UDC 539.186

P. O. Kondratenko[1], Yu. M. Lopatkin[2] , A. V. Glushkov and T. N. Sakun[1]

[1]National Aviation University, 1, Komarov Ave, 03680 Kiev, Ukraine
[2]Sumy State University, 2, Rimsky-Korsakov Street, 40007, Sumy, Ukraine
E-mail: nucsukh@mail.ru
[3] Odessa State Environmental University, 15, Lvovskaya str., 65016, Odessa, Ukraine

EXPERIMENTAL AND THEORETICAL STUDYING OF PHOTOCONDUCTIVITY OF POLYMERIC LAYERS WITH DYES

We present the results of the experimental and theoretical studying photoconductivity of polymer layers with the dyes. It's investigated photoconductivity of organic dyes in solid polymeric matrices with rectangular pulse excitation light. The obtained experimental data indicate on the quadratic (i.e. non-linear) relationship between photocurrent values that are obtained for two different levels of radiation intensities.

1. Introduction

To present time there are carried out numerous experimental and theoretical works data showing that the excitation relaxation processes in polymeric materials with different impurities do not prevent leakage of important science and practice processes in the highly excited states such as generation of carriers, photochemical and radiation-chemical processes [1-15]. Studying photo-conductivity of the polyacene linear crystals (anthracene, tetracene, pentatsen) showed that its high quantum efficiency is observed only under irradiation of the highly excited molecules when there is possible a birth of holes and free electrons.

In this paper we present the results of the experimental and theoretical studying photoconductivity of polymer layers with the dyes. It's investigated photoconductivity of organic dyes in solid polymeric matrices with rectangular pulse excitation light (methodics details in Refs. [3,4,6,7]). Initially, samples were kept at a constant high voltage (for most of them was taken U = 80 V) for some time until it is established steady dark current. Then through the transparent electrodes cell sample are radiated by a light from a mercury lamp, and a light had been focused so that the sample was evenly lit. The photocurrent appearance is recorded on the recorder and a photocurrent grew exponentially to a constant value i_c. Time of stationary photocurrent is dependent on dye concentration, nature of the polymer matrix, and presence of alkali in the layer, and equal one to a few min.

After the cessation of current lighting around the same time period reached its original value. Typical kinetics of the photocurrent growth and decline for most of the samples (PVP= polyvinylpyrrolidone; PVA= Polyvinyl acetate; PVC= Polyvinyl alcohol; PVE= Poliviniletylal) is shown in Fig.1.

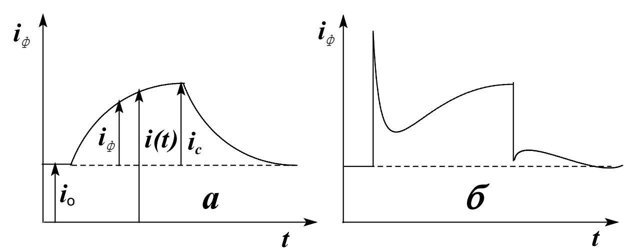

Figure 1. Time dependence of the photocurrent changing for solid solvents of rezazuryne: a) in polymers of PVP, PVA, PVC, b) in PVE (C = 10-³).

Kinetics of photoconductivity for PvE layer of rezazuryne (P = 10^{-3} mol/l) without alkali was somewhat complicated character. As it is shown in Fig. 1b, photocurrent model has two components (fast and slow) which are superimposed, giving the appearance of a complex curve. Quick component met in some other examples, and they have not helped to increase and sharp decline in photocurrent for the first time after turning on the light.

This component of the photocurrent disappears quickly, and for some samples it did not appear. Its rapid disappearance indicates that there are traps in the sample volume that capture electrons and holes, or carriers localized near the sample surface, creating an electrical double layer. As it is shown in Fig.1a, the growth photocurrent relaxation curve has exponential areas (i.e. relaxation occurs in a continuous lifetime on the considerable distance). To obtain quantitative information it is suggested that the increasing the photocurrent satisfies to the law:

$$i(t) = i_0 + i_c\left(1 - e^{-\frac{t}{\tau}}\right),$$

and

$$\tau = -\frac{t}{h\left[1 - \frac{i(t) - i_0}{i_c}\right]}.$$

It is reasonable to portray the results in the coordinates , where

for a curve of the photo current increasing.).

