Characteristics of vertical type organic light emitting transistor using C_{60} as a N-type semiconductor material and MEH-PPV as an emitting polymer

Jung Bae Lee[1], Hee Suk Jin[2] and Se Young Oh[1,2]
[1] Interdisciplinary Program of Integrated Biotechnology, Sogang University
[2] Department of Chemical & Biomolecular Engineering, Sogang University, Seoul, 121-742, Korea
TEL:82-2-714-3880, e-mail: syoh @sogang.ac.kr.

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Abstract

We have fabricated vertical type organic thin film transistor using C_{60} as a n-type active material to improve the problems of conventional OTFTs. In general, it can be argued that the characteristics of organic transistor were influenced by carrier mobility and density. We have used several kinds of metals as source and gate electrodes to optimize the device characteristics using C_{60}. In addition, we have examined the feasibility of fabrication of organic light-emitting transistor (OLET) using MEH-PPV as an emission layer.

1. Introduction

Organic field effect transistors (OFETs) are promising for the active devices for flexible, low cost, simple process and large area photoelectric devices.[1-3] However conventional field effect transistors (FETs) using organic materials have low-speed, low-power and high-resistivity because of their long channel length between drain and source electrodes. Vertical type static induction transistor is a promising device to obtain high speed and high power operation compared to the conventional field effect transistors because of short channel length.[4-5] Also vertical type transistors have some advantages for organic photoelectric devices. In this study, we have investigated the effects of high electron mobility of C_{60} on the performance of light emitting diode and then fabricated vertical type light emitting transistor using C_{60} as n-type semiconductor active material and MEH-PPV as an emitting polymer. C_{60} can be used as an organic semiconductor material as well as electron transfer layer owing to have high electron mobility.[6] However, photoinduced charge transfer between C_{60} and conducting polymer induces the electroluminescence quenching in C_{60}/conducting polymer system, which leads to weak electroluminescence in C_{60} containing devices.[7] In the present work, we have introduced Bphen as a blocking layer in OLET consisting of Al/C_{60}/gate/C_{60}/Bphen/MEH-PPV/PEDOT:PSS/ITO in order to improve the electroluminescence quenching in C_{60}/poymer system.

2. Experimental

The organic thin film transistors (OTFTs) consisting of Al/C_{60}/gate/C_{60}/ITO were fabricated. All layers were fabricated on patterned ITO ($\leq$15 Ω/□) glass substrate. Before film fabrication, the patterned ITO substrates were immersed into ultrasonic bath of DI water, acetone and methanol for 60 min, subsequently. Then cleaned ITO glass substrates were rinsed in DI water and blown by N_2 gas. C_{60}/gate/C_{60} were deposited on the ITO film. The electrodes were used several kinds of metals such as LiAl, Al, Ag, Au.

The organic light emitting transistor (OLET) configuration used in this study was Al/C_{60}/gate/C_{60}/Bphen/MEH-PPV/PEDOT:PSS/Al. PEDOT:PSS and MEH-PPV were sequential spin-coated on the ITO. And then Bphen, C_{60} and gate, source electrode were deposited onto the MEH-PPV by the same method of OTFTs experimental. Current - voltage - radiance characteristics were measured using source meters (KEITHLEY-2400, 237) and a Newport 1830-C photodiode under N_2 atmosphere at room temperature.

3. Results and discussion

We have investigated the effects of different source electrodes on the performance of the prepared OTFTs.

Several source electrodes having different work-function (Ø) were used in the present work. Table 1 showed the properties of devices using Au, Ag, Al and LiAl as source electrode. I_{DS} at a constant V_{DS} decreased with increasing metal work-function of source electrode, because high metal work-function of source electrode forms high potential barrier to the active layer.[8,9] So, it is hard to inject electron carriers from source to drain electrodes. On the other hand, low work-function metal is easy to inject electron carriers. LiAl has the lowest work-function among these metals. Thus, electron injection was much better than the other metal electrodes, Au, Ag and Al. However, the on-off ratio showed a maximum value of 66.7 at Al source electrode. The results imply that the high current does not guaranty the high on-off ratio.

TABLE 1. I-V characteristics of OTFT using various source electrodes under C_{60} active layer

Source (work-function)	V_{DS}	Current (mA)	On-off ratio
LiAl (3.0)	3	V_G = 0 V ; 36.383 V_G = -3 V ; 2.8209	12.9
Al (4.3)	6	V_G = 0 V ; 7.4710 V_G = -4 V ; 0.1120	66.7
Ag (4.6)	6	V_G = 0 V ; 3.4702 V_G = -4 V ; 0.1071	32.4
Au (5.2)	6	V_G = 0 V ; 1.5928 V_G = -4 V ; 0.0538	29.6

Drain-source current (I_{DS}) at a constant drain-source voltage (V_{DS}) decreased with increasing a gate voltage (V_G) as shown in Fig. 1. The electron carriers injected from the source electrode flow between source and drain electrodes through potential barrier near the gate electrode. The gate electrode blocks the carrier flow from the source to drain electrodes through the formation of double Schottky barriers.[10,11] The potential barrier is increased with the increase of gate voltage. Thus, I_{DS} could be controlled by the negative gate voltage. We have fabricated OLED consisting of Al/C_{60}/MEH-PPV/PEDOT:PSS/ITO. Low radiance performance was obtained due to the charge transfer between C_{60} and polymer induces the electroluminescence quenching. Thus, we have fabricated OLED consisting of Al/C_{60}/Bphen/MEH-PPV/PEDOT:PSS/ITO. The electroluminescence quenching was deactivated by the blocking effect of Bphen. L-V curves of the devices with Bphen or without Bphen are shown in Fig. 2.

