Vertical Type Organic Transistors and Flexible Display Applications

Kazuhiro Kudo
Electronics and Mechanical Engineering, Chiba University, Chiba 263-8522, Japan
kudo@faculty.chiba-u.jp

Keywords: Organic field-effect transistor, Vertical type transistor, Flexible display, Light emitting transistor

Abstract
Organic transistors are promising in the future development of active devices for flexible, low-cost and large-area photoelectric devices. However, conventional organic field-effect transistors have low-speed, low-power, and relatively high operational voltage. Vertical type transistors show high-speed and high-current characteristics and are suitable for driver elements of flexible displays.

1. Introduction
Recently, field effect transistors (FETs) using organic materials [1-5] are promising in the future development for low-cost and large-area organic devices such as flexible displays, RF-ID tags, bio-sensors, etc. However, conventional organic FETs have a channel formed in the lateral direction and their performances are not sufficient for electronic devices. For practical applications, it is necessary to improve not only the electrical parameters of organic material itself but also the device structure.

In the application field, optoelectronic elements using organic materials show promise for low-cost, large-area and flexible devices. In particular, liquid crystal and OLED are expected to be used as display components of mobile electronic devices. On the other hand, organic transistors have seen great improvements in recent years and all-organic display devices are expected by combining the OLED with organic transistors. To be practical, however, conventional FETs using organic materials have low-speed, low-power, and relatively high operational voltage. These low device performances are mainly due to their low-mobility and high-resistivity. The vertical type transistors, particularly organic static induction transistor (OSIT), are suitable for flexible displays and the basic SIT characteristics as a driving element for organic display devices were already reported [5,6]. From this point of view, organic light emitting transistors (OLET) combined with the OSIT and OLED were proposed [6].

This report describes the basic characteristics of OSIT and OLET on glass or plastic substrates.

2. Organic transistors
Typical FET structures proposed in literature are shown schematically in Fig. 1. The lateral type FET (Fig. 1(a)) is proposed as a prototype of thin film transistor (TFT) and the current flows along the channel formed in the lateral direction. In the lateral type FET, highly doped Si substrate is used as a gate electrode. To fabricate a flexible FET, the substrate is replaced to plastic films (Fig. 1(b)). On the other hand, the current of the vertical type FET flows in the vertical direction. The device structure of vertical type FET is shown in Fig. 1 (c). In the vertical type FET

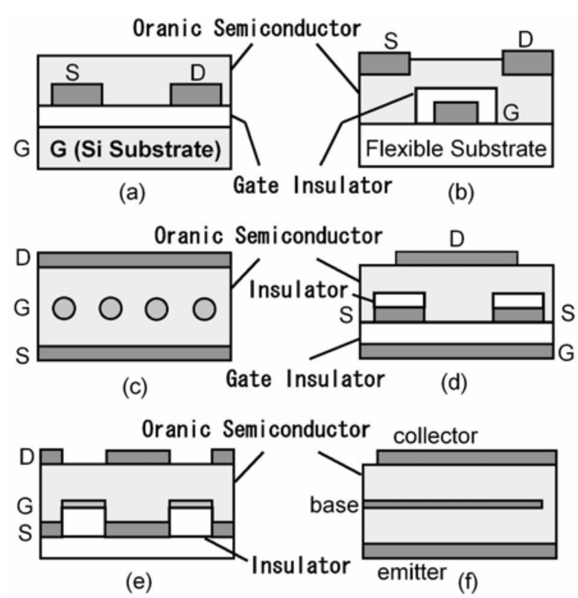

Figure 1 Typical structures of organic transistors

(SIT in Fig. 1(c)), the channel length corresponds to the film thickness and high-speed and high-power operations have been realized [5]. Another metal-insulator-semiconductor (MIS) type vertical FET as shown in Fig. 1 (d) has also excellent characteristics similar to SIT. The SIT structure shown in Fig. 1 (e) can be fabricated by the simple and fine process called SPHOS (spontaneous patterning of higher order nano-structures) method [7]. On the other hand, another type transistor having a simply layered structure, namely metal base transistor (MBT) as shown in Fig. 1 (f), have been reported [8].

The vertical type OSITs show stable electrical characteristics in bending experiments [9]. Figure 2 shows the illustration of the crack and carrier flow in type lateral and vertical FETs, and the I_{DS} variation under bending conditions.

