Transparent Polymer Photodetector to Control Electronic Devices

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ABSTRACT

The increasing demand for improved electronic devices in the wide area of information technology enforced the research for organic semiconductors, because they can be possible to use soluble and room temperature process and flexible substrates.

If the transparent photodetector is located in front of the display unit, it can control electronic devices by measuring the position data of illuminated point source of light similar to the operating principle of a touch screen. For technical realization of such construction, photodetetcor should be transparent. Therefore the polymer photodetector has the structure of PEDOT:PSS/heterojunction photoactive layer/ITO, where heterojunction photoactive layer consists of PVK and PCBM and fabricated by spin coating and spray method. It generates 25 mV in 15mW 405nm laser and has high transmission of 84.3 % at 580 nm.

To control electronic devices using electrical signal from polymer photodetector, the output voltage of polymer photodetector should be amplified and transmitted to electronic devices by electrical signal processing system which is composed of op-amp, multiplexer and microcontroller, etc. The electrical signal processing system converts electrical signal from polymer photodetector to the position data of illuminated ultraviolet ray and shows on monitor.

This paper presents transparent polymer photodetector to control electronic devices by using organic semiconductor. It can solve limitations of the earlier controllers for electronic devices on convenience and accuracy. We suggest possibility of transparent polymer photodetector to control electronic devices by demonstration using 4 inch transparent polymer photodetector samples and electrical signal processing system.

Keywords: polymer photodetector, transparency, remote controller, organic semiconductor

1 INTRODUCTION

In recent years, various electronic devices such as PC, smart phone, IPTV is significantly developing from day to day. However, its user interface cannot accommodate the demand of user. Although there are many controllers such as touch screens and remote controllers which are consisted of gyroscope and infrared sensors to control electronics, those controllers are limited on convenience and accuracy. Therefore an improved remote controller is demanded for electronic devices.

This paper presents transparent polymer photodetector to control electronic devices. If the photodetector using transparent organic semiconductor is located in front of the display devices like touch screen, it could be controlled by point source of light like laser pointer.

The researches on polymer photodetector were carried out during the past decades and are based on organic solar cells [1], [2], organic photodiodes and organic phototransistors [3]-[5]. It is mainly because the organic thin films have several clear advantages over inorganics: large areal coverage, mechanical flexibility, low cost, low temperature process-capability, and etc.

Among principles of polymer photodetectors, photovoltaic effect of organic semiconductor in organic solar cells is most suitable for transparent polymer photodetector to control electronic devices. Because there are more research results about transparent materials and structure in organic solar cells [6], and their structure are simpler than other organic devices.

In this work, we present a user-friendly controller to control electronic devices and transparent polymer photodetector.

2 STRUCTURE

Figure 1 shows the main construction of transparent polymer photodetector to control electronic devices. The transparent photodetector is over the front of the display unit and can measure the position data of illuminated point source of light like laser pointer. Electronic devices can be controlled by the position data of light like the operating principle of a touch screen.

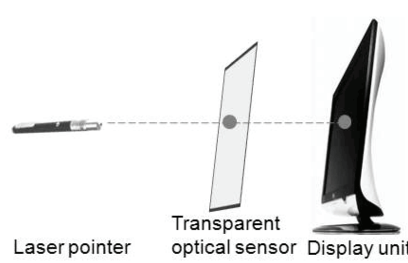

Figure 1: The main construction of transparent polymer photodetector to control electronic devices.

For technical realization of this construction, photodetetcor responding to certain wavelength light is needed and materials of photodetetcor array have high transparency in the wavelength range of visible light.

To fabricate high transparent photodetetcor array, photoactive layer which contains donor and acceptor materials is transparent. Besides, all electrodes containing anode and cathode are also transparent. In other words, metal cathode cannot be used due to its characteristics of reflection in transparent photodetetcor array.

In order to solve transparency of materials, we propose improved structure of high transparent polymer photodetetcor like figure 2. In this device, Poly(9-vinylcarbazole) (PVK) and [6,6]-phenyl-C61 butyric acid methyl ester (PCBM) is used as donor and acceptor, respectively at photoactive layer and anode is poly(3,4-ethylenedioxylenethiophene)-polystylene sulfonic acid (PEDOT:PSS) (Baytron PH500 from H. C. Starck) and cathode is Indium Tin Oxide (ITO).

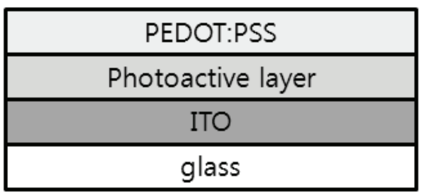

Figure 2: The structure of high transparent polymer photodetector.

