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Fabrication of FET Using Charge-Transfer-Complex LB Films

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1. Introduction

Charge transfer (CT) complexes are formed by partial transfer of electric charge from donor molecules to acceptor molecules. The formation of CT complexes usually produces higher conductivity that is not intrinsic to individual molecules, which is of great interest in connection with their anisotropic optical and electrical properties. The conductivity of the thin film of CT complex can be controlled if the degree of charge transfer is varied by applying an external force such as electric field[1-3].

In this study, we have fabricated field-effect transistors (FETs) using CT complex Langmuir-Blodget (LB) films, and tried to control the conductivity of the CT complex layers by gate voltages.

2. Experimental

The chemical structures of the materials employed in this study are shown in Fig. 1. TMPD was used as a donor molecule and $C_{15}TCNQ$ as an acceptor. A highly doped Si substrate, which works as a gate electrode, was thermally oxidized to a thickness of approximately 200 nm. The Au/Cr source and drain electrodes were formed on the SiO_2. The channel length and width were 0.02 and 25 mm, respectively.

The CT complex films were formed by an adsorption LB method which is schematically shown in Fig. 2 [4]. First, a monolayer film of $C_{15}TCNQ$ was formed on a surface of distilled water. Since the spreading area was restricted by a rigid frame, a proper initial surface pressure was obtained by adding a certain amount of the molecules. Second, a small amount of TMPD solution was injected into the subphase using a microsyringe. After 3 h to allow TMPD to adsorb to $C_{15}TCNQ$, the floating film was compressed. A substrate was vertically immersed at a speed of 5 mm/min, leaving 15 m drying time between every dipping cycle. Both Z-type and Y-type LB films can be deposited by varying the fabrication conditions [5].

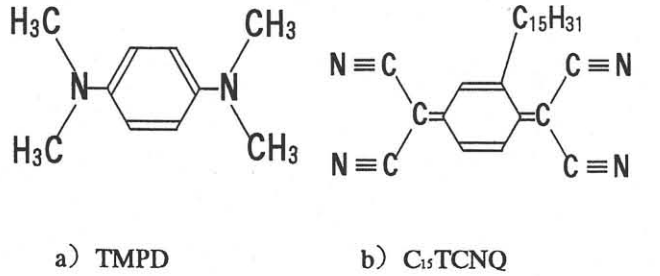

Fig. 1 Chemical structures of a)TMPD and b)$C_{15}TCNQ$

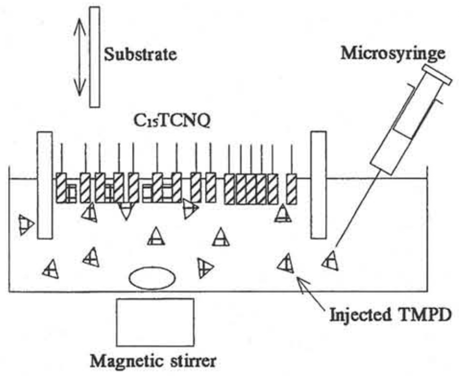

Fig. 2 Schematic illustration of adsorption LB method

Electric measurements were performed in a vacuum at room temperature (around 20 ℃). The drain-source current (I_{DS}) versus drain-source voltage (V_{DS}) characteristics were measured by applying various V_G. Transconductance (g_m) was estimated from the I_{DS}-V_{DS} measurement as a function of V_G, which demonstrates the performance of FET.

