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Organic thin-film transistors for driving organic light emitting diode

Masatoshi Kitamura, Tadahiro Imada and Yasuhiko Arakawa

Research Center for Advanced Science and Technology, University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo, 153-8505, Japan
Phone: +81-3-5452-6098 ex 57590 Fax: +81-3-5452-6247 e-mail: kita@iis.u-tokyo.ac.jp

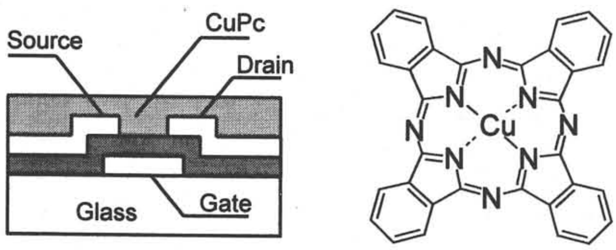
1. Introduction

Organic thin-film transistors (OTFT) have attracted attention over the past years because of their potential advantages and applications. Various kind of organic transistor circuits, inverter, ring-oscillator, and integrated circuit with organic light-emitting diode (OLED) [1,2], have been demonstrated as application of OTFT. In case of integrating OTFT with OLED, it is necessary for channel materials of OTFT to be stable in the same environment as OLED operation. Copper phthalocyanine (CuPc) is expected as the channel material of integration circuit because the material is chemically and thermally stable, and acts as hole transport layer of OLED [3] and the channel material of OTFT [4].

In this study, we fabricated and investigated organic transistors based on CuPc. In addition, as its application we demonstrated driving OLED with CuPc as hole injection layer by OTFT with the same layer structure as the OLED.

2. Experimental

The transistor device structure and molecular structure of CuPc are shown in Figs. 1 (a) and (b). Organic TFTs were fabricated on glass substrate to apply to integration with optical devices. Chromium gate electrodes were first defined by lift-off process. Silicon dioxide as the gate insulator was deposited by rf-sputtering. The thickness of the gate insulator is 150 nm. Then, source and drain electrodes (Cr/Au) were defined by life-off process. The device was completed by the evaporation of CuPc as the channel material.



(a) (b)

Fig. 1 Device structure of OTFT and chemical structure of CuPc.

In case of integration devices, indium tin oxide (ITO) pre-coated glass was used as the substrate. The patterned structure, consists of the electrodes for transistor, the anode (ITO) of OLED and the gate insulator, were fabricated by the same process as the single transistor. The organic multi-layer, CuPc (30 nm), α-NPD (30 nm), Alq doped with Coumarin 6 (20 nm) and Alq (40 nm), was deposited on the patterned substrate. The device was completed by the evaporation of LiF/Al as the cathode over the LED region. The integrated device structure and circuit fabricated in this work are shown in Fig. 2.

The single transistor and integrated device were encapsulated in a glove-box under dry nitrogen, and then measured in air.

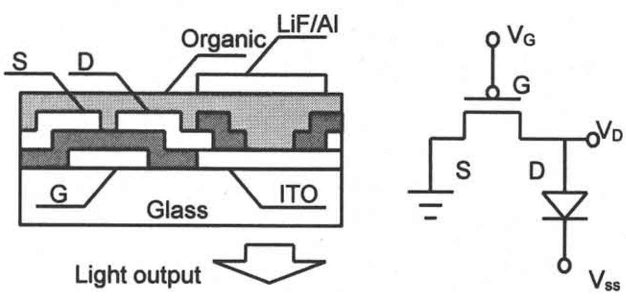


Fig. 2 The integrated device structure and circuit.

3. Results

We investigated the characteristics of the individual transistor. The channel (gate) length and width of the transistor are 2 μm and 250 μm, respectively. The voltage-current characteristics are shown in Figs. 3. The current saturation is clearly observed at high drain voltages in fig. 3 (a). The characteristic of the OTFT was similar to those of ideal MOS transistor. Figure 3 (b) shows square root of drain current versus the gate voltage at saturation region. The field-effect mobility and threshold voltage were estimated to be 2×10^{-3} cm^2/V s and –9 V from the drain current characteristic. The drain current at –20 V gate voltage and –20 V drain voltage was about -0.3 μA. Current in the order of 0.1μA will be available to drive a

OLED with about 100 μm × 100 μm in emitting area size.

