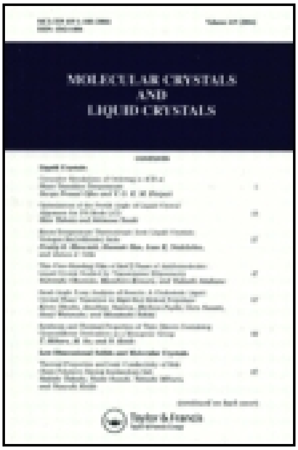

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Growth Temperature Dependence of Donor-Acceptor Layered Structure FET

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Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 350, pp. 371-374
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Growth Temperature Dependence of Donor-Acceptor Layered Structure FET

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We have fabricated field-effect transistors (FETs) using a TMTSF (donor) and TCNQ (acceptor) layered structure and investigated the basic FET characteristics. The transconductances of FETs depended on the substrate temperature.

Keywords: charge transfer complex; layered structure FET; transconductance; substrate temperature

INTRODUCTION

Organic thin-film field-effect transistors (TFTs) have recently received increasing interest because of their potential applications in low-cost and large-area devices such as organic electroluminesence devices and liquid crystal displays. Although there are a number of reports [1-3] on using conducting polymers and organic semiconductors, there is little information concerning on their charge transfer (CT) complexes multi-layer systems. CT complexes composed of donor and acceptor molecules are known as attractive organic compounds because of their anisotropic electrical and optical properties derived from their unique crystal structure. A degree of charge transfer (ρ) from the donor to acceptor molecules is directly related to the electrical conductivity and mostly cased by the crystal structure of the CT complexes [4].

If ρ were modified by the external field, the electrical conductivity of the CT complexes were drastically changed. In this report, we have fabricated FET using TMTSF (donor) and TCNQ (acceptor) layered structure at substrate temperatures (T_s) of 0℃ and 22℃ (room temperature), and investigated the basic FET characteristics.

EXPRERIMENT

TMTSF (tetrametyltetraselenafulvalene) and TCNQ (tetracyanoquinodimethane) are used as donor and acceptor molecules.

The structure of the donor and acceptor layered structure FET is shown in Figure 1. The highly doped Si substrate which works as a gate electrode was covered with thermally grown SiO_2 with a thickness of approximately 200 nm. The Au/Cr interdigital source and drain electrodes were formed on the SiO_2 layer. The channel length and width were 0.2 and 56 mm, respectively. TMTSF and TCNQ were deposited on the substrates successively by a standard vacuum evaporation technique. We fabricated layered structure FETs at T_s of 0 ℃ and 22 ℃ (room temperature). In-situ field effect measurements were measured immediately after depositing the first layer and second layer at T_s in the vacuum chamber without breaking the vacuum. The transconductance (g_m) of TFTs was calculated from field effect measurement ($g_m = dI_{DS}/dV_G$, V_{DS}=const) [5].

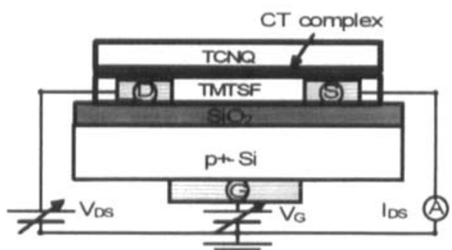
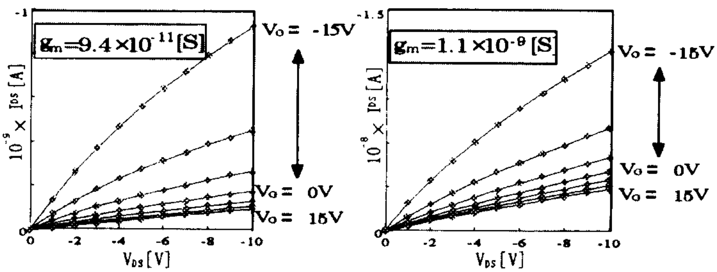


FIGURE 1 Layered structure FET

RESULTS AND DISCUSSION

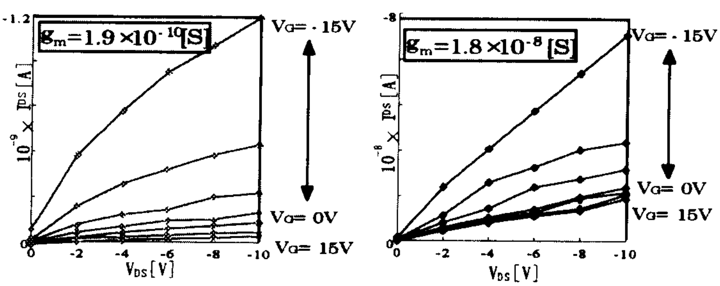
Typical characteristics of drain current (I_{DS}) versus drain voltage (V_{DS}) for different gate voltages (V_G) are shown in Figures 2 and 3. Figure 2(a) shows the characteristics of a single-layer FET measured after the TMTSF deposition at T_s of 22℃. I_{DS} of TMTSF single-layer FET was increased by increasing negative bias of V_G. The TMTSF single-layer FET showed p-channel FET characteristics and the majority carriers of the accumulation layer were holes. Figure 2(b) shows the characteristics of a TCNQ/TMTSF layered structure FET just after the second deposition of TCNQ fabricated at T_s of 22℃. The FET characteristics for the layered structure FET were similar to those of the TMTSF single-layer FET. However, I_{DS} was one order larger than that of TMTSF single-layer FET. The values of g_m estimated for the TMTSF single-layer FET and the TCNQ/TMTSF layered structure FET are 9.4×10^{-11} and 1.1×10^{-9}[S], respectively. These results indicate that CT complex layer works mainly as a conductive channel of the TCNQ/TMTSF layered structure FET.

On the other hand, Figure 3(a) and (b) show the characteristics of the TMTSF single-layer FET and TCNQ/TMTSF layered structure FET fabricated at T_s of 0℃. The values of g_m estimated for the TMTSF single-layer FET and



(a) TMTSF single-layer FET (b) TCNQ/TMTSF layered structure FET

FIGURE 2 Field effect characteristics of the FETs fabricated at T_s of 22℃



(a) TMTSF single-layer FET (b) TCNQ/TMTSF layered structure FET

FIGURE 3 Field effect characteristics of the FETs fabricated at T_s of 0℃

TCNQ/TMTSF layered structure FET are 1.9×10^{-10} and 1.8×10^{-8}[S], respectively. These results indicate that the CT complex layer works mainly as a conductive channel of the TCNQ/TMTSF layered structure FET fabricated at T_s of 0°C. However, the g_m of TCNQ/TMTSF layered structure FET fabricated at 0°C showed much larger than that at 22°C. These phenomena could be explained as follows. The FET characteristics are governed by the conductivity change near the CT complex layer formed at the interface between the donor and acceptor layers. The TCNQ/TMTSF layered structure FET grown at higher T_s forms a thicker CT complex layer and has a higher conductivity. Although a thin CT layer leads to higher g_m, a thick CT layer having higher conductivity prevents the conductance change by the external electric field due to the electric shield effect.

CONCLUSION

We have fabricated field-effect transistors (FETs) using TMTSF and TCNQ, layered structure and investigated the basic FET characteristics. The FETs characteristics are governed by the conductivity change near the CT complex. Although the formation of CT layer leads to a higher g_m, too high conductivity of the thick CT complex layer grown at high T_s prevents the conductivity change by the external electric field applied with the gate electrode.

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