Characteristics and Fabrication of Vertical Type Organic Light Emitting Transistors

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Abstract
We have fabricated vertical type organic thin film transistors (OTFTs) using organic semiconductor materials such as F16CuPc, NTCDA, PTCDI C-8 and C_{60}. The layers of OTFT were fabricated by vacuum evaporation technique and spin casting method onto the Indium Tin Oxide (ITO) coated glass. I-V characteristics and on-off ratios of the fabricated OTFTs were investigated. In addition, we have fabricated light emitting transistor using MEH-PPV and then investigated EL electroluminescent properties.

1. Introduction
In recent years, OTFTs have much attention due to their attractive characteristics such as large area coverage, structural flexibility, low temperature processing and especially low cost. However, conventional OTFTs have low-speed, low-voltage, relatively high operational voltage and poor device performances due to their long channel length between drain and source electrodes. Vertical type static induction transistor (SIT) is a promising device to improve the problems because of the high speed and high-power operation.[1-7] Vertical type transistors have short channel length because current carriers flow across the multilayered organic films as shown in Figure 1.

In this work, we have fabricated organic SITs with a vertical structure using n-type organic semiconductor materials such as F16CuPc (copper hexadecafluorophtahlocyanine), NTCDA(1,4,5,8-naphthalenetetracarboxylicdianhydride), PTCDI C-8 (N,N-dioctyl-3,4,9,10-perylenetetracarboxylic diimide) and C_{60}.

We have investigated the effects of carrier mobility in organic active materials, the thickness of thin film and gate structure on I-V characteristics and on-off ratios. Additionally, the device performance of organic light emitting transistor using n-type SIT and light emitting polymer was described.

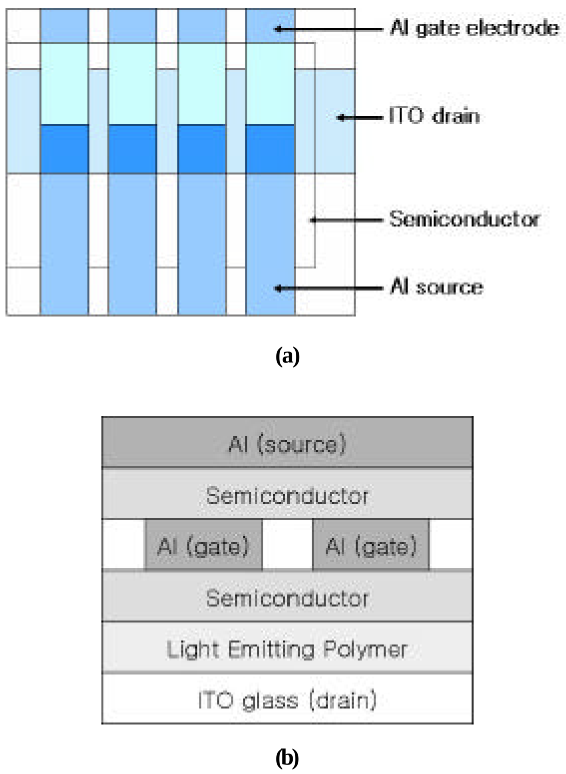


Figure 1. Schematic illustration of vertical type organic transistor (a) The front side of device, (b) The lateral face of device

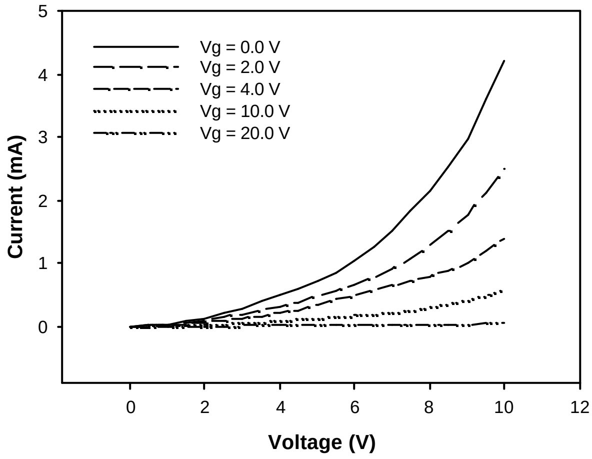
2. Experimental
F16CuPc, NTCDA, PTCDI and C_{60} were used as n-type semiconductor materials. F16CuPc, NTCDA and C_{60} were purchased from Aldrich and PTCDI C-8 was synthesized according to the publication reported previously.[8] Light emitting polymer, MEH-PPV (poly(2-methoxy-5-(2'-ethyloxy)-1,4-phenylenevinylene))) and PEDOT-PSS (poly(3,4-ethylenedioxy thiophene) / poly(styrenesulfonic acid)) as hole injection material were purchased from

Aldrich and Bayer Co. Ltd., respectively. Chloroform was distilled from first grade solvent purchased on the market. ITO (Indium Tin Oxide) coated glass substrate (Samsung Corning, Korea) with sheet resistance less than 20 O was cleaned ultrasonically with a series of organic solvents.

