

Cathode buffer layer composed of hyper-branched polymer having imidazoline moieties for organic devices

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Abstract

We investigated anode buffer efficiency of hyper branched polymer with imidazoline groups, HI-DVB in organic solar cells (OSC). Open circuit voltage (V_{oc}) and Power conversion efficiency (PCE) increased compared with the device without the buffer. The electron injection property was also improved by insertion of HI-DVB in an electron only device (EOD) with electron transporting polymer. The work function of the electrode can be reduced with HI-DVB layer and very thin Cu evaporated. The imidazoline could form a complex with evaporated metal and provide n type doping to shift the vacuum level.

1. Introduction

Organic solar cells (OSCs) are expected as low cost, printable, light-weight, flexible, and portable energy sources, and these advantages have encouraged intensive research on OSCs. Various approaches for increasing efficiency and stability, low band gap donor materials, tandem OSC cell, inverted OSCs, controlling nanostructure of active layer have been proposed.[1]

Typical OSC has a stacked structure of the substrate / transparent anode electrode / anode buffer / active layer / cathode buffer / metal cathode. The cathode buffer layer provides a quasi ohmic contact between active layer and cathode, and electron transport and hole blocking effect. Although cathode buffer layers are known, the mechanism is still unexplored.

Hyper-branched polystyrene with imidazoline moieties (HI-DVB, Fig. 1) was investigated as cathode buffer layer.

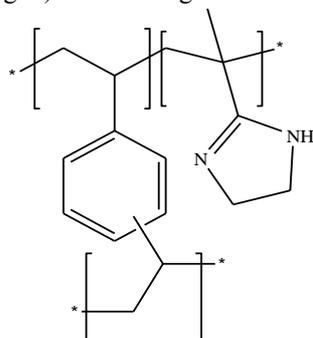


Fig.1 Chemical structure of HI-DVB

2. Experimental

2.1 Fabrication of OSC and EOD

For OSC, ITO coated glass substrates were cleaned sequentially with detergent, deionized water, acetone and ethanol, followed by boiling and steam cleaning by ethanol and UV-O₃ treatment for 20 min. Poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate)(PEDOT:PSS) was spun from the solution (Baytron P VP Al4083 from H. C. Stark, filtered through 0.45 μ m PVDF syringe filter) at 2000rpm for 30s, followed by annealing at 150°C for 10min. The active layer was spin-coated from the solution of Poly(3-hexyl thiophene)(P3HT):[6,6]-Phenyl-C₆₁-Butyric Acid Methyl Ester (PCBM) = 1:1 w/w in *o*-dichlorobenzene (3wt% , filtered with a 0.5 μ m PVDF syringe filter) at 500rpm for 60s, followed by thermal annealing at 120°C for 10min. As cathode buffer, HI-DVB propanol solution (0.1 wt%) was spun on the active layer. As a reference, typical buffer layer LiF was deposited instead of HI-DVB. Finally Al (100nm) was deposited at a pressure of 10⁻⁷Torr. The area of each device was 0.04 cm².

For EOD, a glass substrate with Al (100nm) was used. An electron transporting polymer, Poly[(9,9-di-n-octylfluorenyl-2,7-diyl)-alt-(benzo[2,1,3]thiadiazol-4,8-diyl)] (F8BT) was spun on the electrode and treated at 120°C for 3 min. The HI-DVB and the upper Al electrode was deposited as described above.

2.2 Characterization of OSCs and EOD

I-V characteristic of OSC and EOD was measured by Keithley 238 source meter. The light intensity was calibrated to be AM1.5 100mW/cm² using calibrated Si solar cell.

The ionization potential was measured with photo yield spectroscopy (PYS, AC-2 riken keiki)

3. Result and discussion

The I-V characteristics of OSC with Hi-DVB or typical buffer were shown in Fig.2 and table 1. Open circuit voltage (V_{oc}) was almost identical in the devices with HI-DVB and LiF. Obviously, HI-DVB can act as a buffer layer.

The electron current can be improved in the EODs with the buffer HI-DVB as the LiF buffer (Fig. 3). The workfunction of ITO can be modified by HI-DVB and very thin Cu.

