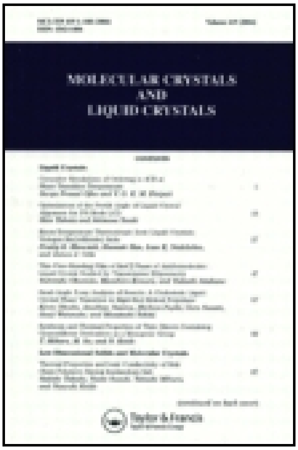


Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Investigation of Basic Parameters in Organic Photovoltaic Cells

Masaaki Iizuka [a], Kazuhiro Kudo [a], Sigekazu Kuniyoshi [a] & Kuniaki Tanaka [a]

[a] Department of Electronics and Mechanical Engineering, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba, 263-8522, Japan

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 349, pp. 487-490
Reprints available directly from the publisher
Photocopying permitted by license only

Investigation of Basic Parameters in Organic Photovoltaic Cells

MASAAKI IIZUKA, KAZUHIRO KUDO, SIGEKAZU KUNIYOSHI and KUNIAKI TANAKA

Department of Electronics and Mechanical Engineering Chiba University, 1–33 Yayoi-cho, Inage-ku, Chiba 263–8522 Japan

We have fabricated photovoltaic cells using merocyanine and copper phthalocyanine dyes. The basic parameters, such as diffusion length of the photogenerated excitons, dielectric constant, and the carrier density in organic photovoltaic cells were estimated.

Keywords: organic film; diffusion length; excitons; dielectric constant

INTRODUCTION

Recently, photovoltaic cells using organic dyes have attracted much attention because of their peculiar photoelectric characteristics. For examples, the high photovoltaic conversion efficiencies about 1% of the two-layered organic cells [1] and the new functional color sensors using organic dyes were reported [2-4]. The photocurrent in the photovoltaic cells is generated near the p-n junction and Schottky contact. However, the mechanism of carrier generation in organic semiconductors is not simple compared with that in inorganic semiconductors, because the photoexcited excitons play a dominant role in organic layers. Since the dissociation of the excitons needs sufficient energy, the efficiency of photogenerated free carriers strongly depends on both the wavelength of the incident light and the internal electric field. Therefore, for practical applications, it is important to investigate the basic parameters in organic cells, such as the generation efficiency of free carriers, the diffusion length of excitons, etc.

THEORETICAL SECTION

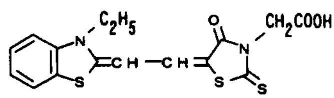
The photocurrent in Schottky barrier type photodiodes is generated near the Schottky contact. We used the equation of the carrier generation in organic layers in a similar manner reported by Ghosh et al.[5],

$$\frac{1}{J} = C\frac{1}{L}\frac{1}{\alpha} + C \qquad (1)$$

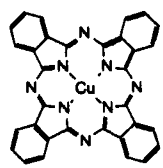
where J, α, L and C are the short-circuit photocurrent, absorption constant, diffusion length of exciton, and constant, respectively.

EXPERIMENTS

P-type organic dyes used in the present work are a copper phthalocyanine (CuPc) and a merocyanine derivative (MC). Their chemical structures are shown in Figure 1. Organic dye films and metal electrodes are formed by a standard vacuum evaporation technique. The structure of the cells is a Schottky barrier type photodiode (Au/organic films/Al/glass). The film thicknesses of MC and CuPc were approximately 100 and 220nm, respectively. Optical absorption spectra, photocurrent spectra, cell capacitance, and capacitance-voltage characteristics were measured.



(MC)



(CuPc)

FIGURE 1. Chemical structures.

RESULTS AND DISCUSSION

Photocurrent measurement and diffusion length of excitons

Figure 2 shows the absorption constant and the photocurrent spectra of the Au/MC/Al/glass cell. The light was incident through the Al side. In the same way, the results of Au/CuPc/Al/glass cell are shown in Figure 3. The estimate of the diffusion length (L) of the photogenerated excitons was based on experimental data and Eq. (1).

The obtained L depens strongly on the wavelength as shown in Table 1.