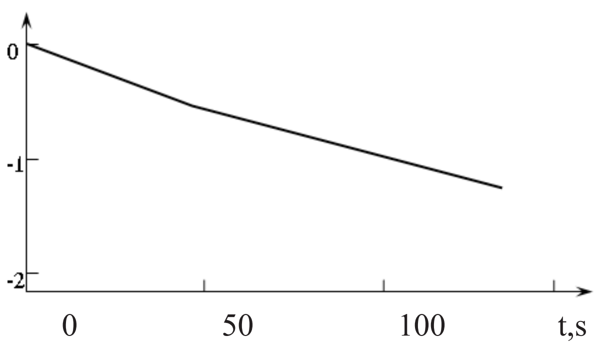

Figure 2. Kinetics of the photocurrent for rezazuryne in PVP (C = 10^{-3}mol/l in presence of the KOH) in the coordinates "t-ln(1-i_{ph}/i_c)

The exponential areas are plotted by the straight lines with a slope that determines τ, which is on the absolute value equal to the cotangent of the angle of the curve inclination (look Figure 2). Found lifetimes depending on the concentration rezazuryne polymer matrix and the presence of alkali are shown in Table. 1.

Table 1.

The lifetimes τ (s) in dependence on the rezazuryne concentration (C) in a polymer matrix and availability an alkalis KOH (light without filter).

Polimer	τ, s			
	Pure	C = 10^{-3}, KOH.	C = 10^{-3}, KOH	C = 10^{-4}, KOH
PVP	123	90	65	78
PVE	42	42	70	95
PVA	67	60	76	–

In Figures 3a,b,c we present the related changing photocurrent in polymers with different concentration of rezazuryne in dependence on a light intensity *I*.

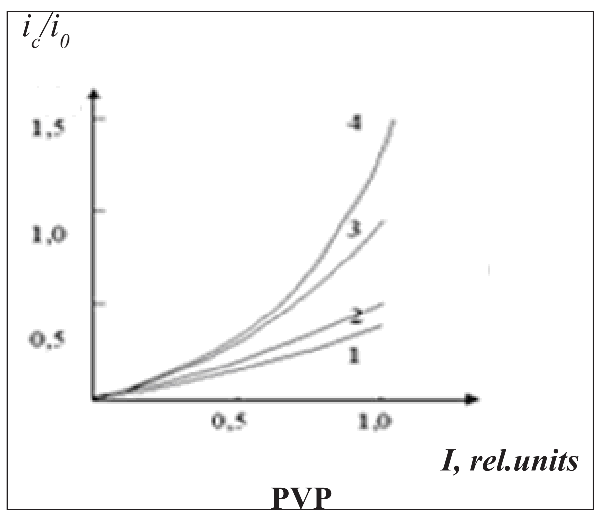

Figure 3a. The related changing photocurrent in polymers with different concentration of rezazuryne in dependence on a light intensity a) PVP (1 – C = 0; 2 – C = 10^{-4}, KOH; 3–C = 10^{-3}; 4 – C = 10^{-3}, KOH); n = i_c/i_o: 3(2), 3 (3), 4 (4);

Using the obtained kinetical curves of a photocurrent for all polymers with the rezazuryne concentration C=10^{-3} *mol/l* , it has been found the following relationship:

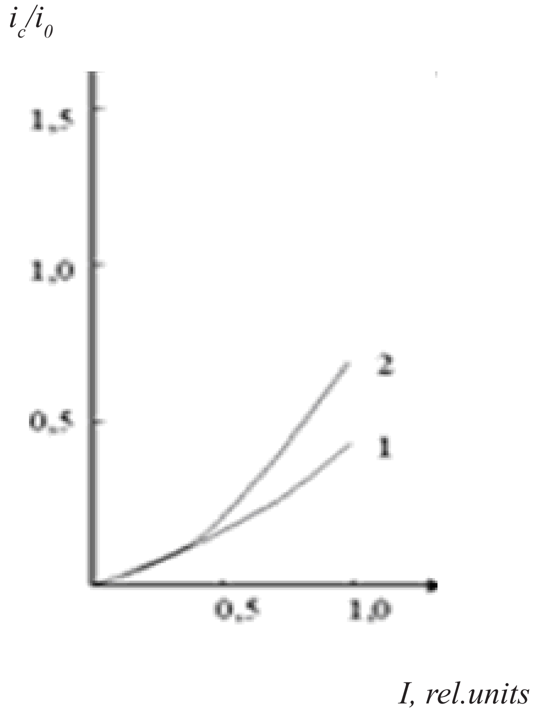

Figure 3b. The related changing photocurrent in polymers with different concentration of rezazuryne in dependence on a light intensity: b). PVE (1 – C = 10^{-4}, KOH; 2 – C = 10^{-3}, KOH); n = i_c/i_o: 2,5 (1), 4,2 (2);

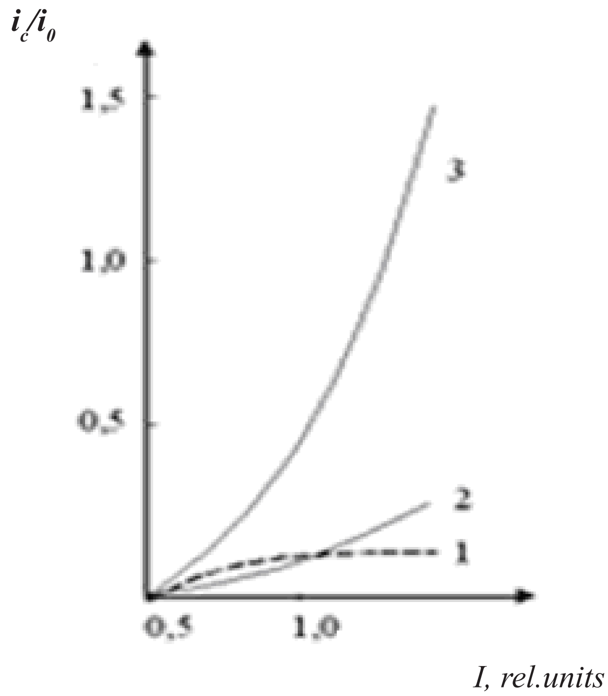

Figure 3b. The related changing photocurrent in polymers with different concentration of rezazuryne in dependence on a light intensity: c) PVA (1 – C = 0; 2 – C=10^{-3}; 3 – C =10^{-3}, KOH); n = i_c/i_o:3 (3,7).

$$\left(\frac{i_c}{i_0}\right)_{I=1} \Bigg/ \left(\frac{i_c}{i_0}\right)_{I=0,5} = 4,$$

where i_c is the value of a photocurrent under saturation; i_0 is the value of a dark current under some constant voltage.

In order to determine an influence of the dyes concentration on a photosensitivity of the polymer layer it is studied a dependence $i_{ph}/i_0 = f(t)$ for different concentrations of the rezazuryne (look Figure 4).

