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Organic Transistor with Mesophase Semiconductors Possessing Two Thienyl Groups

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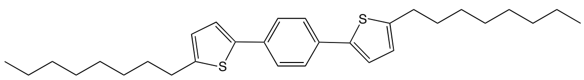
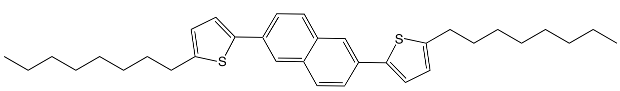
1. Introduction

Recent studies on transistors fabricated with liquid crystalline semiconductors with high solubility into the common organic solvents have shown the characteristic features provided by its "*mesomorphic properties*". In particular, the calamitic liquid crystals showing 3D-plastic mesophases are interesting in the self-assembling nature in terms of thin film formation by wet processing because of the spontaneous alignment behavior relating inter-a dn intra-domain structures of the film. Even though such materials are used in the solid state (crystals), the films involve the features reflecting the orientational orders of liquid crystalline states.[1)] *Liquid crystalline semiconductors* are being evolved into *mesophase semiconductors* following the definition of liquid crystals, meaning a new class of organic semiconductors could be designed by molecular architectures of highly ordered liquid crystals .

Here in this communication, recent works of mesophase semiconductors (TPT8 and 8TNAT8), of which central core part contains dithienyl groups and the field effect transistors are shown.



8TPT8



8TNAT8

Table I Phase transition temperatures of 8TPT8 and 8TNAT8

compound	phase transition temperature / °C
8TPT8	Cryst 47 °C M_1 71 °C M_2 87 °C M_3 145 °C Iso
8TNAT8	Cryst 93 °C M_4 182 °C Iso

2. Results and discussion

Carrier Mobilities in the Mesophases

DSC measurements and the microscoic observations of optical textures for the mesophases indicate the compound 8TPT8 and 8TNAT8 show three and one mesophases, respectively. These all mesophases are in viscous states of matter, implying highly ordered mesophases. In fact, X-ray diffraction studies of these phases indicate the similar orders to 3D mesophase with layered structures like smectic liquid crystalline phases. The phase transition behavior is summarized in Table I.[2,3)]

The Time-Of-Flight (TOF) technique was applied to evaluate the carrier mobilities in the mesophases under temperature control. The cells for measurements consist of two ITO-coated glasses as transparent electrodes with a spacer (glass beads / polyimide film). A pulsed N_2 gas laser (0.6 nsec, 337 nm) is used as the incident light source. The film thickness is ca. 5 -17 μm and polydomain structures were observed under microscope.

Any clear bias dependence of the mobility was not seen and it is almost bias-independent similar to the common liquid crystalline semiconductors.

The temperature dependence of mobility is shown in Fig. 2 and one can see week dependence, where the carrier mobility decreases as the temperature goes up. These compounds were found to have the mobility in the order of 10^{-1}-10^{-3} cm^2 V^{-1} s^{-1} in these mesophases. These values are comparable to those of liquid crystalline semiconductors and the fastest one is comparable to that of amorphous silicon.

Transistor Fabrication and the Performance

Thin film transistors with top-contact geometry were fabricated with these mesophase semiconductors (Fig.3). The output and transfer characteristics were measured at room temperature *in vacuo*.

Table II shows the transistor performance for an as-prepared and the HMDS-treated device using 8TNAT8 (the HMDS layer positions between the SiO_2 insulating and active layers),

