9)$$

where μ_c – holes mobility along **c**′ axis, τ_p – timelife of free hole up to capture. From Fig. 2c dates it is followed, that the value of τ_p decrease with the increasing of electrical field F_0. From another hand, the crystal annealing leads to the lifetime increasing at three times aproximately (Fig. 2c — curve 3). In paper [3] was shown, that this character of carriers behaviour is connected

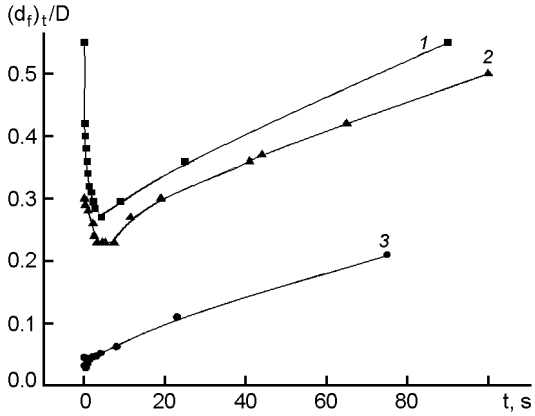

Fig. 4. Dependence of PIP geometrical parameter $(d_f)_t/D$ on irradiation time t in solution grown crystal (D = 60 μm, λ = 392 nm, $k = 10^5$ cm$^-$ 1, I = 1016 photon/m2s). Fo = 1.3·107 V/m — *1*; Fo = 1.45·106 V/m — *2*; upper blocking layer removed, Fo = 1.3·107 V/m — *3*.

with current "flexing" along nonbasic dislocations lines. Thus, in current conditions free carriers motion is in the nature of quasy one-dimentional anisotropic character. This assumption is supported by comparison of crystals properties before and after annealing. For the crystals before annealing the lifetime depends on the field strength as $\tau_p \sim F^{-1.7}$. After annealing the density of nonbasic dislocations decreases as in 20 times approximately. Simultaneously, the dependence of lifetime from the field decreas is as $\tau_p \sim F^{-0.85}$ (Fig. 3).

In more perfect crystals, that were grown from the solution, the one-dimentional effect disappeares. The comparison of curves 1 and 2 (Fig. 2c, initials points of $(V_t')_o$) shows, that relation $(d_f)_t/D$ decreases on the order of magnitude at initial field moderation on ten times. At $F_o = 1.45 \cdot 10^7$ V/m it takes place the relation $(d_f)_t/D = 0.55$, and for $F_o = 1.3 \cdot 10^6$ V/m – $(d_f)_t/D = 0.07$. Thus, the value of lifetime in crystals grown from solution is practically non dependent from electrical field strength.

It is interesting, that the removal of apper (from electrods 2′ side) artificial blocking layer, leads to decreasing of initial carriers displacement in two times (Fig. 4, curve 3). In this case $(d_f)_t/D = 0.30$ opposite to 0.55 at the presence of upper blocking layer. Simultaneously, initial velocity of decay is in two time less also. This effect is produced by small normal component of electrical field on surface.

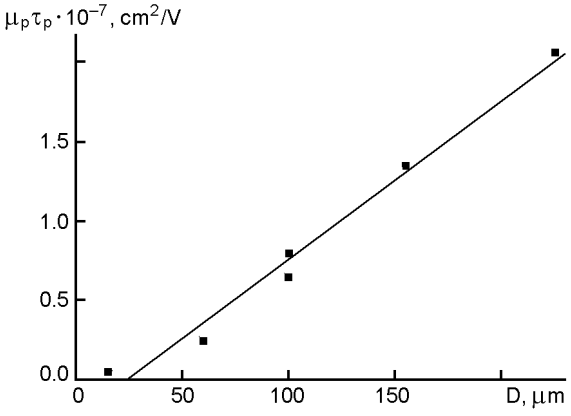

Fig. 5. Dependence of initial shift on thickness of solution grown crystals.

On the base of obtained results it can be supposed the following mechanism of opposite-EMF formation. Electron-hole pairs are generated on the irradiated crystal side at the positive electrod. The holes move to opposite negative electrod, they are captured by traps. Localized volume charge is created. Due to it the field is decreased in transport region. As result, for the crystals obtained from solution, the holes drift displacement decreases with the field direction. As consequence, position of charge "centroid" move to positive electrode. For the crystals grown from the melt the decreasing of $(d_f)_t/D$ is not naturally observed. The efficiency of charge carriers generation on irradiation side of crystal is dropped too. At the limit, when $\sigma_f \cong \sigma_{oi}$, the carriers generation and transport near positive electrode are stopped. In the region between the position of holes distribution "centroid" and negative electrode, the field changing is small. Simultaneously, the concentration of localizated holes increases. Therefore, the number of holes that are released by triplet exitons, increases. Triplet exitons arise from reabsorption of photons, that are emitted by fluorescence from irradiated side of crystal [4].

On Fig.5 the dependence of initial shift $\mu_p\tau_p$ on thickness of solution grown crystals in unit field is shown. The observable increase $\mu_p\tau_p$ with thickness, is evidently connected with the decrease of role of the near surface regions abounded by defects, at currents move in thick crystals.

This methodology of treatment data of coronaelectrets photodecay allows to reveal the number of significant features in photogeneration and transport of charge carriers at issue model system. Obviously, this ap-

proach can be applied for new slightly investigated high-resistance materials, particularly polymers.

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Два типи характеристик розряду короноелектретів

Р.Н.Кузьмін, Е.В.Мокринська

Вивчено фоторозрядні характеристики короноелектретів. Запропоновано просту модель релаксації фотопровідних короноелектретів. Ця модель заснована на припущенні про формування внутрішньої противо-едс. Отримано вираз для геометричного параметра, що описує противо-едс. На підставі експериментальних даних розраховано електропольові й товщинні залежності часу життя вільних носіїв заряду. Підтверджено, що у багатих структурними дефектами кристалах антрацену транспорт дірок обумовлений їхнім рухом уздовж небазисних крайових дислокацій.