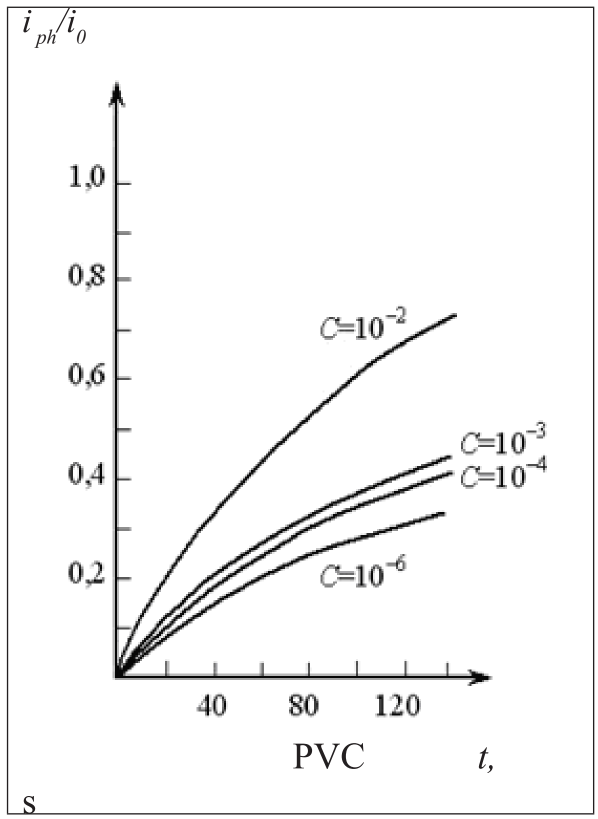

Figure 4a. Dependence $i_{ph}/i_0 = f(t)$ for different rezazuryne concentrations in matrix PVC

The obtained experimental data indicate on the quadratic (i.e. non-linear) relationship between photocurrent values that are obtained for two different levels of radiation intensities.

This phenomenon is characteristic for the two-quantum processes and confirms earlier obtained the results [5,6]. Note that when irradiated the sample through the filter UFS-1

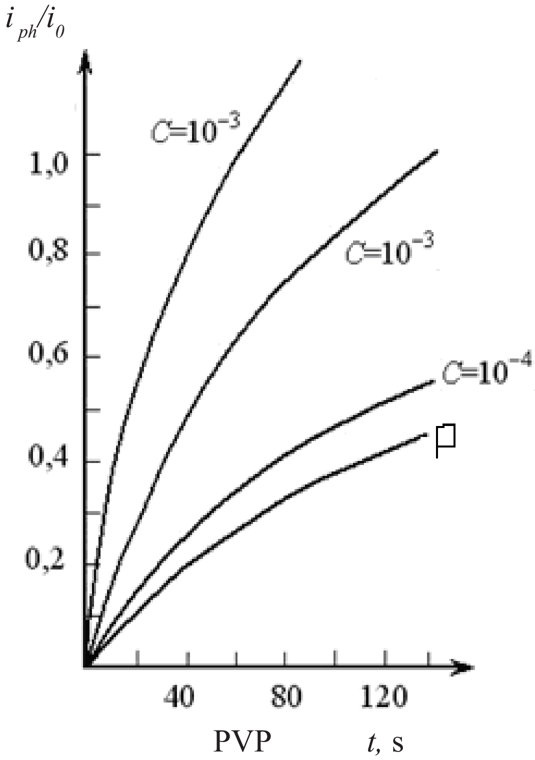

Figure 4b. Dependence $i_{ph}/i_0 = f(t)$ for different rezazuryne concentrations in matrix PVP (P- pure)

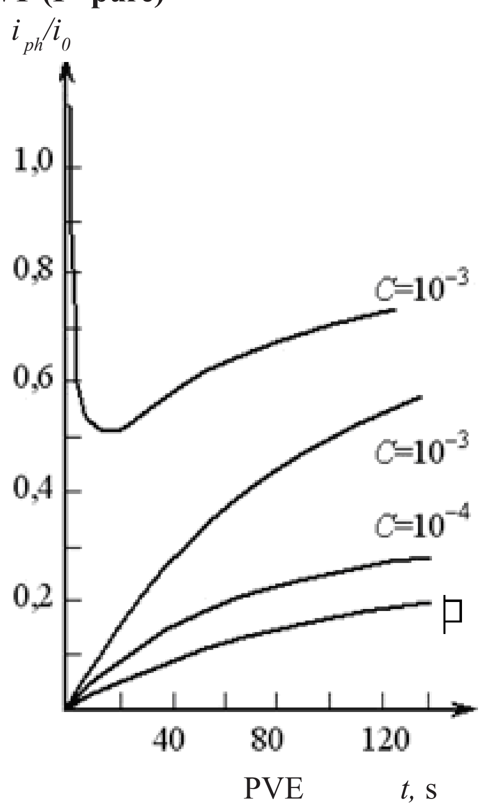

Figure 4c. Dependence $i_{ph}/i_0 = f(t)$ for different rezazuryne concentrations in matrix PVE (P- pure)

