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# The influence of optical absorbing layer thickness on measurement accuracy in inverted structure organic position-sensitive detectors

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**Abstract**

**The influence of the organic optical absorbing thickness on measurement accuracy is investigated in one-dimensional organic-sensitive detectors using Al doped ZnO resistive layer. The linearity has been increased as the optical absorbing layer becomes thicker and the maximum measurement error has been improved by increasing the sensitivity of the active layer.**

## 1. Introduction

Organic optoelectronic conversion devices are expected to be the opto-electrical conversion elements such as solar cells and optical integrated circuits on a flexible substrate[1-9], and they have been studied for their high-speed response and application areas, making use of their advantages such as light wavelength selectivity and the flexibility of the organic material is important. In addition, the application to an optical imaging sensor device has been studied[9]. However, a complex manufacturing process is necessary, e. g., micro fabrication of the organic thin film, and practical application is difficult. Therefore, we suggest stacking of the position-sensitive detector having sensitivity to monochromatic light using organic semiconductor materials, thereby realizing an imaging sensor device that is flexible with an extremely simple structure. In our experiment, the position detection sensor is prepared with a copper phthalocynanine CuPc: fullerene $C_{60}$ bulk-heterostructure having sensitivity of red light, and we report the characteristics of the device with inverted structure using Al-doped ZnO (ZnO:Al). The metal oxide such as ZnO and $TiO_2$ has been used as an electron transport material or electron-collecting material in the inverted structure organic solar cells. Using meal oxide as a cathode electrode is effective to prevent the active layer from photo-induced diffusion of $O_2$ by UV irradiation and air exposure. The use of ZnO layer in the solar cell with inverted structure, such as ITO/ ZnO/ $C_{60}$ /CuPc/ PEDOT:PSS/ Ag, improves electron collection as a result of the lowering of Fermi energy level at the cathode.

The position sensitive detector consists of two electrodes, a surface resistance layer, an optical absorbing layer, and a common electrode. In this study, ZnO:Al with reduced resistivity by doping Al to ZnO was prepared by sol-gel method, and used for electron collecting layer and surface resistance layer of the devices.

## 2. Experimental

Inverted device structures of ITO /ZnO:Al/ CuPc:$C_{60}$(1:1) /CuPc /$MoO_x$ /Ag were fabricated on an ITO-coated gralls substrate, as shown in Fig. 1. Two of the ITO output electrodes, which were separated by 5 mm, were fabricated by lithography within a width of 100 μm. A 450-nm thick ZnO:Al resistive layer was deposited by the sol-gel method.

The measured beam position d is calculated by the following equation:

$$d = \frac{I_2}{I_1 + I_2} L \qquad (1)$$

where $I_1$ and $I_2$ are the output photocurrents at either side of the device, and $L$ is the total device length.

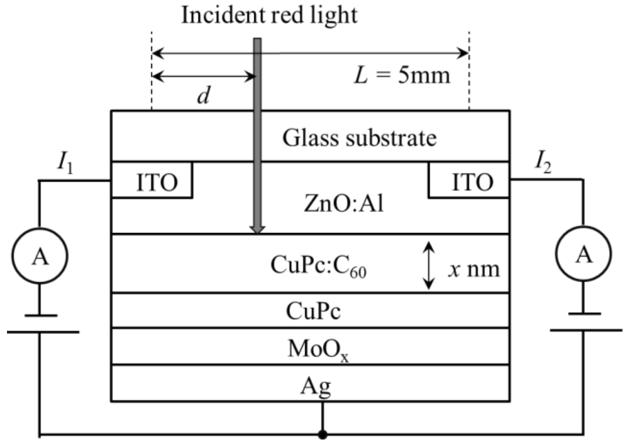


Fig. 1 Schematic diagram of the inverted organic position-sensitive detector with optical absorbing layer CuPc:$C_{60}$. Incident red light were illuminated by an optical fiber LD (SM 9μm/ 125μm)

Fig. 2 shows the actual incident beam position versus the measured beam position from the center of the ITO output electrodes at an applied electic field of -20 MV/m. The ideal liner response is shown by a solid line. The measured beam position is calculated by the eq. (1). Table I shows the results for each linearity error. The linearity error $\delta$ is obtained by

$$\delta = \frac{2\sigma}{a} \qquad (1)$$

where $\sigma$ are the output photocurrents at either side of the device, and L is the total device length. The linearity error δ is obtained by

$$\sigma = \sum_{k=1}^{b} \sqrt{\frac{X_k^2}{b}} \qquad (2)$$

where, $X$ represents the difference between the theoretical value and measured value.

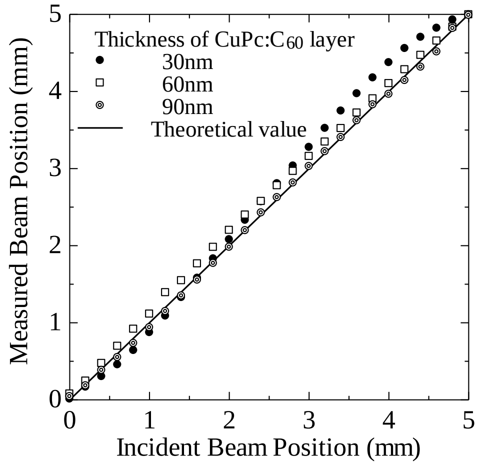


Fig. 2 Dependence of position detection error on incident light position for different thicknesses of CuPc:$C_{60}$ layer at an applied electric field of -20MV/m and at incident beam power of 327 mW/cm$^2$.

Table I Dependence of position detection error on incident light position for different thickness of CuPc:$C_{60}$ layer

| Thickness of CuPc:$C_{60}$ layer | Detection error rate at applied bias of -20MV/m | Detection error rate at applied bias of -2V |
|---|---|---|
| 30 nm | 9.3 % | 8.8 % |
| 60 nm | 5.6 % | 5.3 % |
| 90 nm | 1.7 % | 2.0 % |

From the results in Fig. 2 and Table I, it was found that the linearity increases as the light asorption layer becomes thicker. This result seems to be caused by an increase in the amount of electric chage generated with respect to electric chage lost before the generated photocurrent reaches the electrode.

## 3. Conclusions

In this study, we fabricated one-dimensional inverted structure organic position sensitive detectors, and we investigated the measurement linearity of the devices with the recombination loss model in the interface between the resistive layer and active layer. Although low linearity of the measurement accuracy by the charge traps and recombines to be taken out to the output electrodes has been a major issue for practical use, a maximum measurement error has been improved by increasing the sensitivity of the active layer.

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