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Fast Response of Organic Photo Detectors Utilizing Multi-layered Metal-Phthalocyanine Thin Films

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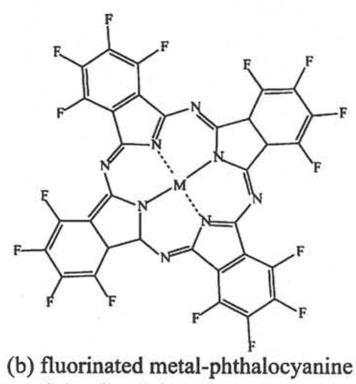
1. Introduction

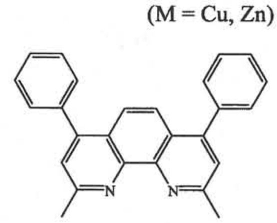
Recently, organic materials have been attracted a great deal of attention to the scientists because of their unique characteristics and potential for applications, such as light-emitting devices [1-3], transistors [4], photovoltaic cells[5,6], and so on[7]. These devices can be fabricated onto a wide variety of substrates, such as flexible conducting foils by the progress in the fabrication process of organic thin-film devices.

Metal-phthalocyanines are well-known materials of which showing good stability, high mobility[8] and photo activity. The chemical structures of titanyl-phthalocyanine (TiOPc) and fluorinated metal-phthalocyanine ($F_{16}MPc$) are shown in Fig.1 (a) and (b), respectively. Among them, fluorinated copper phthalocyanine ($F_{16}CuPc$), which has been revealed as n-type semiconductor shows a mobility of 1.7 cm^2/Vs at room temperature[8].

(a) titanyl phthalocyanine



(b) fluorinated metal-phthalocyanine (M = Cu, Zn)



(c) bathocuproine

Fig.1. Chemical structures of organic materials used for photo detectors, (a) titanyl phthalocyanine, (b) fluorinated metal-phthalocyanine (M = Cu, Zn), and (c) bathocuproine.

In this study, we report the results of an investigation of high bandwidth photo-detectors, which consist of the multi-layered *p*-like and *n*-like phthalocyanine thin films with bathocuproine (Fig.1(c)) contact layer[9].

2. Experimental

The photo detectors were fabricated on precleaned transparent conductive glass substrate (ITO) by molecular beam deposition method. The device active region consists of alternating layers of TiOPc, $F_{16}MPc$ (M = Zn, Cu) and bathocuproine (BCP) as shown in Fig.2. These layers were deposited onto substrate in vacuo (5 – 8 x 10^{-7} Torr). The thickness of total layers has been kept at 500Å. The number of active layers was chosen from single heterostructure to 10 periods of alternate layers. Following the deposition of active layer, 100-Å-thick layer of BCP was evaporated. This is followed by the deposition of metal cathode evaporated at 1 x 10^{-4} Pa through a mask. Finally, the device was sealed in an environment of inert gases (Ar).

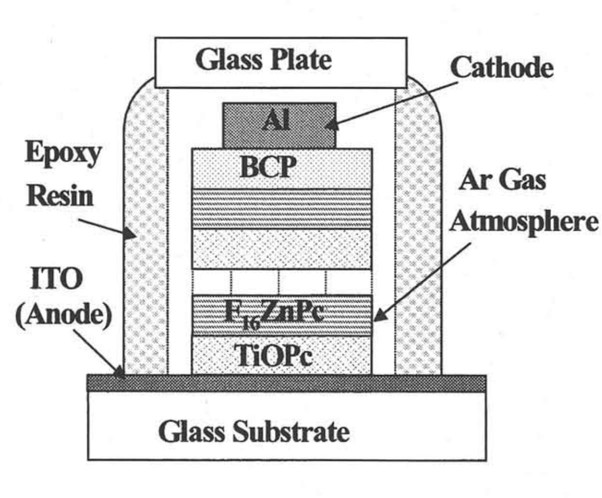


Fig. 2. A schematic of typical device structure of photo detectors. Organic multilayers were deposited onto ITO substrate, followed by the deposition of metal (Al, Au, or Ag) electrode. Then, active area was sealed by transparent glass in inert gas.

