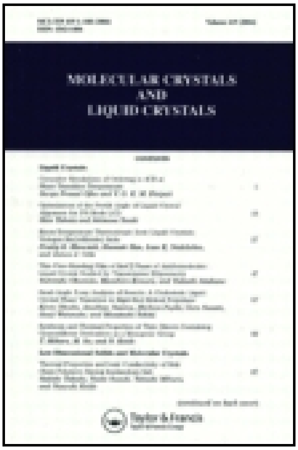

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Optical and Electrical Properties of Multi-Layered Organic Cells

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Version of record first published: 04 Oct 2006

Mol. Cryst. Liq. Cryst., 1997, Vol. 295, pp. 55–58
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OPTICAL AND ELECTRICAL PROPERTIES OF MULTI- LAYERED ORGANIC CELLS

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Abstract We have fabricated photoelectric cells using multi- layered organic dyes and evaluated their photoelectric properties. These cells have both functions of color filtering and bias voltage dependence of the dissociation of photoexcited excitons. The photocurrent spectral sensitivity of the multi- layered cells can be controlled by the bias voltage.

INTRODUCTION

Recently, photoelectric cells using organic dyes have attracted much attention because of their peculiar characteristics. In the study of photovoltaic cells, C.W.Tang have reported the high photovoltaic conversion efficiencies (more than 1%) of two layered organic cells using phthalocyanine and perylene derivatives. [1] K.Kudo et al. reported that the photocurrent spectral sensitivity of the three layered cell using inorganic and organic materials was changed by the external bias voltage. [2] In the present work, we have fabricated multi- layered cells using p- , n- type organic dyes and evaluated their photoelectric properties comparing with the simulation results of a carrier generation model in the layered organic cells.

THEORETICAL SECTION

The photocurrent in multi- layered cells is generated at near the p- n heterojunctions and Schottky contact. The mechanism of carrier generation for organic semiconductors is not as simple as that for inorganic semiconductors. Because the photoexcited excitons play a dominant role in organic layers. Therefore the dissociation of excitons need enough electric field and can be changed by the external bias voltage (voltage dependence of dissociation of photoexcited excitons). Furthermore, the organic dye layers work as the optical filter as well as the photoactive layer for the carrier generation. These functions can be utilized the design of the spectral sensitivities in photovoltaic cells. We employed the equation of carrier generation in organic layers in a similar manner reported by A.K. Ghosh et al. [3] and K.Yamashita et al. [4]

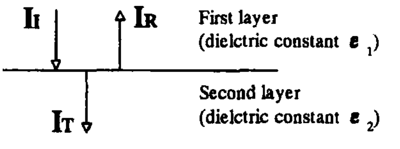

Figure 1 Light transmission and reflection at the junction. I_I, I_T and I_R are intensity of incident,transmission and reflection light.

For normal incident light, the transmittance T and reflectivity R in energy are expressed by

$$T=|I_T|/|I_I|=(\varepsilon_1/\varepsilon_2)^{1/2}\cdot|t|^2$$

$$R=|I_R|/|I_I|=|r|^2$$

where t and r are the Fresnel's coefficient for transmission and reflection light, respectively. Figure 1 shows light transmission and reflection at the junction.

EXPERIMENTS

P-type and n-type organic dyes used in the present work are phthalocyanine derivative(CuPc), quinacridone derivative(QC) and perylene derivative(PTCDI). Their chemical structures are shown in Figure 2. Organic dye films and metal electrodes are formed by a standard vacuum evaporation technique. The structure of the cells is shown in Figure 3. Optical absorption spectra and photocurrent spectra under the several bias voltages are measured. Current-voltage characteristics under the dark and illuminated states are also measured.

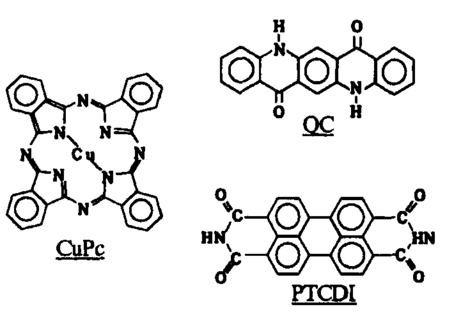

Figure 2 Chemical structures

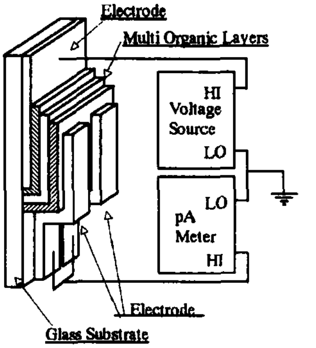

Figure 3 Cell structures

RESULTS AND DISCUSSION

Thickness Dependence of Organic Layers on Photocurrent Spectra

Figure 4 shows the photocurrent spectra in the Au/CuPc/PTCDI/Al/glass cell. In this case, the thickness of PTCDI is changed(25, 65, 95nm) and that of CuPc is fixed(70nm). Optical absorption spectra of each layer are also shown in Figure 5. The photocurrent decreased gradually with increasing the thickness of PTCDI, and the photocurrent peak shifts toward longer wavelengths. A reasonable explanation for these phenomena is that the light intensity arrived to the photoactive CuPc/PTCDI heterojunction decreases with the increasing the thickness of PTCDI and the optical absorption spectra of PTCDI change sharply around 600nm.