Figure 3 shows absorbance of PVK. The optical property of PVK is almost transparent in the wavelength range of visible light (400 nm~700 nm) and has a high absorbance in the ultraviolet wavelength range. Therefore PVK is not seen transparently by the human eye, but has selectively photovoltaic effect in ultraviolet ray.

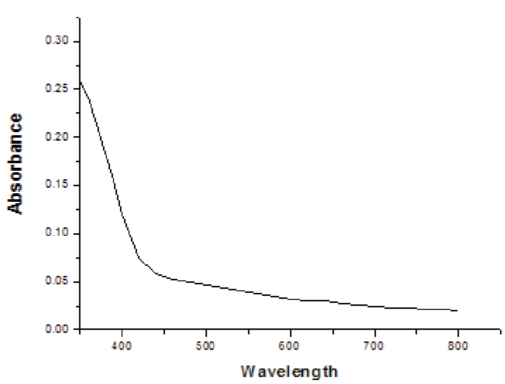

Figure 3: Absorbance of PVK.

To improve transparency of electrodes, PEDOT:PSS is used as anode and ITO is used as cathode. PEDOT:PSS has higher work function than ITO and good conductivity and it can be made to transparent thin layer. Figure 4 shows work functions and the HOMO and LUMO energies of each of the component materials in energy-level diagram.

We cannot get high performance in this structure and material, but this device can produce electric signal enough to detect light.

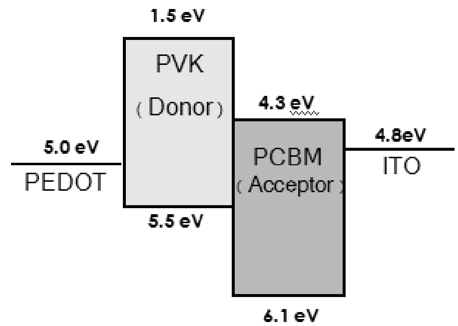

Figure 4: Energy-level diagram of polymer photodetector.

3 EXPERIMENTS

3.1 Fabrication of Photodetectors

In order to verify our idea, the polymer photodetectors are fabricated on 4 inch circular glass ITO substrates which are thoroughly cleaned in an ultrasonic bath using organic solvents and dry in a dry nitrogen stream. Those ITO substrates have 11 ITO lines with a width of 2.5 mm.

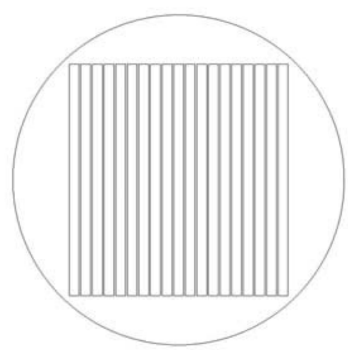

Figure 5: 4 inch circular glass ITO substrates.

Photoactive layers of the photodetector are bulk heterojunction composite of PVK and PCBM, and are spin-coated at 2000 rpm and dried at 120 ℃ for 20 min.

There are PEDOT:PSS anodes on photoactive layers. Since PEDOT:PSS has hydrophilic property, it is difficult to coat on hydrophobic surface of photoactive layer. In order to form good contact at the interface between PEDOT:PSS anode layers and photoactive layers, spray coating method is used and PEDOT:PSS is purposely modified to become adhesive. This adhesive and conductive PEDOT:PSS layers are obtained by doping isopropyl alcohol (IPA), dimethyl sulfoxide (DMSO) and DYNOL™ 604 surfactant into PEDOT:PSS. In the spray coating process, modified PEDOT:PSS is spraied on 150 ℃ substrate by air brash and dried at 150 ℃ for 20 min.

Since a 4 inch circular glass ITO substrate has 11 ITO lines using by cathodes, a polymer photodetector has 11 photoactive cells which share one PEDOT:PSS anode.

This polymer photodetector is almost transparent in the wavelength range of visible light and responds to ultraviolet ray.

3.2 Signal Processing Circuit

Photoactive cells on a polymer photodetector have electrical signal in response to laser beam of 405 nm. When point source of ultraviolet ray illuminates a certain photoactive cell on a polymer photodetector, we can know which cell is illuminated by measuring electrical signal.

