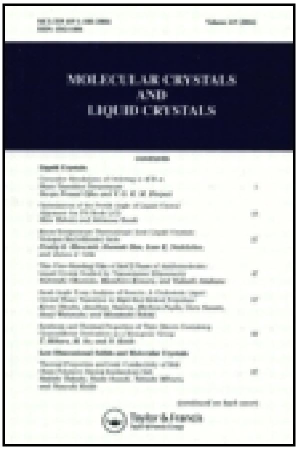

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PHOTOVOLTAIC PROPERTIES OF C_{60}/LIQUID CRYSTAL COMPOSITES AND HETEROSTRUCTURES

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An increase of the photovoltage was found in LC/C_{60} composites and heterostructures comparing C_{60} film in the 2–3 eV range, where two charge transfer states (CT-states) at 2,4 eV and 2,7 eV are present in C_{60}. A sufficient increase of an intensity and area for 2,4 eV CT-band is observed for the composite sample, while HS photovoltage rises more strongly at the region of 2,7 CT-band.

Band gap values estimated from the comparison of photovoltage spectra of C_{60}/LC composite and heterostructure with photovoltage of C_{60} film were following: 2,18 eV for the composite and 2,26 eV in the case of heterostructure.

The origin of observed effects has been discussed.

Keywords: composites; heterostructures; liquid crystals; fullerene; photovoltage and band gap

INTRODUCTION

An increasing attention has been given over last years to investigations of physical properties of composites and heterostructures (HS) [1–8]. These studies have been focused on LC–polymer composites [1,2], LC–colloid particles composites [3,4] and photosensitive molecular crystal–polymer composites [5,6] as well as LC HS [7,8].

The interest to the investigation of composites is the result of their possible application, e.g., as materials for information recording [2,3], in displays [1–4,8], photosensitive devices [5,6] etc.

It has been found that properties of composites and HS aren't the sum of properties of components and they are enhanced in comparison with those of pure components [1–8]. So parameters of structures obtained are improved.

The aim of present paper is to investigate processes in C_{60}/LC composites and HS.

EXPERIMENTAL

To prepare composites and HS as photosensitive component we used fullerene C_{60}. The nematic LC 5CB was used in the preparation of composite and HS samples, also nematic LC mixture BL055 (LC Licrilite®,Merck Ltd.) was used to prepare some HS samples. Composite samples were prepared by mixing fine powdered crystallites of C_{60} (33 weight %) and LC (67 weight %) at 300 K. The mixture was placed in a cell between two glass plates with deposited SnO_2-electrodes. Samples thickness (10 μm) and area (8 × 10 mm) were set by teflon spacers. Freshly prepared samples were homogeneous, as was confirmed by measurements of photovoltage (V) in the strong absorption region under the excitation from different sides of the sample: the difference of V was inferior to 10%. Photosensitive C_{60} layer of HS were prepared by vacuum deposition onto glass substrates coated with SnO_2 transparent electrodes. Temperature of substrate was ~300 K. C_{60} and LC layers thickness was set equal to 0,1–0,4 and 10 microns, respectively.

Cells containing C_{60} film only, having the same parameters (thickness, area etc.) as those made of LC heterostructures, and insulator teflon dielectric layer between film and top electrode,[9] were also prepared for comparison.

Spectral dependences of the photovoltage were measured in all samples by illuminating them with modulated light ($f_{mod} = 80$ Hz). Iodine lamp (120 W, ≪Hitachi≫) was used as light source. Photovoltage (V) was measured with a lock-in nanovoltmeter UNIPAN 232B, supplied with a 233-7 preamplifier (10^9 Ohm). All photovoltage spectra were normalized to the equal number of incident photons. The experimental setup and measurement technique have been described in more detail in [10].

RESULTS AND DISCUSSION

Figure 1 shows spectral dependence of absorbance (curve 1) and photovoltage (curve 2) of C_{60}. From Figure 1 it is seen that the spectrum of film photovoltage is generally similar to absorption spectrum with the change in the ratio of bands intensity.

