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Enhanced organic opto-electronic conversion by using ionic liquid

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[Introduction] Organic photovoltaic devices such as organic photodetectors and solar cells have become one of the most popular research topics in the past decades. Up to date all the organic photovoltaic devices possess one common point in use which is light should irradiate from one electrode of the device through the active layer and reach the another electrode, namely the overlap area of the active layer between the top and the bottom electrode of the devices is the effective area for producing photocurrent. Based on the above mechanism indium tin oxide (ITO) has been used as the most popular incident electrode in such devices because of its transparency. Recent years some other transparent or semitransparent electrodes such as carbon nanotubes, grapheme, silver nanowire, metal grids, and conducting polymers have been reported for replacing ITO because of its high cost and brittleness. The transparency of the incident electrodes is very important for the organic photovoltaic devices because the incident light must go though them to excite the behind active layer then the charges generated by the dissociation of the excitons will be injected to them to produce conduction current. However if the displacement current can be produced between the electrodes and active layers it seems such electrodes can be positioned not along the incident light because the propagation of the displacement current is by the electrical field and it is unnecessary for the direct contact of the electrodes and active layers to the displacement current. The phenomenon which the electrodes can be positioned not along the incident light can be called electrodes free. If the electrodes can be free there will be various conducting materials which can be a wide selection for the organic photovoltaic devices.

In this work, we design to use displacement current taking the place of conduction current between the electrodes and active layers in order to make the electrodes free. Based on this concept we have developed an organic photodetector with the structure of Glass/ITO/Ionic Liquid/Active Layer/Metal (figure 1). By inserting ionic liquid between the active layer and the electrode it will act as a capacitor to make the displacement current be produced and propagate from the active layer to the electrode. The responsivity and internal quantum efficiency (IQE) of the device can reach

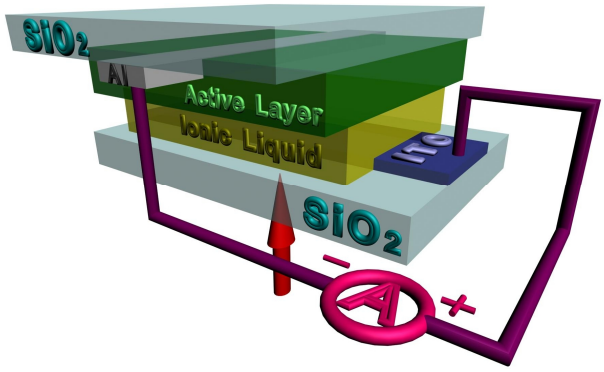

Figure 1 The structure of the device

142mA/W and 93% at 620nm respectively under the irradiation from the monochrometer. The ITO electrode can be free for a large distance from the incident light.

[Experiment] Vacuum codeposition thin film of zinc phthalocyanine (ZnPc) and fullerene (C_{60}) with the ratio of 1:1 was used as active layer. A layer of the ionic liquid, N,N-diethyl-N-methyl(2-methoxyethyl) ammonium bis(trifluoromethylsulfonyl)imide (DEME-TFSI), was formed by dropping method with the thickness of 0.15mm. Transient photocurrent was observed by the current amplifier connected to the oscilloscope when the incident light modulated by optical chopper with 3000 Hz.

[Results and discussion] Figure 2 shows the transient photocurrent obtained by the irradiation of modulated 532nm continuous wave (CW) laser with power density of 13mW/cm^2 in which the active layer is 50nm. It clearly shows the positive and negative current peak which produced by the ionic liquid served as a capacitor. The device with 25nm active layer has been used for the external quantum efficiency (EQE) and IQE measurement under the irradiation from monochrometer. The peak of transient photocurrent was used as conventional current for calculation in each wavelength. The EQE and IQE both reach the maximum at 620nm shown in figure 3. The top of IQE can reach 93% which indicates nearly all the absorbed photons have been converted into photocurrent. The responsivity of the device and the absorbance of the active layer with 25nm thickness are shown in figure 4. The peak responsivity can reach 142mA/W without applying a bias voltage. When the incident light leaves away from the ITO along the aluminum electrode the photocurrent also can be observed. The ITO electrode can be free in this device for a large distance.

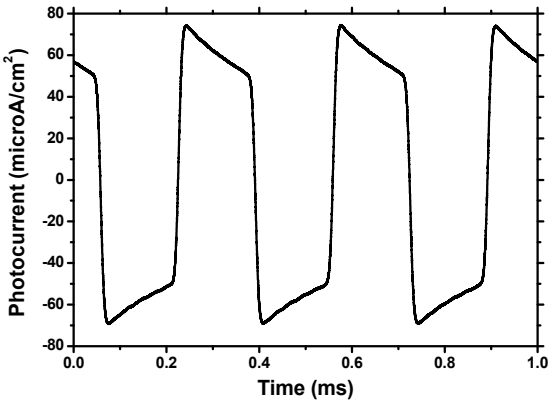

Figure 2 The photoresponse of the device

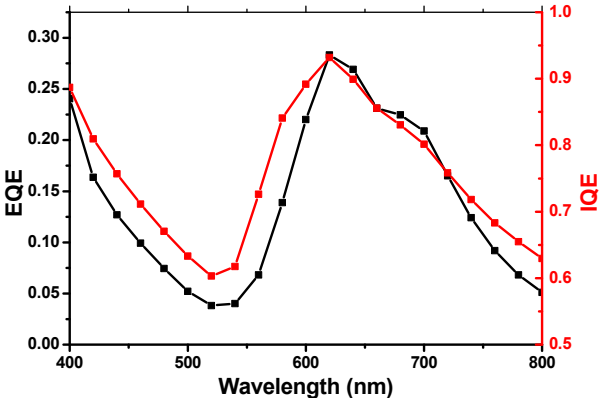

Figure 3 The EQE and IQE of the device

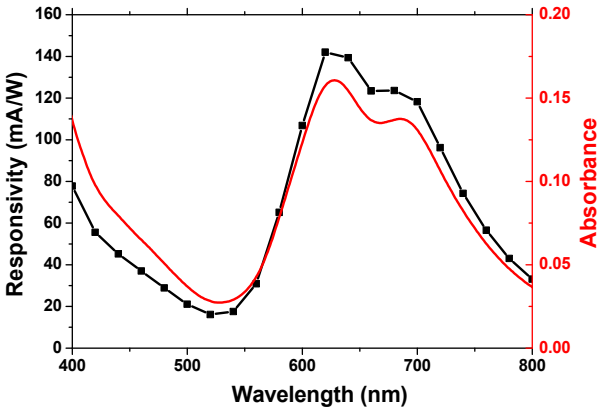

Figure 4 The responsivity of the device and the absorbance of the active layer