THE WAYS of DECREASING of CHARGER CARRIERS RECOMBINATION in ORGANIC HETEROSTRUCTURES

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In this report we review the work carried out during four last years in the Laboratory of Photovoltaic (Department of Molecular Photoelectronics in Institute of Physics, NAS of Ukraine). The review deals with the study of the properties of the films and the heterostructures (HS) that can be used for organic solar cells. In this work we paid special attention to the ways of decreasing of the rate of charger carriers recombination (*S*) at the interface of the HS and on the surface of HS components.

We have studied the morphology, absorption and photovoltage spectra of the films (n-type) N, N` - dimethyl perylene-tetracarboxylic acid diimide (MPP), dichlorotinphthalocyanine ($SnCl_2Pc$), (p-type) hexathiopentacene (HTP), aniso-type (p-n) and iso-type (p-p) HS of these films with pentacene (Pn) and lead phthalocyanine (PbPc) layers. The structures were prepared by thermal deposition at different substrate temperatures (*Ts*).

In spite of low change of absorption spectra for MPP and HTP films with *Ts* increasing from 300 to 370 K the photovoltage of the films rise in some times. It can be associated with increasing of diffusion length of excitons and decreasing of *S*, subsequent upon the improvement of structure ordering of crystallites in the films. At *Ts* increasing up to 410 K the photovoltage decrease because the increase of structural defects number, subsequent diffusion length of excitons decreasing and increasing of *S*.

Double layer aniso-type HS based on MPP (or $SnCl_2Pc$) layers with Pn, HTP, PbPc are photosensitive in spectral range that widen in the line: MPP/Pn → MPP/HTP → MPP/PbPc. The deposition of Pn layer on free surface of $SnCl_2Pc$ [1] (MPP [2]) and preparing of HS result in the rise of the photovoltage from 10 to 90 times in comparison with the photovoltage of components. The photovoltage increases in the range of strong absorption of both layers of HS that is evidence of formation of sufficient barrier and according built-in electric field at the interface. As result the efficiency of charge carriers formation increase in the range of space charge of heterojunction. The highest photovoltage was observed for MPP/Pn, $SnCl_2Pc$/Pn, PbPc/MPP HS that witness to prospect of development of organic solar cells based on these structures. As well as the spectral range of photosensitivity for PbPc/MPP HS are wider, than for organic HS based on MPP and ZnPc (or TiOPc) and are close to spectral photosensitivity of Si-photocell.

Photovoltage spectra correlate with absorption spectra for studied aniso-type HS, while for HS components the photovoltage does not change (or even decrease) with increasing of absorption in the range of strong absorption [1,2]. This is the evidence of sufficient decreasing of *S* at the interface of HS. The photovoltage of HS in accord with the height of potential barriers determined using Anderson model, which does not take into account surface states.

The properties of iso-type Pn/PbPc HS prepared at *Ts* = 300 K are well described by model of two Schottky diodes engaged towards that testify the formation of high *S* at the interface. The photovoltage is significantly higher and *S* is lower at the interface of Pn/PbPc HS prepared at *Ts* = 370K in comparison with HS obtained at *Ts* = 300K. Therefore, these HS can be used for creation of p-p+ junctions in multi-layer organic solar cells to increase of charge carrier photogeneration.

Thus, studied aniso- and iso-type HS based on MPP, Pn, PbPc, $SnCl_2Pc$ prepared at *Ts* = 370 K are perspective elements for development of organic solar cells.

[1] P. Lutsyk, J. Misiewic, A. Podhorodecki, Ya. Vertsimakha, Photovoltaic properties of $SnCl_2Pc$ films and $SnCl_2Pc$/pentacene heterostructures, *Solar Energy Materials and Solar Cells* **91**, 2007, p. 47-53.

[2] Ya. Vertsimakha, P. Lutsyk, p-n type heterostructures based on N, N`-dimethyl perylene-tetracarboxylic acid diimide, *Molecular Crystals and Liquid Crystals* **467**, *2007*, p. 107-122.