Figure 2 shows spectra of photovoltage for C_{60} cell (curve 1), C_{60}/LC heterostructure (curve 2) and composite (curve 3). Photovoltaic response of HS and composite is sufficiently greater by an absolute and relative value comparing C_{60} film containing cell. It can be seen in Figure 2. Averaged values of V relative increase determined as the ratio of $\int VdV$ for composite and HS and $\int VdV$ of corresponding film (areas under curves in Fig. 2) are ~1,2 for HS, and 1,27 for composite. It should be noted that going from

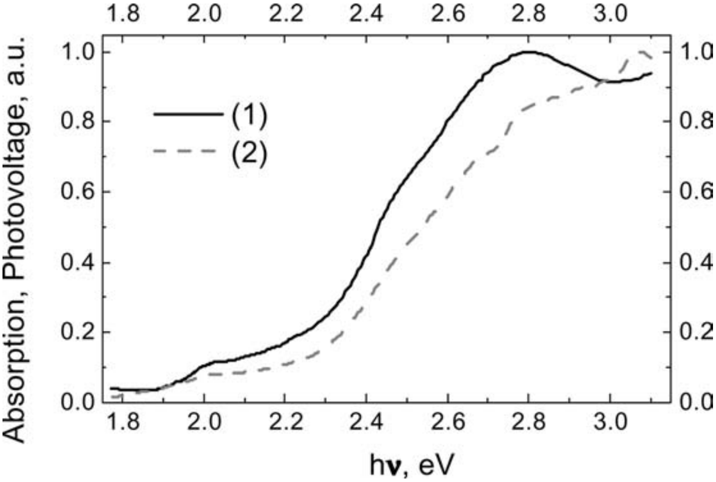

FIGURE 1 Spectral dependence of absorption for C_{60} film (1) and photovoltaic response of C_{60} cell (2).

thinner to more thick layers, which used as components of HS, the increase of photovoltaic signal is observed. This is caused by the increase of bulk component deposit (so called Dember voltage) and by the change of surface properties with thickness. Maximal photoresponse for HS is observed

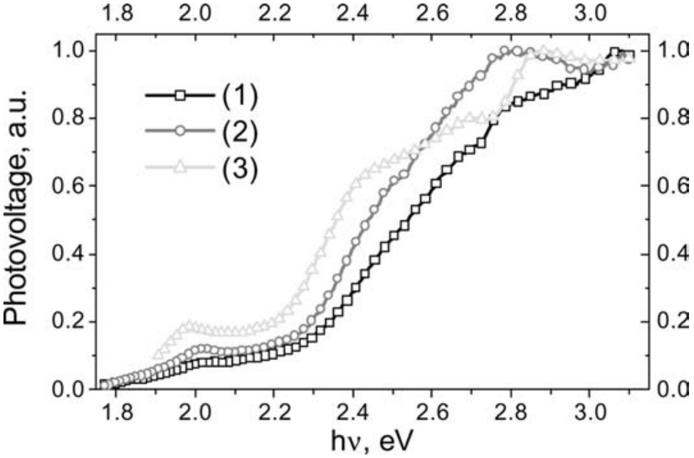

FIGURE 2 Spectral dependence of photovoltage for C_{60} cell (1), C_{60}/LC heterostructure (2) and composite (3).

by illumination from LC side that evidences about a sufficient deposit into photovoltaic signal of a near-interface (LC/C_{60}) region.

Spectral region of the increase is 2,2 eV – 3 eV (Fig. 2). According to [11] two charge transfer states (CT – states) are observed in this region for C_{60}. The energies of CT-states estimated by electroabsorption measurement are c.a.2,4 eV and 2,7 eV.[11] Detailed analysis of an electronic scheme of C_{60} was made in.[12]

The photovoltage increase observed in LC composites and HS in this region can be explained by an enhancement of the internal electric field at the interface between MC/LC due to a high electric permittivity of LC, the thickness of the space charge region at the interfaces should significantly decrease.

To clarify the change observed in the energy position of peaks we provided detailed Gaussian deconvolution of both absorption and photovoltage spectra of C_{60}/teflon cell, HS and composite. As starting parameters we used values from energy diagram of solid C_{60} presented in.[12]

Figure 3 shows the Gaussian fitting of photovoltage spectrum of C_{60} containing cell together with elementary Gaussian.

Table I summarizes the results of all deconvolutions. The main conclusion from the Table is the fact that area under elementary curve (S) for ~2,4 eV CT – band is maximal for composite cell while for ~2,7 eV band the maximal band area is observed for C_{60}/LC HS.