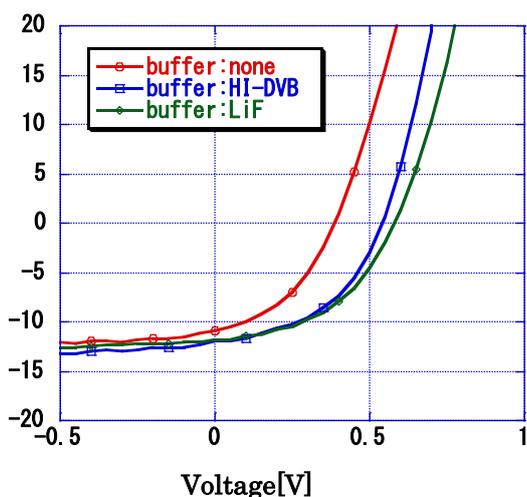


Fig. 2 I-V characteristics of OSCs with LiF or HI-DVB.

Table 1 OSC parameters

	none	HI-DVB	LiF
Jsc(mA/cm2)	10.9	11.9	11.8
Voc(V)	0.386	0.541	0.580
PCE(%)	1.630	3.00	3.19
FF	0.426	0.468	0.469

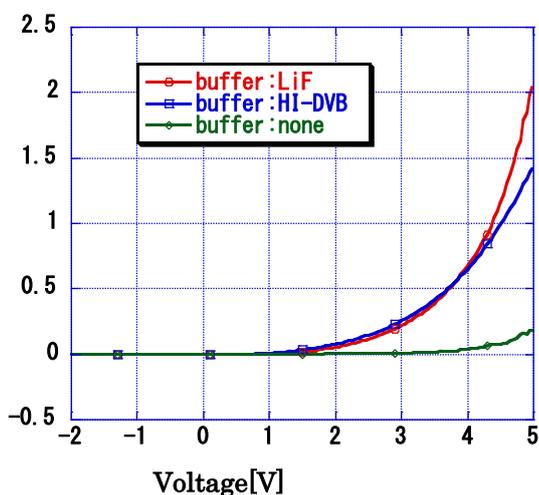


Fig. 3 I-V characteristics of EODs with LiF or HI-V, without buffer layer.

The work function was obviously reduced when very thin Cu was deposited on ITO/HI-DVB. This shift was not observed in ITO/polystyrene even thicker deposition of Cu. This observation indicates that the metal deposited onto HI-DVB would form some sort of complex with imidazoline and metal and provide n-type doping. It is known that imidazoline can act as a ligand against metal ions to form a complex.[2]

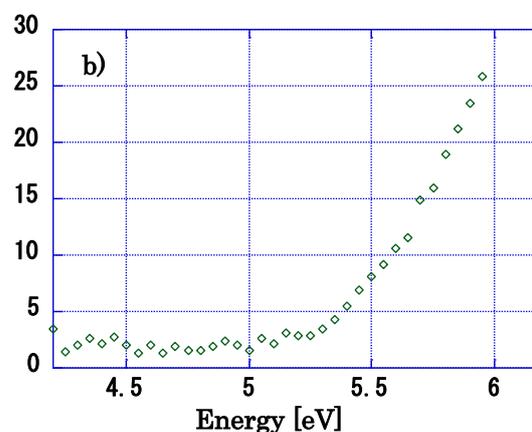
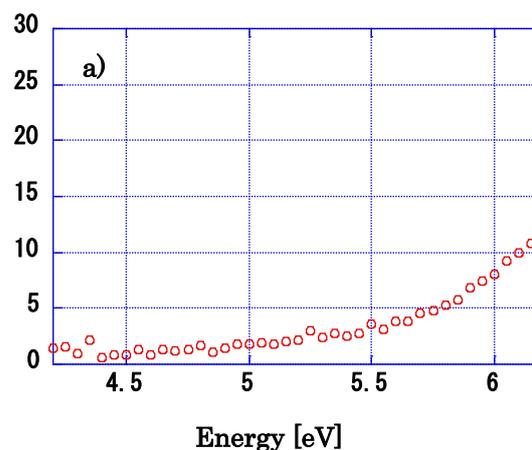


Fig. 4 PYS of a) ITO/HI-DVB and b) ITO/HIDVB/Cu (0.5nm)

4. Conclusions

HI-DVB can act as cathode buffer for OSC, and the ability is almost identical to the representative buffer LiF. The electron injection also can be improved, therefore, the vacuum level should shift. The work function of electrode can be reduced by depositing metal onto HI-DVB. The complex formation with imidazoline and metal would be the key for the buffer effect.

References

- [1] Felix Nickel et al., *Appl. Phys. Lett.* **101**, 053309 (2012)
- [2] Nevin Gurbuz, *Appl. Organometal. Chem.* **17**, 777 (2003)