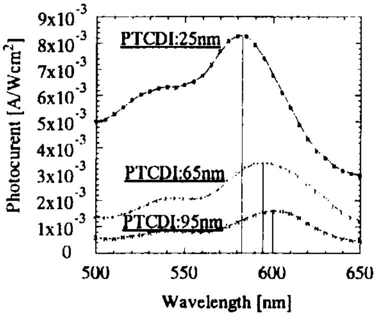

Figure 4 Photocurrent spectra

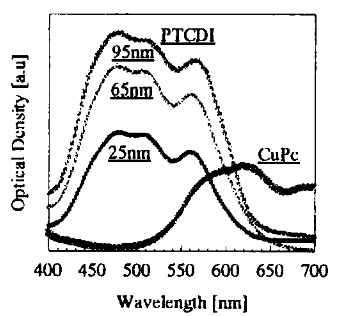

Figure 5 Optical absorption spectra

Optical and Electrical Properties of pnp Cell

The multi-layered organic cell has a p-n-p layered structure of Al/CuPc/PTCDI/QC/ITO. The thicknesses of the CuPc, PTCDI and QC layers are 70, 65, 120nm, respectively. Optical absorption spectra of each organic film are shown in Figure 6. In the multi-layered cell, the Al/CuPc junction is a Schottky contact, the QC/ITO junction is a Ohmic contact and CuPc/PTCDI, QC/PTCDI junctions are p-n heterojunctions. Figure 7 shows the photocurrent spectra of the cell for light incident on the ITO side. The positive bias is defined as the positive voltage applied to the ITO electrode and the positive current flows toward Al electrode through an external circuit. In the case of positive bias, the photocurrent spectra have a peak sensitivity at 600nm. For negative bias, however the peak shifts toward 640nm. In this structure, the dissociation of photoexcited excitons will occur at the Al/CuPc Schottky contact and CuPc/PTCDI, QC/PTCDI p-n heterojunctions.
In order to determine the dominant junction for the dissociation of excitons, we analyzed the photocurrent spectra using the photogenerated carriers calculated by the

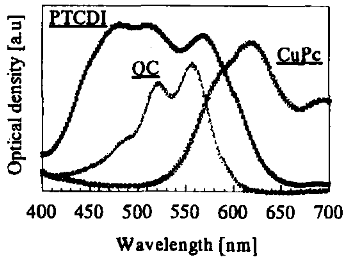

Figure 6 Optical absorption spectra of organic dyes

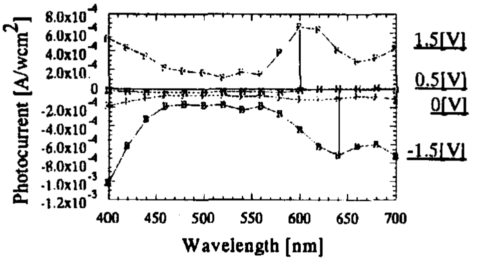

Figure 7 Photocurret spectra of pnp cell

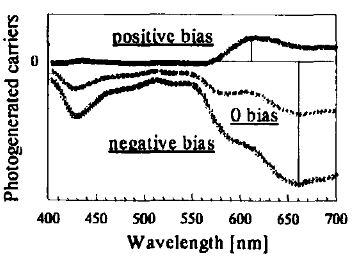

Figure 8 Photogenerated carriers of pnp cell

equations including the exciton diffusion and the transmission and reflection effect of each layer. Figure 8 shows the spectra of the number of photogenerated carriers obtained by the calculation in the Al/CuPc/PTCDI/QC/ITO cell. In this calculation, the carriers from the Al/CuPc Schottky contact lager than other junctions. Comparing Figure 7 and 8, the photocurrent spectra show a good agreement with the number of photogenerated carriers for the exciton. These results indicate that the dominant junctions for the exciton dissociation under the negative bias is the Al/CuPc junction.

CONCLUSION

We have investigated photoelectric properties of multi-layered organic cells. The spectral sensitivity depends not only on the kind of organic dyes but also on their thickness, and are shows a good agreement with the calculation by the model of carrier generation in the organic photovoltaic cells. These results demonstrate that the spectral sensitivities of multi-layered organic cells can be controlled by the external bias voltages.

REFERENCES

1. C.W.Tang Appl. Phys. Lett. 48,183(1986)
2. K.Kudo et al. Appl. Phys. Lett. 39,609(1981)
3. A.K.Ghosh, et al. Appl. Phys. Lett. 45,230(1974)
4. K.Yamashita et al. J.Phys. Chem. 91,3055(1987)