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Control of FET Characteristics by Electric Field During CT Complex Deposition

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1. Introduction

Charge transfer (CT) complexes exhibit anisotropic optical and electrical properties, so they are known as very attractive organic compounds. These unique characteristics of CT complexes derive from their crystal structures and a partial charge transfer between donor and acceptor molecules. The degree of charge transfer (ρ) from a donor molecule to an acceptor molecule depends not only on the kind of molecules but also on the crystal structure of the CT complexes, and ρ is directly related to the electrical conductivity. Most CT crystals have the structure of a segregated system (donors and acceptors stack independently) or a mixed system (donors and acceptors stack alternately). TMTSF-TCNQ CT complex has two types of crystal structure (red crystal or black crystal), and its ρ is 0.21 or 0.57 [1].

If ρ could be modified by the external field after or during the fabrication, the electrical conductivity of the CT complex could be changed [2-3]. In this report, we describe the unique characteristics of organic FETs using CT complex layer fabricated by a electric field assisted deposition.

2. Experimental

TMTSF and TCNQ are used as donor and acceptor molecules. Their chemical structures are shown in Fig. 1. The evaporation source was TMTSF-TCNQ CT complex which was recrystallized from TMTSF-TCNQ solution.

Fabrication system of TMTSF-TCNQ FET by electric field assisted deposition are shown in Fig. 2. The highly doped Si substrate, which works as a gate electrode, was covered with thermally grown SiO₂ with a thickness of approximately 200 nm. The Au/Cr interdigital source and drain electrodes were formed on the SiO₂. The channel length and width were 0.2 and 56 μ m, respectively. After the sample had been connected to the electrical circuit, TMTSF-TCNQ was deposited in the vacuum chamber. During the evaporation, gate voltage (V_G) was applied, the substrate temperature was kept at 40 °C. The film thickness was approximately 100 nm. In-situ electrical characterization under the quasi-static condition was performed at the room temperature in the vacuum chamber without breaking the vacuum. The drain-source

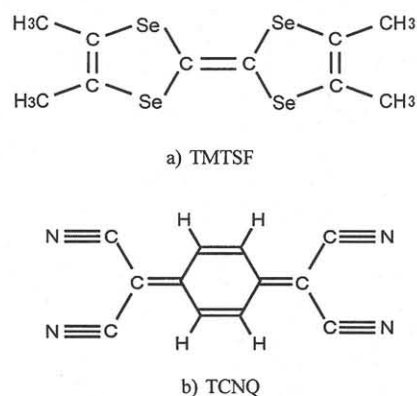


Fig. 1 Chemical structures of a)TMTSF, b)TCNQ.

voltage (V_{DS}) versus drain-source current (I_D) characteristics with applying various V_G were measured after depositing the TMTSF-TCNQ layer and the thermal treatment at 50 °C. In-situ field effect measurement is a promising method for investigating intrinsic electrical properties of organic thin films since the influences of atmosphere gases and impurities are excluded during measurements.

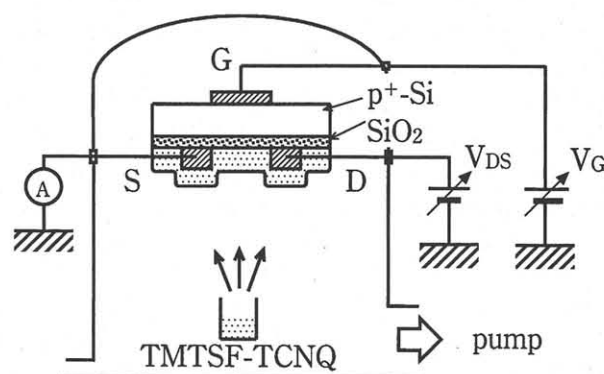


Fig. 2 TMTSF-TCNQ FET fabricated by a electric field assisted deposition.