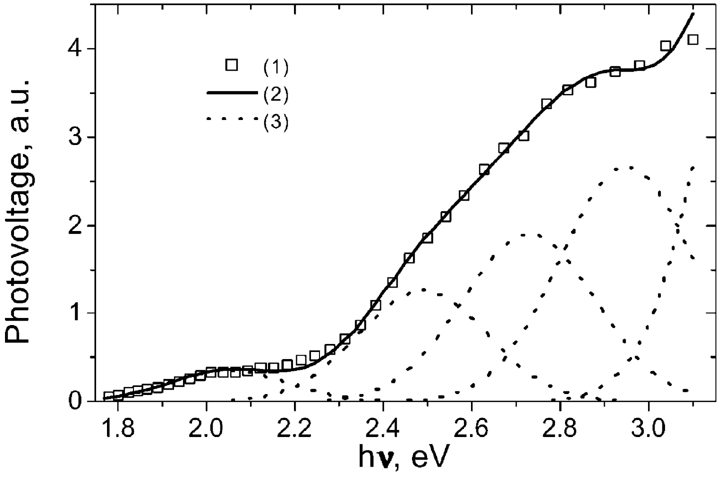

FIGURE 3 Spectral dependence of C_{60} photovoltage (1) Gaussian fit (2) and component of fitting (3).

TABLE 1 Values of Relative Areas of Bands (Areas under Elementary Curves – S) for Investigated Structures

Structure		Peak position				
		2,05	2,46	2,73	2,95	3,30
Composite	S, %	5.6	17.6	16.7	21.4	39.8
C_{60} film		2.5	9.7	15.1	21.1	51.7
Heterostructure		2.4	13.9	22.2	20.3	41.2

Since both V and ΔV depend in the same way on the number of absorbed quanta, then the ratio ΔV/V ratio should not depend on absorbance, being proportional to the quantum efficiency of photogeneration (β). According to [13] it is possible to determine E_g of MC by extrapolation of the linear section of $\beta(h\nu)$ dependences.

In previous paper [14] we described the estimation of band gap E_g for organic solid films, using ΔV/V ratio, where ΔV is difference between V of composite (or HS) and V of film (powder) of organic photoconductor. We have shown [14] that such technique gives values of E_g, which are close to

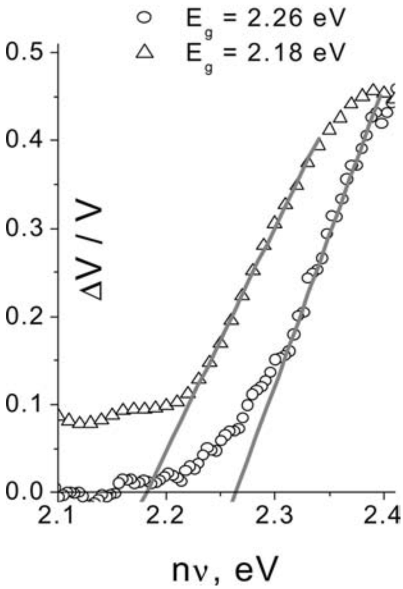

FIGURE 4 ΔV/V dependence determined for C_{60}/LC heterostructures (circles) and composite (triangles). Lines show the extrapolation of linear parts of dependences.

the values determined independently for different phthalocyanines, acenes and their derivatives.

It can be seen in Figure 4 above procedure gives following values of E_g: 2,18 eV for the composite and 2,26 eV in the case of HS.

The difference between two values can be explained by the different area of the effective interfaces. Such area in the case of composite is equal to the sum of local interfaces areas and significantly greater than area of the interface in HS. This naturally leads to some re-distribution in the deposit of different mechanisms of photogeneration to the photovoltage value.

The 2,26 eV value is close to the value of E_g determined by surface photovoltage measurements, and 2,18 eV is most close to the value estimated from photoemission studies [15].

CONCLUSIONS

1. An increase of the photovoltage (significantly exceeding than that of C_{60} film) was found for the first time in LC composites and HS in the region of CT-states.
2. This increase can be caused by the influence of LC and namely by the enhancement of an intrinsic electric fields at the C_{60}/LC interface in HS and C_{60}/LC local interfaces in the composite, due to higher electrical permittivities of the latter components.
3. The values of E_g estimated from photovoltage studies of C_{60} films, LC composites and heterostructures are correlated with E_g value of C_{60} determined by other methods and measurements.

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