All measurements of the accomplished cells were performed in air. The dark and photo I-V characteristics were measured by using KEITHLEY 6514 system electrometer and ADVANTEST R6144 DC voltage source. The measurement of transient photo responses were performed by using Agilent 8114A pulse generator and Tektronics TDS3054 digital oscilloscope. The measurement of photo response has been examined with and without applied reverse-bias field to the photo-detectors under the illumination of pulsed light of red LED for optical link with the peak emission wavelength at about 640nm.

3. Results and Discussions

Photo-detection characteristics of the thin-film multilayered devices which consists of TiOPc and F_{16}ZnPc has been examined. In this study, total layer thickness has been kept at a same value in order to keep the absorbed photons in the same value. Figure 3 shows the comparison of 3dB bandwidth of photo-detectors by comparing 4 periods with 10 periods of multilayer of TiOPc/F_{16}ZnPc heterostructured devices with the active area of 0.05mm^2. The heterostructure device with 4 periods of multilayer of TiOPc/F_{16}ZnPc still remains at about 4 KHz of cut-off frequency.

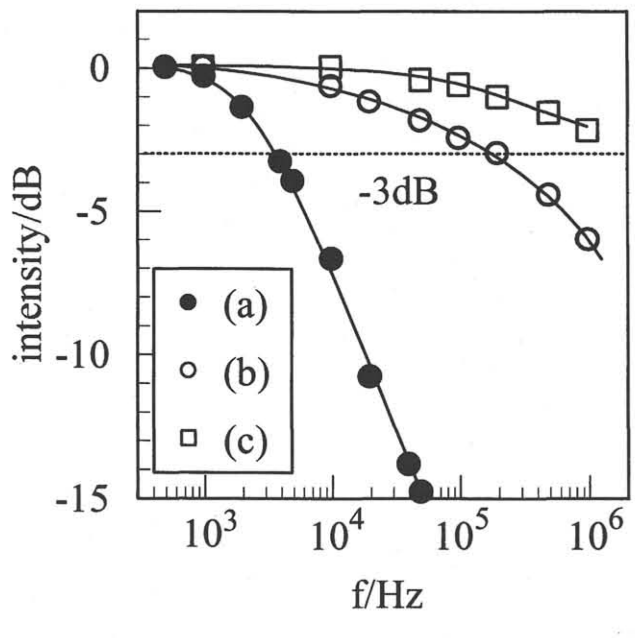


Fig.3. Frequency dependence of the output intensity of (a) 4 periods of multilayered TiOPc / F_{16}ZnPc heterostructure devices with the active area of 0.05 mm^2 at no bias, and (b) 4 periods and (c) 10 periods of devices at an applied bias voltage of -5.5 V.

The response time for the photo-detectors has been increased drastically by applying a reverse bias field. Under the reverse bias condition, as shown in Fig. 3, the photo response of 10 periods of multilayer of TiOPc/F_{16}ZnPc heterostructured device with BCP contact layer shows the remarkable increase in cut-off frequency up to more than 1MHz.

As decreasing the layer thickness, the response time increased. The cutoff frequency (3dB bandwidth) markably increases with decreasing the layer thickness under the same total layer thickness. The results will be due to the increase of the probabilities of carrier generation and dissociation with decreasing the layer thickness and increasing the numbers of active layers.

4. Conclusions

The pulse response of photo-detectors, which consists of multilayered metal-phthalocyanines with TiOPc/F_{16}ZnPc, has been examined. The thin film multilayered device with TiOPc/F_{16}ZnPc heterostructure has been drastically improved the cutoff frequency with applying reverse bias voltage.

Acknowledgments

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