We show the photographs of the integration device of OTFT and OLED in Fig. 4. The channel (gate) length and width of the transistor are 2 μm and 400 μm, respectively. The emitting area of OLED is 100 μm × 100 μm in size. The cathod voltage of the LED (Vss) was –16 V, and the gate voltages were (a) 0 V and (b) –16 V. There was no light output from the OLED pixel at zero gate voltage. On the other hand, the light output was obtained at $V_G = -16$ V. The visible light from the pixel was observed over $V_{ss} = -10$ V and $V_G = -10$ V.

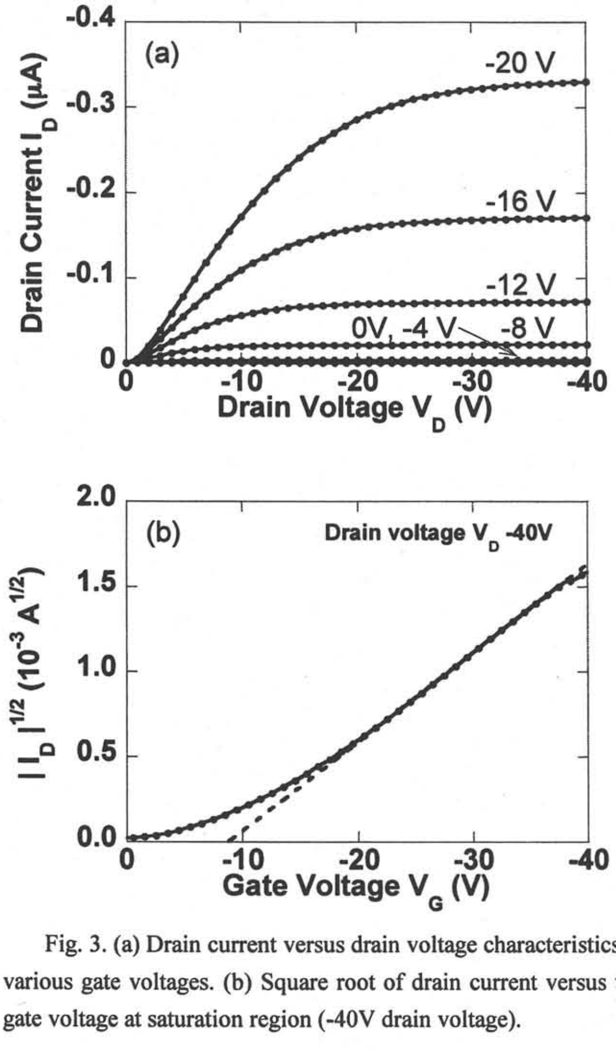


Fig. 3. (a) Drain current versus drain voltage characteristics at various gate voltages. (b) Square root of drain current versus the gate voltage at saturation region (-40V drain voltage).

4. Summary

We have fabricated organic TFT based on CuPc. The voltage-current characteristic with saturation region has been obtained. Moreover, we have demonstrated the integration device of OTFT and OLED, and have realized switching emission from OLED by the gate voltage of OTFT.

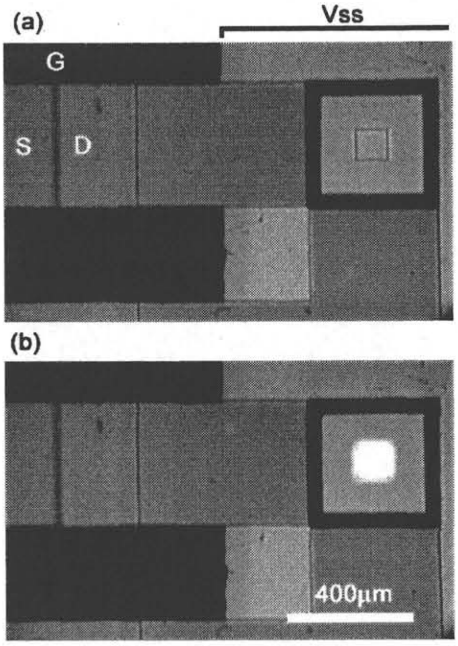


Fig. 4 Photographs of the integration device of OTFT and OLED. The gate voltages of the transistor are (a) 0 V and (b) –16 V. The emission from the pixel of OLED was obtained at –16 V gate voltage.

Acknowledgments

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