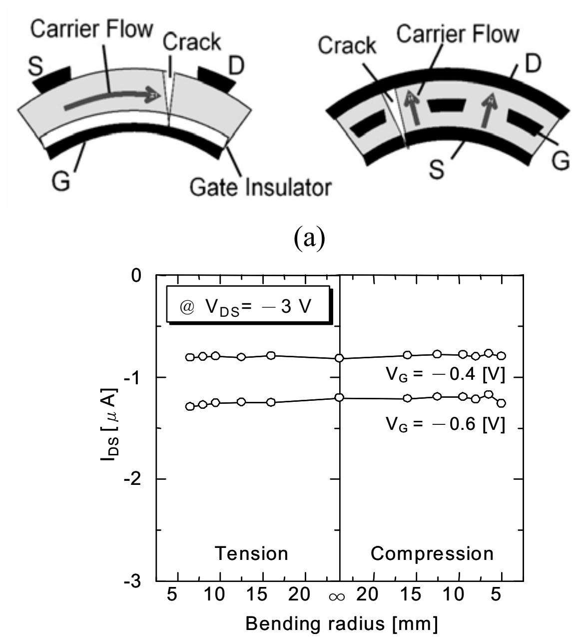

Figure 2 (a) Cross-sectional views of lateral and vertical FETs under bending conditions, (b) Variation in I_{DS} of OSIT as a function of bending radius.

3. OLET

Figure 3 (a) and (b) show SIT type and MIS type OLETs. In the SIT type OLET, OLED is combined vertically with SIT. The OLET has a simple structure similar to the OLED. The MIS type OLET improved On/Off ratios over 100 times by reducing the leakage current [10].

Both SIT and MIS type OLETs show excellent characteristics on a plastic substrate. The results obtained here demonstrate that the OLET is a suitable element for flexible sheet displays.

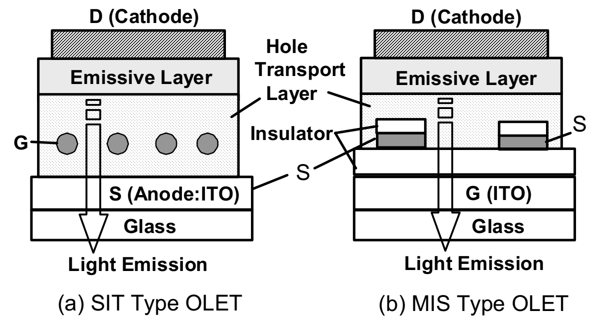

Figure 3 Device structures of (a) SIT type OLET and (b) MIS type OLET.

4. Conclusions

The basic characteristics of OSIT and OLET are investigated. Relatively high luminance modulation by low gate voltage was observed in the OLET by optimizing the gate electrode and layer thicknesses. These results demonstrate that the OLET described here is expected for the application in flexible displays.

5. Acknowledgements

A part of this work belongs to "Advanced Organic Device Project" which OITDA contracted with New Energy and Industrial Technology Development Organization (NEDO).

References

[1] C.D.Dimitrakopoulos, P.R.L.Malenfant, Adv.Mater., 1499,(2002).
[2] A.Dodabalapur, Z.Bao, A.Makhija, J.G.Laquindanum, V.R.Raju, Y.Feng, H.E.Katz, and J.Rogers, Appl.Phys.Lett.,73142,(1998).
[3] H.Sirringhaus, N.Tessler, R.H.Friend, Science, 2801,741(1998).
[4] K.Kudo, D.X.Wang, M.Iizuka, S.Kuniyoshi and K.Tanaka, Synth.Metal, 111-112,11 (2000).
[5] K.Kudo, D.X.Wang, M.Iizuka, S.Kuniyoshi and K.Tanaka, Thin Solid Films, 331,51 (1998).
[6] K.Kudo, Current Appl.Phys., 5,337 (2005).
[7] K. Fujimoto, T. Hiroi, K. Kudo, M. Nakamura, Adv. Mater. (2007).
[8] S. Fujimoto, K. Nakayama and M. Yokoyama, Appl. Phys. Lett. 87, 133503 (2006).
[9] Y.Watanabe, H.Iechi and K.Kudo, Appl.Phys.Lett., 89, 233509(2006).
[10] K. Nakamura, T. Hata, A. Yoshizawa, K. Obata, H. Endo, K. Kudo, Appl. Phys. Lett. 89, 103525 (2005).