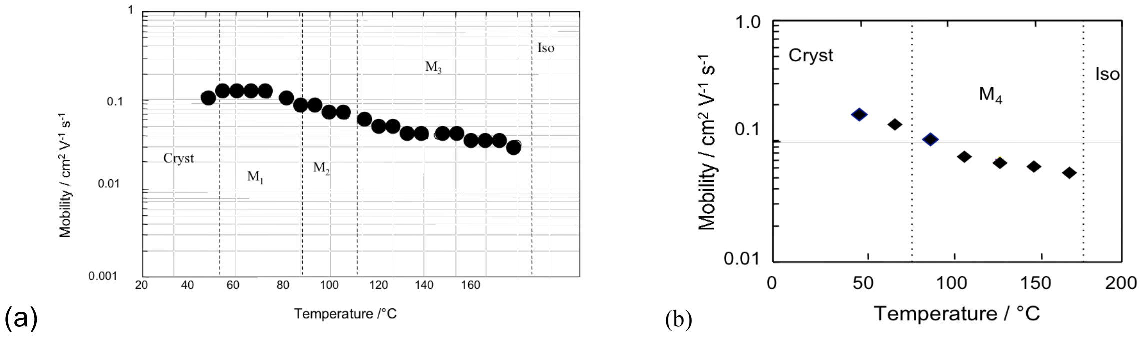


Fig. 2 Temperature dependence of carrier mobility (positive charges) for (a) 8TPT8 and (b) 8TNAT8.

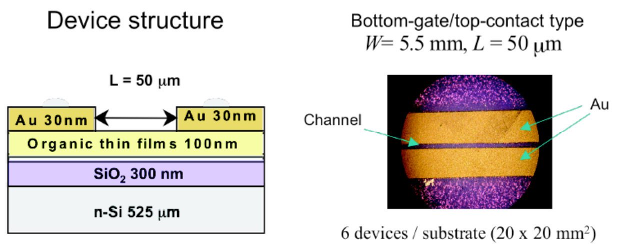


Fig.3 A top-contact geometry of the field effect transistor fabricated with 8TNAT8.

The observed FET mobility is 0.14 $cm^2\ V^{-1}\ s^{-1}$ for the HMDS-treated one and this is comparable to the draft mobility of material obtained by TOF technique (Fig.4). The active layer in this device was prepared by dry process (vacuum deposition) and the device with wet-processed active layer did not give clear response under bias. [4]

On the other hand, the FET devices with 8TPT8 did show the worse performance ($\sim 10^{-3}\ cm^2\ V^{-1}\ s^{-1}$) in the same conditions of measurements. A small effect of thermal annealing was observed to improve the performance by 2.5 times of the non-annealed device.

3. Conclusions

Two dithienyl derivatives were studied as mesophase semiconductors and the mobility in the mesophases was found to be in the order of $10^{-2} – 10^{-1}\ cm^2\ V^{-1}\ s^{-1}$ for positive carriers. Transistor devices with a top-contact/bottom gate configuration were fabricated and the FET mobility for a 8TNAT8 was measured to show a comparable value to that in the mesophase bulk.

Table II Transistor characteristics

SiO_2 substrate	μ_{FET} (cm^2/Vs)	On/off ratio
as-prepared	0.03	1.1×10^3
HMDS	0.14	1.6×10^3

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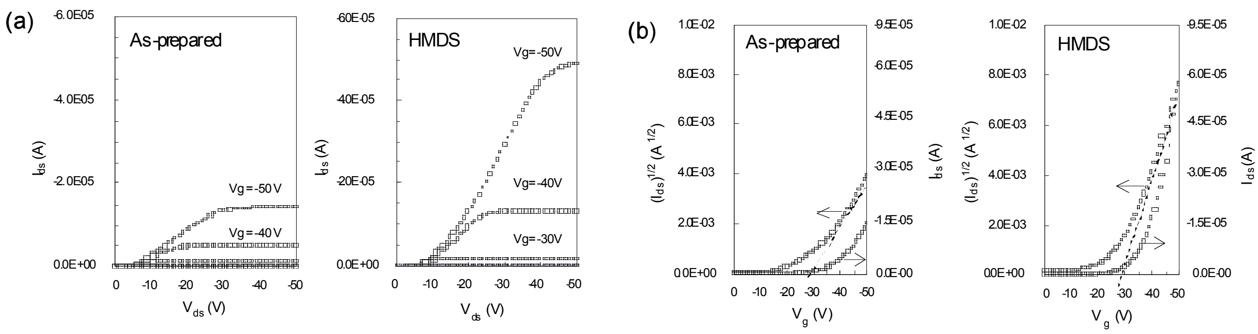

Fig.4 . (a) Output and (b) transfer characteristics of the 8TNAT8-OTFTs with W = 5.5 mm L = 50 mm, exhibiting charge-carrier mobility of 0.03 (as-prepared) and 0.14 cm^2/Vs (HMDS).