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ELECTRON MICROSCOPY STUDY OF VACUUM DEPOSITED ORGANIC THIN FILMS

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Abstract: In the paper thin films of zinc phthalocyanine (ZnPhTc), perylene tetracarboxy diamine (PTCDA) and fullerene (C_{60}) are studied with the view to their application as active layers in organic solar cells (OSC). The microstructure and surface morphology of the films are observed by transmission (TEM) and scanning (SEM) electron microscopy. Their polycrystalline structure is established and visualized in TEM by the bright field imaging and selected area electron diffraction (SAED). The mean size of crystallites varies from 20 to 70 nm in different compounds. A presence of texture is clearly seen for fullerene layers. The column growth and the typical fullerene crystal structure with 5-member and 6-member carbon rings are demonstrated by means of SEM. The study of the microstructure is very important with regard to the fact that the structure defects, interfaces and grain boundaries are traps for the electric charges – electrons and holes, and thus they influence the efficiency of the optoelectronic devices.

Keywords: vacuum deposited organic films, microstructure, solar cells

1. Introduction

An essential challenge to photovoltaics is the development of high-efficiency and low-cost structures. The probability to achieve these goals has been increased in the last few years due to the combination of theoretical and material progress, particularly by improved understanding of the processes occurring during the light and matter interaction [1,2]. This allows the introduction of new materials – dyes, organic low weight materials, polymers, in the study and already in the production of solar cells for application in mobile phones, cameras, watches, etc. The new materials are attractive not only with almost unlimited number of compounds but also because of their low costs. Regardless of their organic character, some of the materials posses a significant thermal stability, permitting the evaporation in vacuum and formation of thin films compatible with the vacuum deposition technology. This technology is of great importance for the production of the electronic devices, since it offers some advantages over the alternative "wet" methods – the absence of a chemical solution, reduction of the residual atmosphere during the films formation, easier control of the film deposition processes, etc. [3].

In 1986 Tang [4] created a device, which carried out a hetero-junction between donor and acceptor organic semiconductors, resembling a p-n junction in conventional solar cell. To understand the role of each component of the OSC it is necessary to follow the processes after illumination. The simplest OSC can be made by sandwiching thin films of organic semiconductors between two electrodes with different work functions – Fig. 1a. As a consequence of the light absorption, electrons are excited in the conduction band (Fig.1b, stage 1, e^- points) and holes (positive-charge carriers) appear in the valence band (Fig.1b, h^+ points). Both carriers interact and usually build the excitons [5]. They diffuse in the active layer and under the influence of the existing electric field pull the photogenerated electrons to the low-work-function electrode from Al (stage 2 -3) and holes to the high-work-function electrode from indium thin oxide (ITO), thereby generating a current. The parameters of the created excitons, holes and electrons – diffusion lengths, times of life, influence the degree of the conversion efficiency of the cells. Simultaneously, it is well known that on the surface and in the volume of the thin films numerous structural and mechanical defects exist, like fractures due to the presence of prickles from the substrates. All of the defects influence the growth of the bottom and the upper film and all of them favor the creation of the traps for electrons or holes. The presence of the defects and traps is a consequence of the production conditions like the purity of the initial substances, the reproducibility of the composition and structure of the active layers etc. We have already studied the influence of the thickness and the type of the substrate on the surface structure [6]. Therefore, the aim of the present paper is to investigate the surface structures and the films growth for different dyes and fullerene – $C_{60,}$ as prerequisites to prepare layers with reproducible composition and structure as preliminary conditions for producing active layers for OSC with improved parameters. In the next step of the study we will try to show the influence of the structure on the electrical parameters of the cells.

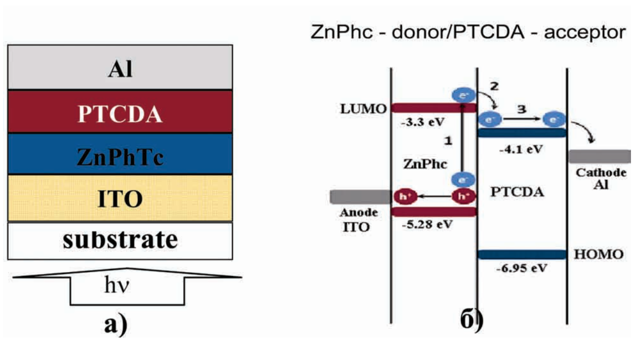

Figure 1. Principal scheme of the hetero-junction organic solar cell (a) and the electronic scheme of the ZnPhTc and PTCDA (b), LUMO – lowest unoccupied molecular orbital and HOMO - highest occupied molecular orbital.