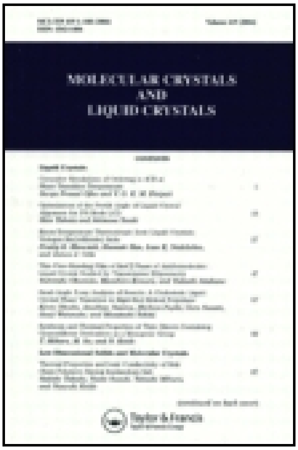


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# Light-Emitting Field-Effect Transistors Based on Organic Monolayers of Dihexylsexithiophene

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# Light-Emitting Field-Effect Transistors Based on Organic Monolayers of Dihexylsexithiophene

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*Field-effect transistors (FETs) based on dihexylsexithiophene (DH6T) films were prepared on a $SiO_2/Si$ substrate with asymmetric gold source and aluminum drain electrodes. DH6T grew in layer-by-layer manner on $SiO_2$ with its molecular axis perpendicular to the surface. Visible light emission from the channel region was observed as the gate and drain voltage increased, and the emission spectra varied depending upon the layer thickness.*

**Keywords:** asymmetric electrodes; carrier transport; DH6T; emission spectra; light-emitting OFETs; monolayer

## INTRODUCTION

Much attention has recently been paid to light-emitting organic field-effect transistors (LEOFETs) with unipolar [1–3] and ambipolar [4–5] operations because of their potential applications to novel optoelectronics devices including organic lasers. In our previous papers, we demonstrated that the luminous intensity and efficiency of LEOFETs were improved by using asymmetric gold and aluminum electrodes as well as by operating the device in vacuum [3]. In addition to the control of these factors, the careful treatment of the surface of gate

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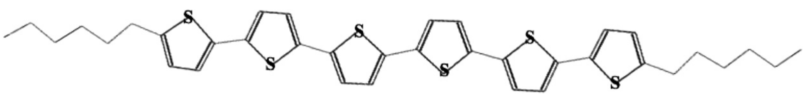

**FIGURE 1** Molecular structure of DH6T.

insulator with organic materials has recently proven to improve the luminous efficiency by an ambipolar operation [4–5].

The device structures of OFETs have advantageous to study basic mechanism of carrier injection, transport, and recombination processes in organic semiconductors. In the present study, we have prepared LEOFETs based on organic mono- to multi-layers of dihexyl-sexithiophene (DH6T, see Fig. 1) and studied thickness dependence of electrical and optical properties.

## EXPERIMENTAL

Experimental details were shown elsewhere [6]. DH6T was purchased from Aldrich and used after purification by vacuum sublimation. The organic layers were deposited onto the $SiO_2$/Si substrate with interdigital electrodes of Au/Cr and Al in an ultra high vacuum chamber. The substrate temperature was kept at 100°C during the deposition.

Emission spectra were measured with a spectrograph (Oriel, FIC 77441) and a CCD detection system (Andor, DU420-OE). Surface morphology was observed using an atomic force microscope (AFM) (JEOL, JSPM-5200) with a non-contact mode in ambient condition.

## RESULTS AND DISCUSSION

Figure 1 shows a molecular structure of DH6T of which the length is estimated to be 3.8 nm. Figure 2(a) shows AFM image of DH6T layers on $SiO_2$ at 100°C. It was revealed based on the cross section view shown in Figure 2(b) that the molecules grew in layer-by-layer manner with their molecular axes almost perpendicular to the surface.

Figures 3(a), 3(b) and 3(c) show output characteristics of DH6T FETs with the average thickness of monolayer, bilayer and multilayer (c.a. 35 layers), respectively. DH6T FETs were found to be operated in a p-channel. It should be noted that the drain current of bilayer-FETs was approximately 10 times larger than that of monolayer-FET, while slight difference in the drain current was observed from bilayer- to multilayer-FETs. The carrier mobilities of monolayer-, bilayer- and multilayer FETs were evaluated to be $4.5 \times 10^{-3}$, $3.2 \times 10^{-2}$, $3.0 \times 10^{-2}\,cm^2/Vs$, respectively. These results indicated that carriers transported mainly in the first