3. Results and discussion

Figure 3 shows FET characteristics of TMTSF-TCNQ layer evaporated at $V_G=0V$. Just after the deposition, the

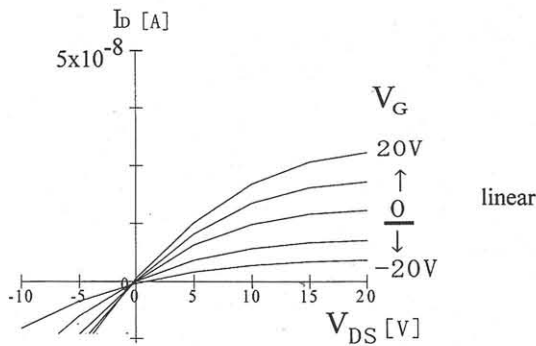


Fig. 3 FET characteristics of TMTSF-TCNQ fabricated at $V_G=0V$, $V_{DS}=0V$. (as deposition)

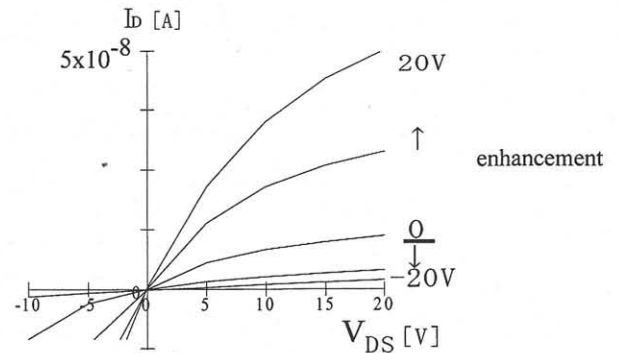


Fig. 5 FET characteristics of TMTSF-TCNQ fabricated at $V_G=20V$, $V_{DS}=0V$. (after the thermal treatment)

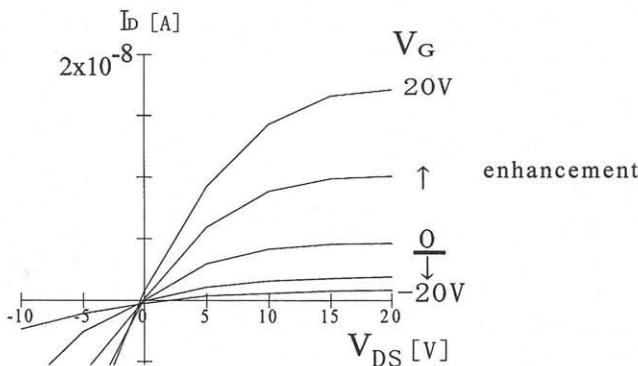


Fig. 4 FET characteristics of TMTSF-TCNQ fabricated at $V_G=0V$, $V_{DS}=0V$. (after the thermal treatment)

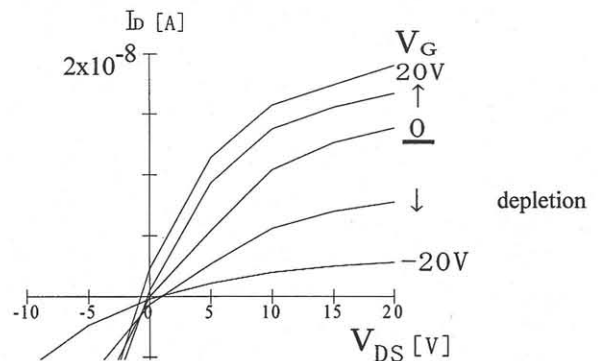


Fig. 6 FET characteristics of TMTSF-TCNQ fabricated at $V_G=-20V$, $V_{DS}=0V$. (after the thermal treatment)

variation of I_D of the FET was almost linear by the V_G from 20 V to -20 V. However, FET characteristics after the thermal treatment changed to the enhancement mode operation as shown in Fig. 4. The variation of I_D with positive V_G was much larger than that of negative V_G . TMTSF-TCNQ FET characteristics fabricated at $V_G=20V$ and after the thermal treatment are shown in Fig. 5. FET characteristics fabricated at $V_G=20V$ were similar to those of $V_G=0V$. On the other hand, FET characteristics fabricated at $V_G=-20V$ and the thermal treatment showed the depletion mode operation (Fig. 6). These phenomena seem to be due to the modification of the crystal structure and charge transfer state of the CT layer. Accordingly, the CT layer is modified to be a certain specific CT state, and the state is frozen in the device at the room temperature.

These results strongly indicate that FET characteristics can be controlled by the electric field assisted deposition and thermal treatment.

4. Conclusions

We have fabricated TMTSF-TCNQ CT complex FET using the electric field assisted deposition technique. Two

mode operations of CT complex FET characteristics were observed, which were depletion mode, and enhancement mode. These results demonstrate that CT complex FET with different operation mode can be controlled by electric field deposition technique.

References

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