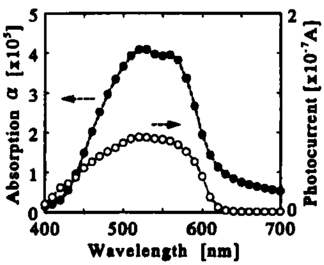


FIGURE 2. Photocurrent spectra and absorption constant of MC cell.

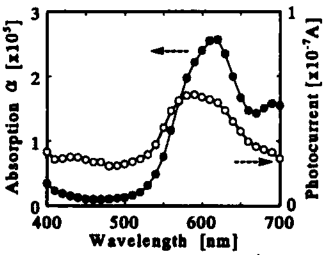


FIGURE 3. Photocurrent spectra and absorption constant of CuPc cell.

TABLE 1. Diffusion length of the photogenerated exciton.

MC		CuPc	
Wavelength	L	Wavelength	L
480-520 nm	12.5 nm	620-640 nm	11.6 nm
520-570 nm	7.1 nm	640-660 nm	7.0 nm
570-590 nm	7.9 nm		

Two types of exciton were observed in both MC and CuPc cells. One is the higher energy exciton (L is large) and the other is the lower energy exciton (L is small). A similar result was reported in merocyanine derivative photovoltaic cells [5] and the wavelength dependence of diffusion length can be explained by modified Onsager model [6].

Dielectric constant and carrier density

The dielectric constant (ε) was measured by using a capacitance meter (HIOKI 3521). The results are summarized in Table 2. The dielectric constants obtained at 1kHz of MC(ε_M) and CuPc(ε_C) were 6.4 and 6.3, respectively. The value of ε for each sample decreases as the measureing frequency increases. The carrier density (N) estimated was based on the result of C-V measurement (applied triangular voltage; dV/dt=0.018[V/s]). The relationship between capacitance and carrier

TABLE 2. Frequency dependence of the dielectric constant.

MC		CuPc	
Frequency	ε_M	Frequency	ε_C
1 kHz	6.4	1 kHz	6.3
10 kHz	5.1	10 kHz	5.7
100 kHz	3.2	100 kHz	5.2

density is therefore expressed as

$$\frac{1}{C^2} = \frac{2}{q \varepsilon N} (\phi_0 - V) \qquad (2)$$

where q is elementary electric charge and ϕ_0 is built-in potential. The carrier density obtained for MC and CuPc were 9.6×10^{14} and 3.13×10^{14} [cm^{-3}], respectively. On the other hand, the N values of MC and CuPc obtained by the field effect measurement were 1.3×10^{15} and 7×10^{14} [cm^{-3}], respectively[8,9], and were almost same values estimated here.

CONCLUSION

We have investigated basic parameters in organic photovoltaic cells. Two types of exciton have observed, and the diffusion lengths of the photogenerated exciton were 12.5 and 7.9 nm for MC, and 11.6 and 7.0 nm for CuPc. Dielectric constants of 6.3-6.4 were obtained for both MC and CuPc and these values decreased with increasing measurement frequency. The carrier densities were almost same values obtained by the field effect measurement.

References

[1] C.W.Tang *Appl. Phys. Lett. 48*,183(1986).

[2] K.Kudo, T.Moriizumi *Appl. Phys. Lett. 39*,609(1981).

[3] M. Iizuka, S,Muraguchi, K.Kudo, S.Kuniyoshi, K. Tanaka *Mol. Cryst. Liq. Cryst. 295*,55(1997).

[4] M. Iizuka, K.Kudo, S.Kuniyoshi, K.Tanaka To be published in *Synth. Metal.*

[5] A.K.Ghosh, T.Feng *J. Appl. Phys. 49*,5982(1978).

[6] J. Singh, H. Baessler, *Phys. Status. Solidi. b63*,425(1974).

[7] A. J. Twarowski, A. C. Albrecht *J. Chem. Phys. 70*,2255(1979).

[8] K.Hiraga, M. Iizuka, S.Kuniyoshi, K.Kudo, K.Tanaka *IEICE. Trans. Electron. E81-C1, 7*, 1077(1988).

[9] T. Sumimoto, K.Hiraga, S.Kuniyoshi, K.Kudo, K.Tanaka *Mol. Cryst. Liq. Cryst. 294*,193(1997), etc.