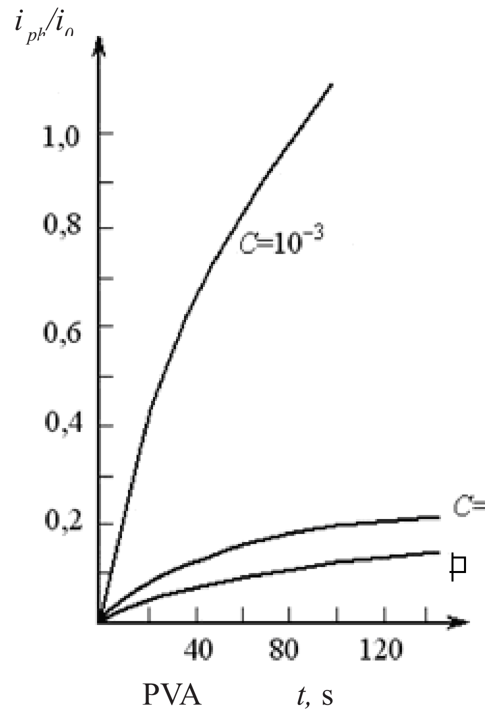

Figure 4d. Dependence $i_{ph}/i_0 = f(t)$ for different rezazuryne concentrations in matrix PVA (P- pure)

it is observed a linear dependence of a photocurrent on the intensity of exposure.

References

1. Kondratenko P.A., Photochemical action of light./ (Tutorial).- Kiev: Publishing center "Kyiv University".-2005.–401P.
2. Turro N., Molecular Photochemistry.- M.:Mir, 1967-328P.
3. Kondratenko P.A., Lopatkin Yu.M, Sakun T.N., Relaxation Processes in Highly Excited Molecules of Resazurin // Physics and Chemistry of Solids -2007.-Vol.8,№1.-P.100-108
4. Kondratenko P.A.,.Lopatkin Yu.M, Sakun T.N., Spectroscopic properties of the resazurin in liquid and solid solutions// Physics and Chemistry of Solids.-2006.-Vol.7,N4. – P.695-700
5. Becker H.G.O., Hoffman G. Israel G. Ionische und radikalische Dediazonierungen von Aryldiazonium-salzen