3. Results and discussion

Figure 3 shows the FET characteristics of a

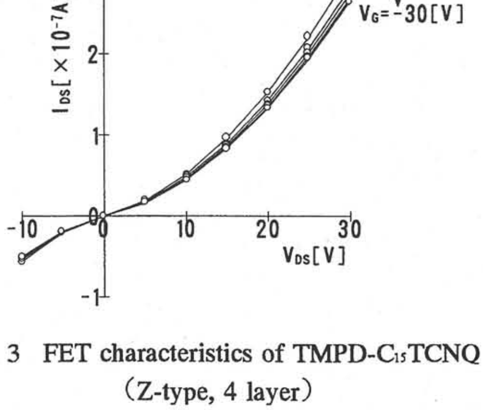

Fig. 3 FET characteristics of TMPD-$C_{15}TCNQ$ (Z-type, 4 layer)

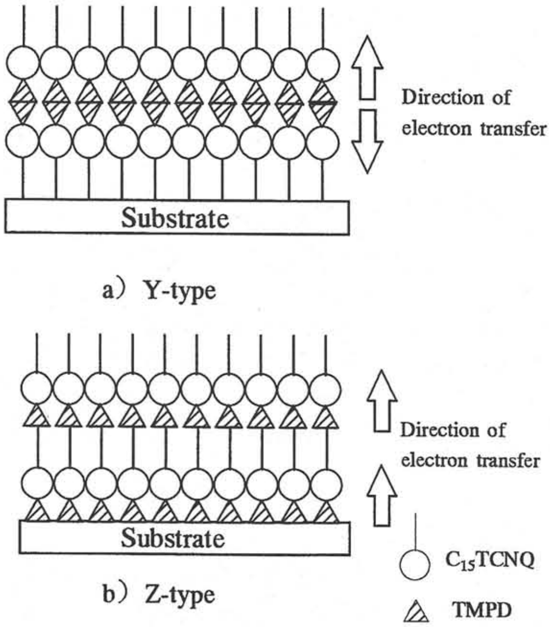

Fig. 4 Stacking structure of Y-type and Z-type LB films

TMPD-C_{15}TCNQ LB film (Z-type, 4 layers).

I_{DS} of the Z-type LB film FET increases by increasing positive bias of V_G. The value of g_m estimated for this FET is 1.3×10^{-9}[S]. A Y-type LB film FET was also measured in the same manner and its source-drain current and g_m were approximately one order of magnitude smaller than these of the Z-type LB film FET.

From these results, we discuss the relationship between the device characteristic and the stacking structure of the LB film. Figure 4 shows the stacking structure of Y-type and Z-type LB films. In Y-type, the influence of V_G on the charge transfer is canceled out due to the alternative stacking directions. In Z-type, however, the influence of V_G is not canceled out. Therefore, the dependence of I_{DS} on V_G for Z-type is larger than that for Y-type.

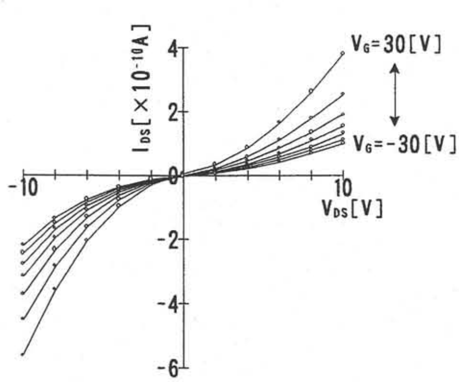

Fig. 5 FET characteristics of TMPD-C_{15}TCNQ (Z-type, monolayer)

The FET characteristics of a TMPD-C_{15}TCNQ monolayer LB film (Z-type) FET is shown in Fig. 5. The dependence of I_{DS} on V_G becomes more obvious than that of the 4 layers FET (Fig. 3), although I_{DS} of the monolayer FET is smaller. These results indicate that stacking the multiple CT layers mainly increases ineffective current with V_G.

4. Conclusion

We have fabricated FETs using TMPD-C_{15}TCNQ CT complex LB films. Two kinds of LB films (Y-type and Z-type) were obtained by choosing proper fabrication parameters. The FET using each film showed different field-effect characteristics. The results indicate that the device characteristics strongly depend on the stacking structure of Y-type or Z-type CT complex layers. In the monolayer FET, the dependence of I_{DS} on V_G appeared more pronounced than that in the 4 layers FET.

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