We have examined the feasibility for fabrication of organic light-emitting transistor (OLET) using MEH-PPV as an emission layer. Bphen as a blocking layer, and C_{60} as a n-type active layer. Fig. 3 showed the I-V and L-V curves of the OLET. The on-off ratio of the devices was about 80.

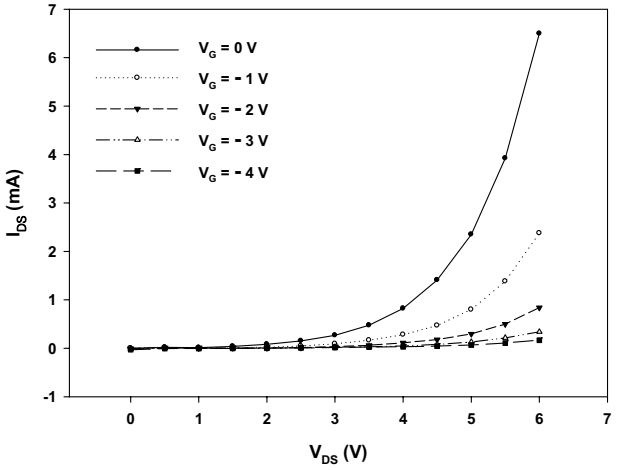

Fig. 1. I-V characteristics of vertical type OTFT consisting of Al/C_{60}/Al gate/C_{60}/ITO.

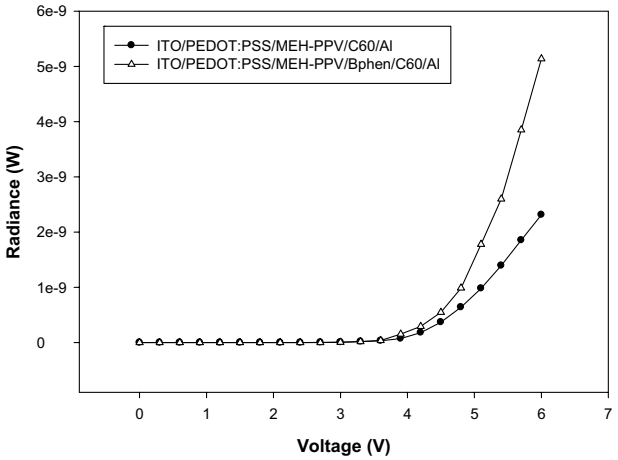

Fig. 2. L-V characteristics of organic light-emitting diode.

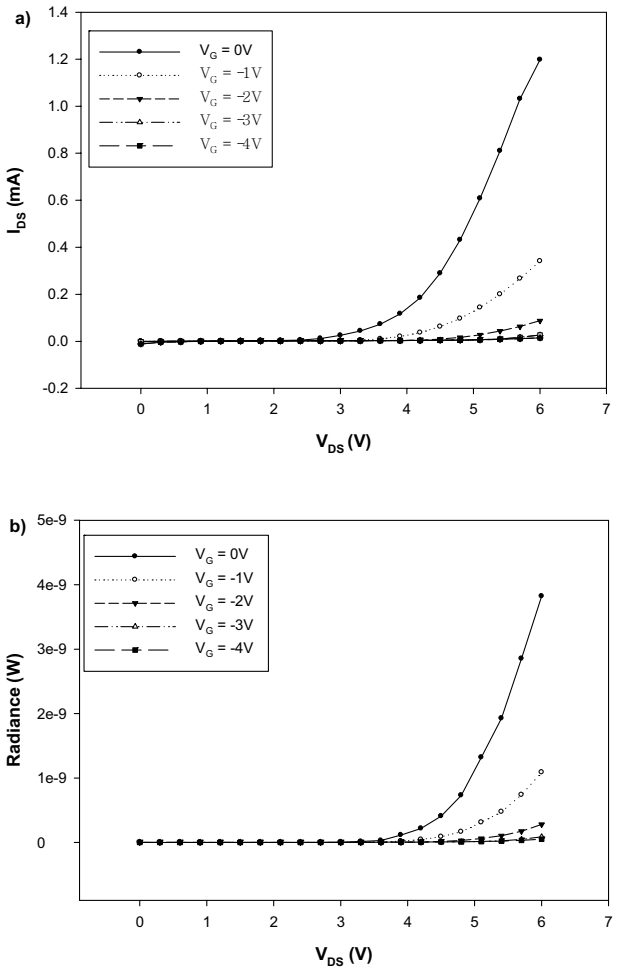

Fig. 3. I-V-L characteristics of OLET consisting of Al/C_{60}/gate/C_{60}/Bphen/MEH-PPV /PEDOT:PSS/Al : a) I-V curve and b) L-V curve.

4. Summary

Vertical type organic thin film transistor using C_{60} was fabricated with several kinds of metals as electrode. Then, the I-V characteristics were investigated. I_{DS} at a constant V_{DS} decreased with increasing a V_G. It should be noted that the low work-function metal is easy to inject electron carriers. We have fabricated OLET consisting of ITO/PEDOT:PSS/MEH-PPV/C_{60}/Al gate/C_{60}/Al, and introduced Bphen as a blocking layer to improve the EL performance in C_{60}/poymer system. The blocking effect of Bphen between C_{60} and polymer was obtained.

5. Acknowledgmen

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5. References

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