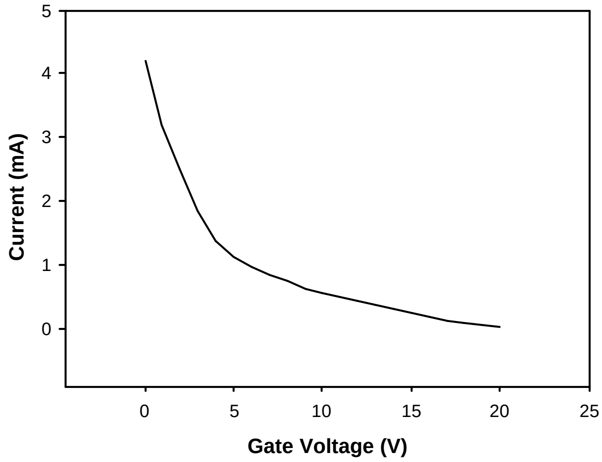
The structure of vertical type organic transistor consisting of n-type organic material thin films is shown in Figure 1 a and b. All layers were fabricated on patterned ITO glass substrate using vacuum evaporation technique (ULVAC VPC-200F evaporator) at approximately 10^{-6} Torr. During the evaporation, the substrate temperature is room temperature. Firstly, n-type organic semiconductor material was deposited onto the patterned ITO glass substrate. The evaporation rate was below 1 Å/sec. The thickness of organic semiconductor layer was approximately 500 Å, 1000 Å and 1500 Å, respectively. Secondly, Al gate electrodes were fabricated with patterned masks of 100 µm line, 300 µm line, 500 µm line and 100 µm grid type. The second organic semiconductor layer was deposited by the same method of first layer. Lastly, Al source electrode was deposited. The structure of organic light emitting transistor using n-type organic semiconductor and p-type light emitting polymer is shown in Figure 1b. MEH-PPV and PTCDI C-8 were spin-coated from chloroform solution at 1000 rpm. The I-V and luminance characteristics were measured by Keithly 237 programmable source meter and Newport 1830-C photodiode. The luminance property of light emitting transistor was obtained by using an Acton 300i spectrofluorometer. During measurement, the temperature is maintained at room temperature.

3. Results and Discussion

I-V characteristics of vertical type organic transistor using PTCDI C-8 were shown in Figure 2. Drain-source current (I_{DS}) at a constant drain-source voltage (V_{DS}) decreased with increasing a gate voltage (V_G). The electron carriers injected from the source electrode flow between source and drain electrodes through potential barrier near the gate electrode. The potential barrier increased with increasing the gate voltage. I-V characteristics of all devices were similar to the results of PTCDI C-8. Especially, high current and on-off ratio (89.2) were obtained in the device using PTCDI C-8. It should be emphasized that I_{DS} of vertical type organic transistors using n type organic semiconductor materials can be controlled by V_G like a field effect transistor of deplection type.



(a)

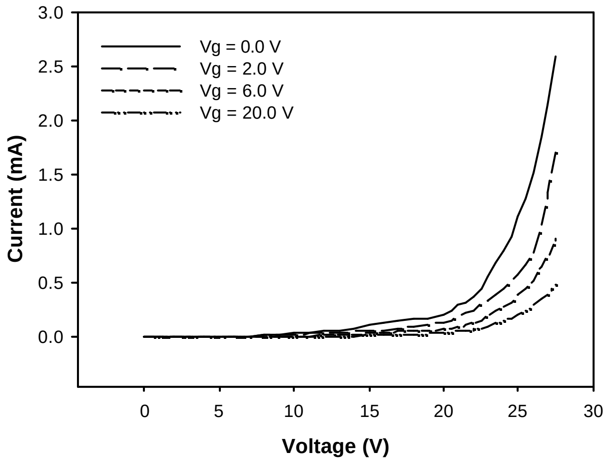


(b)

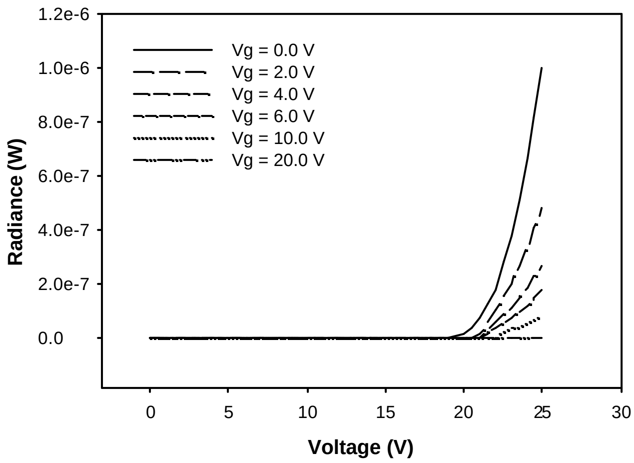
Figure 2. I-V characteristics of vertical type organic transistor consisting of Al/F16CuPc/Al gate/F16CuPc/ITO .
(a) Current-voltage characteristics (b) Current-gate voltage characteristic

In order to improve the performance of vertical type organic transistor, different techniques such as the various thickness of n-type active layers in the each device and various shape of gate electrode were used.

Figure 3 shows I-V-L characteristics of light emitting transistor using F16CuPc of 2000 Å, MEH-PPV of 1000 Å, and PEDOT-PSS. Drain-source current (I_{DS}) at a constant drain-source voltage (V_{DS}) decreased with increasing a gate voltage (V_G). The I_{DS} was controlled by small V_G, and a typical depletion transistor characteristic was obtained. The luminance also decreased corresponding to I-V characteristics and was not observed at a gate voltage of 20 V.



(a)



(b)

Figure 3. (a)I-V characteristics and (b)luminance-voltage characteristics of light emitting transistor consisting of Al/F16CuPc/Al gate/F16CuPc/P3HT/PEDOT-PSS/ITO.

4. References

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6. Acknowledgements

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