Organic photodetective device based on metal phthalocyanine

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Abstract. During the work, organic photosensitive structures were created. The photosensitivity spectra of the samples were analyzed. According to the spectrum of photosensitivity, were made assumptions about possible transitions that take place in structures.

1. Introduction
In the 21st century, humanity faced with a problem of depletion of organic fuel sources. In the future, the resource of such minerals as oil, coal, gas will be exhausted, so the issue of obtaining energy from alternative sources is actual. In the future, out of all available sources, one of the most capacious is the energy of the Sun, coming to the surface of the Earth in huge numbers, many times exceeding the humanity’s global needs. For converting it, we use solar panels. Each year their efficiency increases. To replace silicon batteries, new materials and types of structures come. The most interesting alternative to silicon batteries are organic materials, because they allow you to create flexible structures that are easy to create, as well as cheaper and more environmentally friendly. In addition, the level of development of modern chemistry will create materials with the necessary properties [1].

Organic photosensitive structures can be divided into 2 groups: the elements in which the photoactive elements are applied by separate layers - the structures of the layered type.

Fig. 1 - Diagram of the layered type structure (on the left) and a diagram of a structure with a bulk heterojunction (on the right).

The second group includes elements in which only one photoactive layer, which is a mixture of n- and p-types of electrical conductivity, called structures with a bulk heterojunction. Under the influence of electromagnetic radiation, a photoinduced transfer of electrons from the donor to the acceptor occurs, this phenomenon does not depend on the type of the photosensitive structure. But in elements of a...
layered type this process occurs at the boundary of the donor and acceptor material. In elements with a bulk heterojunction, charge redistribution occurs throughout the entire volume of the active layer. After the separation of charges, it is necessary to prevent the recombination of the charge carriers and to place them on the electrodes. In structures of layered type, electrons and holes can freely move to the electrode in the layer of acceptor and donor materials, respectively. The probability that charge carriers will fall into a layer with opposite electrical conductivity is extremely small, and as a consequence, the probability of recombination is small also. The suppression of recombination and charges transport in structures with a bulk heterojunction is realized only with a clear donors ordering and acceptor phases. [2]

2. Experiment

Device design and fabrication
The structures were based on FTO (Fluorine-doped Tin Oxide)/CuPc (Copper(II) phthalocyanine)/PTCDA (Perylenetetracarboxylic dianhydride)/Al and FTO/ZnPc (Zinc phthalocyanine):C60 (Fullerene)/C60/Al, deposited on a glass substrate. Layers of organic materials and aluminum contact have deposited by vacuum thermal evaporation at a residual gas pressure $2 \cdot 10^{-5}$ torr. During the sputtering process of organic layers, the substrate was heated to 60 °C, and when the metal contact was applied, the substrate temperature was maintained at 70 °C.

Measurements and results
For created structures, were explored the spectrum of absorption and transmission, the I-V characteristic, and the photosensitivity spectrum, which received the highest attention. Investigation of the photosensitivity spectrum is extremely important, because of for maximal range of solar radiation, the sensitivity spectrum of the solar cell should be similar to the spectrum of the solar radiation. The photosensitivity spectra were studied using a diffraction grating monochromator and Keithley 6483 picoammeter, an incandescent lamp was used as a radiation source.

The dependence of the photosensitivity on the wavelength for FTO / CuPc / PTCDA / Al type structures has 4 peaks, the first peak corresponds to a wavelength of 535 nm, the peak width at half-height is in the wavelength range from 481 nm to 591 nm, it corresponds to the absorption in the PTCDA layer. The second peak lies at a wavelength of 648 nm, whose half-width lies in the wavelength range from 632 nm to 688 nm, it is probably associated with indirect interband transitions. The maximum of the third peak is at wavelength of 754 nm, the width of the peak is at half-height 92 nm (716 – 808 nm), is related to absorption in the CuPc layer. The fourth peak corresponds to a wavelength of 1106 nm, the width of the peak is at half-height from 1078 nm to 1128 nm. The short-wave edge of photosensitivity (0.05) is at a wavelength of 446 nm, and the long-wavelength edge is at a wavelength of 1135 nm. But the lack of this structure is low sensitivity in the yellow-red region of the spectrum. Therefore, in the future study, materials with high sensitivity are used in this wavelength range.
The photosensitivity spectrum of FTO / ZnPc: C60 / C60 / Al structures has 3 peaks. The first corresponds to a wavelength of 627 nm, its width at half-height lies in the wavelength range from 623 nm to 649 nm. The second peak occurs at a wavelength of 693.5 nm, the half-height of this peak lies in the range of 683 - 705 nm, it corresponds to the absorption in the layer of a mixture of fullerene and zinc phthalocyanine. The last maximum is at a wavelength of 944 nm, its width at half-height 833 - 1008 nm corresponds to the absorption of light by zinc phthalocian. However, the structure under consideration has a dip in the near-IR region, a thin layer of Bphen (batofenantroline) was added to its structure for eliminating of a dip.

Introduction to the FTO/ ZnPc: C60/ C60/ Bphen/ Al structure of the additional Bphen transport layer has gave a possibility to lower the values of the barriers that arise at the interface of the layers and improve the collection of photocarriers. As a result, a structure with a high sensitivity in the range of 450-1 1150 nm was obtained. Two maximum are observed on the photosensitivity spectrum of the FTO/ ZnPc: C60/ C60/ Bphen/ Al structures. The first peak corresponds to a wavelength of 597 nm, its width at half-height is in the range from 573 nm to 635 nm. The maximum of the second peak is located at 698 nm, the peak half-width covers a significant wavelength range, in the red and infrared region, at 677 nm - at 948 nm. The maximum of the second peak is located at 698 nm, the peak half-width covers a significant wavelength range, in the red and infrared region, at 677 nm - at 948 nm. The short-wave edge of photosensitivity (0.05) is at a wavelength of 455 nm, and the long-wave edge is at a wavelength of 1160 nm.
Fig. 4 - Spectrum of photosensitivity of structures of the type FTO/ZnPc:C60/C60/Bphen/Al.

The features of the obtained dependences from the spectral position of the sensitivity extrema are determined by the band diagram of researched materials and qualitatively consistent with the optical transmission spectra of the deposited layers.

3. Conclusion
Prototypes of organic solar cells based on FTO / CuPc / PTCDA / Al and FTO / ZnPc: C60 / C60 / Al structures have been created and investigated in the work. They have achieved a significant increase in the efficiency of solar radiation conversion using to optimization of transport layers and introduction into the organic matrix inclusions of fullerene. The creation of an energy barrier for holes by the introduction of the Bphen layer prior to the deposition of the Al layer substantially increased the width at half-height of the photosensitivity spectrum, increasing the coefficient of solar energy’s conversion into electric energy. The resulted structures can be used as an alternative energy source.

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References
[1] Egidius R R 2017 International Journal of Photoenergy vol 2017
[2] Toroshin P A, Lyubovskaya R N, Razumov V F 208 Reviews. Russian nanotechnology vol 3 pp 56 - 77