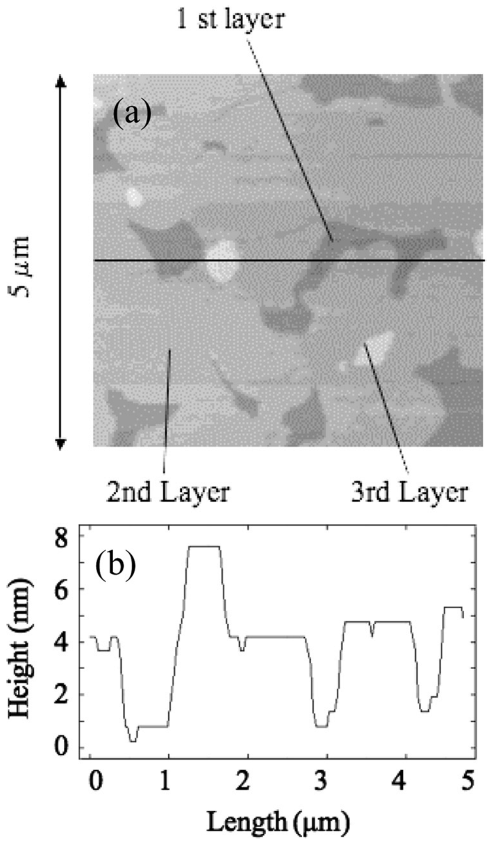


**FIGURE 2** AFM image of DH6T three layers (a) grown on $SiO_2$ surfaces. The image size is 5 μm × 5 μm. The cross section views are also shown in (b).

two layers on the gate insulator as was also pointed out by T. Miyazaki *et al.* [7] and S. Jung *et al.* [8]. It seems that the second layer plays an important role for carrier transport for the devices without a modification of $SiO_2$ surface using organic materials.

As the drain and gate voltages increased, orange light emission was observed along the Al electrodes. Electrons injected from the Al electrodes by high electric field combined with holes passing through the organic layers to exhibit light emission. Figure 4 shows electro luminescence (EL) spectra of DH6T FET with various thicknesses. As the thickness of organic layer increased, emission peak at about 600 nm became remarkable. Similar spectrum was observed for the photo-luminescence measurement of thick DH6T films, which is

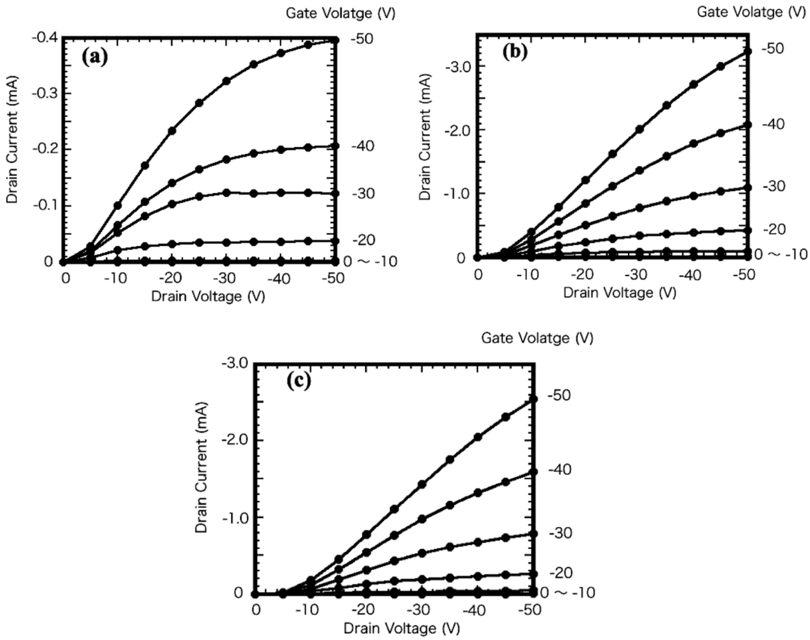


**FIGURE 3** Output characteristics of monolayer (a), bilayer (b), and multilayer (35 layers) (c) FETs.

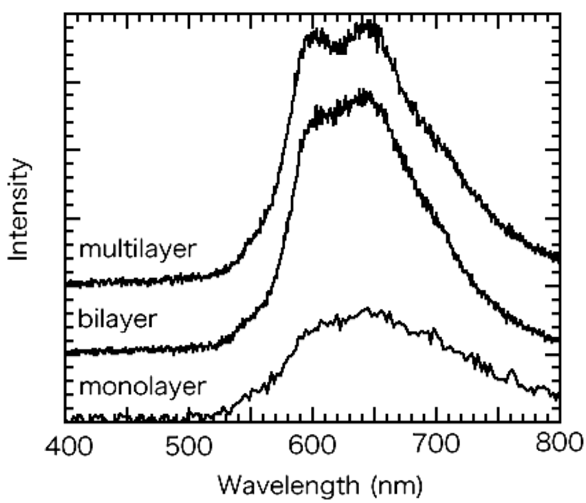


**FIGURE 4** Emission spectra of DH6T-FETs with various thicknesses.

characterized with an intense peak around 600 nm with a shoulder at 650 nm [9]. In multilayer-FETs, carrier recombination is thought to occur in the bulk sites at upper layer near the Al electrode, which generate the emission at approximately 600 nm. On the other hand, carrier recombination occur at the organic layer/$SiO_2$ interface. The peak at approximately 650 nm in thought to be characteristics of the emission from very thin film.

## CONCLUSION

In summary, we have prepared LEOFETs based on DH6T with asymmetric Au/Cr-Al electrodes. Visible light emission was observed even from the monolayer FETs at high drain and gate voltages. It was found that the 2nd layer played a key role for carrier transport and carrier recombination processes in the device prepared.

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