Figure 6 shows electrical signal processing system from photodetector to PC. First, electrical signal of photodetector should be amplified by op-amp (LF442 CN), then scanned by multiplexer and microcontroller (Atmel ATmega128). Next, electrical signal is transmitted to PC by data acquisition board (NI PCI-DIO-32HS). The software which is coded by visual C++ language converts electrical signal from data acquisition board to the position data of illuminated light and shows on monitor.

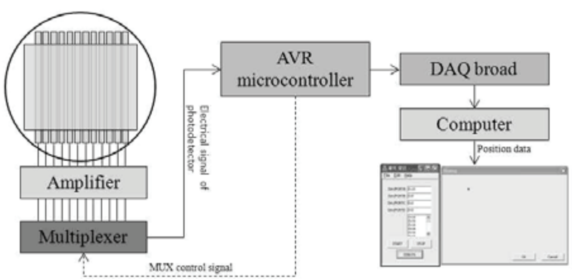

Figure 6: Diagram of signal processing system.

Since the polymer photodetector has photoactive cells in line form, we can measure the position data of only one direction. 2 polymer photodetectors stack and its lines are aligned perpendicularly in order to measure the position data of X and Y directions.

4 RESULTS AND DISCUSSION

Figure 7 shows the fabricated the transparent polymer photodetector to control electronic devices. It generates 25 mV in 15mW 405nm laser and has high transmission of 84.3 % at 580 nm such as figure 8.

Figure 9 shows demonstration to control computer by using transparent polymer photodetectors and electrical signal processing system. A point on computer monitor moves according to motion of 405nm laser beam by electrical signal processing system.

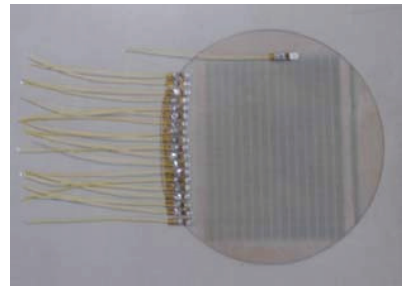

Figure 7: The fabricated transparent polymer photodetector.

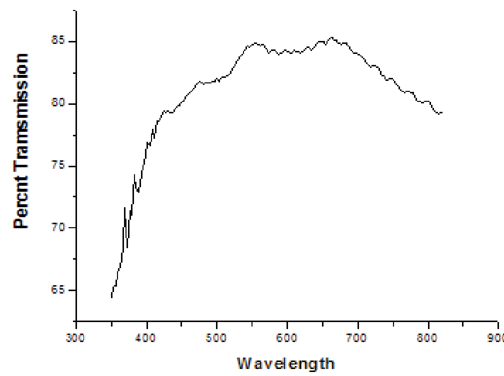

Figure 8: Percent transmission of polymer photodetector.

The output voltage of polymer photodetector is not excellent. However, it can produce electric signal enough to detect light and its electric signal can be amplified by other elements.

This device is almost transparent in the wavelength range of visible light (400 nm~700 nm). Nevertheless, it is not suitable to use display units of the finest class such as TVs and monitors, because it cause to reduce the screen brightness. Therefore additional study to improve transparency of polymer photodetector is necessary.

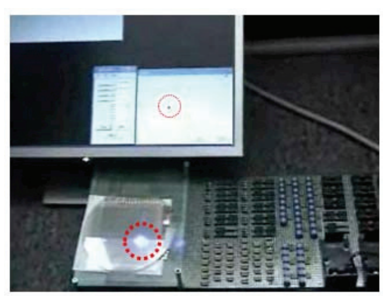

Figure 9: demonstration to control PC.

5 CONCLUSION

To accommodate the demand of modified remote controllers for various electronic devices, we present transparent polymer photodetector in this work. The polymer photodetector has the structure of PEDOT:PSS/heterojunction photoactive layer/ITO, where heterojunction photoactive layer consists of PVK and PCBM to improve transmission and fabricated by spin coating and spray method. As a result, the polymer photodetector is almost transparent in the wavelength range of visible light and has selectively photovoltaic effect in ultraviolet ray due to the absorbance property of PVK. The output voltage from polymer photodetector is transmitted to PC by electrical signal processing system which is composed of op-amp, multiplexer and microcontroller, and etc. The electrical signal processing system converts electrical signal from polymer photodetector to the position data of illuminated point source of ultraviolet ray and shows on monitor.

The transparent polymer photodetector produces electric signal enough to detect ultraviolet ray and is transparent enough to see images back of the polymer photodetector.

We suggest possibility of transparent polymer photodetector to control electronic devices by demonstration using 4 inch transparent polymer photodetector samples and electrical signal processing system. It is required further research to improve transmission, output voltage and to produce large scale.

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