ein Beispiel für wellenlan-genab-häng-ige Photoreaktionen // J. Prakt. Chem. – 1977. – Vol.319, N6. – P.1021-1030.
6. Kondratenko N.P., Kondratenko P.A., Sensitization sensitivity diazonium salts // Scientific Notes of the Dragomanov's NPU. Ser. Phys.-Math.- 2001. - C. 83-88.
7. Kondratenko P.A., Lopatkin Yu.M., Kondratenko N.P. // Molecules with a Xe-O type interfragmentary bond. Diazonium salts and azides. // Functional Materials. – 2002. –Vol.9, N4.- P.713-720
8. Siliņš EA. The electronic states of organic molecular crystals. – Riga: Zinatne.-1978.- 344p.
9. Onsager L., Initial recombination of ions // Physical Reviews. – 1938. – Vol.54. – P.554–557.
10. Kondratenko P.A., Lopatkin Yu.M., Single and double quantum processes in solid solutions of dyes//Physics and Chemistry of Solids.-2004.-Vol.5, № 3.-P.474-480.
11. Kondratenko P.A., Maksimyuk V.A., Tantsyura L.Y., Two-photon processes in the methylene blue in photo-thermoplastic environment//Chemical Physics.- 1983.- N7.-P.955-962.
12. Dewar M.J.S., Zoebisch E.G., Healy E.F., Stewart J.J.P., AM1: A new general quantum mechanical molecular model//J.Amer.Chem.Soc.-1985.-Vol. 107, N3.-P.3902-3909.
13. Dewar M.J.S., Thiel W., Ground states of molecules. 38. The MNDO method. Applications and parameters // J. Amer. Chem. Soc.–1977.-Vol.99,N15.-P.4899 – 4907.
14. Glushkov A.V., Kondratenko P.A., Lepikh Ya.I. , Fedchuk A.P., Svinarenko A.A., Lovett L., Electrodynamical and quantum - chemical approaches to modelling the electrochemical and catalytic processes on metals, metal alloys and semiconductors//Int. Journ. of Quantum Chem.-2009.-Vol.109,N14.-P.3473-3481.
15. Glushkov A.V., Fedchuk A.P., Kondratenko P.A., Lepikh Ya.I., Lopatkin Yu.M., Svinarenko A.A., The Green's functions and density functional approach to vibrational structure in the photoelectron spectra: Molecules of CH, HF// Photoelectronics.-2011.-Vol.20.-P. 58-62.
16. Velikodnaya V.V., Kondratenko P.A., Lopatkin Yu.M., Glushkov A.V. , Sakun T.N., Kovalenko O.A., Quantum chemical studying the trimethine cyanine dye structure and relaxation dynamics// Photoelectronics.-2014.-Vol.23.-P.112-118.

This article has been received within 2015

UDC 539.186

P. O. Kondratenko, Yu. M. Lopatkin, A. V. Glushkov, T. N. Sakun

EXPERIMENTAL AND THEORETICAL STUDYING PHOTOCONDUCTIVITY OF POLYMERIC LAYERS WITH DYES

Abstract.
We present the results of the experimental and theoretical studying photoconductivity of polymer layers with the dyes. It's investigated photoconductivity of organic dyes in solid polymeric matrices with rectangular pulse excitation light. The obtained experimental data indicate on the quadratic (i.e. non-linear) relationship between photocurrent values that are obtained for two different levels of radiation intensities.
Key words: polymer layers with dyes, photoconductivity

УДК 539.186

П. А. Кондратенко, Ю. М. Лопаткин, А. В. Глушков, Т. Н. Сакун

ЭКСПЕРИМЕНАТЛЬНОЕ И ТЕОРЕТИЧЕСКОЕ ИЗУЧЕНИЕ ФОТОПРОВОДИМОСТИ ПОЛИМЕРНЫХ СЛОЕВ С КРАСИТЕЛЯМИ

Резюме.
Представлены результаты экспериментального и теоретического изучения фотопроводимости полимерных слоев с красителями. Приведены результаты исследования фотопроводимости органических красителей в твердых полимерных матрицах со светом (импульс прямоугольной формы). Полученные экспериментальные данные показывают квадратичное (т.е. нелинейное) соотношение между значениями фототока, полученными для двух различных уровней интенсивности излучения.
Ключевые слова: полимерные слои с красителями, фотопроводимость

УДК 539.186

П. О. Кондратенко, Ю. М. Лопаткін, О. В. Глушков, Т. М. Сакун

ЕСПЕРИМЕНТАЛЬНЕ ТА ТЕОРЕТИЧНЕ ВИВЧЕННЯ ПОЛІМЕРНИХ ШАРІВ З БАРВНИКАМИ

Резюме.

Представлені результати експериментального та теоретичного вивчення фотопровідності полімерних шарів з барвниками. Наведено результати дослідження фотопровідності органічних барвників в твердих полімерних матрицях зі світлом (імпульс прямокутної форми). Отримані експериментальні дані показують квадратичне (тобто нелінійне) співвідношення між значеннями фототока, отриманими для двох різних рівнів інтенсивності випромінювання.

Ключові слова: полімерних шарів з барвниками, фотопроводимість