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Preparation of polymer-based light-emitting field-effect transistors

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1. Introduction

Organic field-effect transistors (FETs) have attracted considerable attention because of their potential applications in low-cost integrated circuit and flexible display. Since ambipolar FETs are of especially important for practical applications, there have been various approaches to realize ambipolar states.[1,2] Dodabalapur *et al.* have proposed that an ambipolar operation is useful in novel light-emitting devices since electron and hole are injected simultaneously into the organic materials.[3] However, it is difficult to inject both carriers into active layers with the conventional FET in which the source and drain electrodes is composed of same materials. Both high and low work function metals should be used together in one FET to inject hole and electron simultaneously.

In the present work, we prepared polymer-based FETs which electrodes were composed of Au and Al. The use of Au and Al electrodes realized simultaneous injection of holes and electrons and light emission were observed from the FETs.

2. Experiments

The electrodes of the fabricated devices are summarized in Table I. Figure 1 (a) shows a schematic view of the device prepared. The channel length of the electrodes was 5 μm. Poly [2-methoxy, 5-(2'-ethyl-hexoxy)-1, 4-phenylenevinylene] (MEH-PPV, Fig.1(b)) was used for active layers. It was solution-casted onto FET substrates from a 0.5 weight % solution in chlorobenzene. All measurements were carried out in vacuum (5×10^{-4} Pa) at room temperature. Output characteristics of the FETs were measured with electrometers. Emission spectra were measured with a spectrograph and a CCD detection system. The light intensity was detected with a Si photodiode placed just above the device, through a glass window of the vacuum chamber.

3. Results and discussion

The devices were operated with negative bias voltage applied to drain and gate electrodes. As the drain and gate voltages increased, orange light emission was observed from the FETs. Figure 2 shows luminescent spectra of the light-emitting FET (Device C). All the devices gave the same emission spectra. Figure 3 shows the emission intensity detected with a Si photodiode as a function of the gate voltage. The drain voltage was set at -100 V. The light intensity can be controlled by the gate voltage applied. In the device A, light emission could not be observed at the gate voltage up to -100 V, while weak light emission was observed in the device B. In the device C, there can be seen a significant improvement of emission intensity and the operating gate voltage. The use of Al electrode improved electron injection since the work function of Al (4.06 – 4.26 eV) is lower than that of Au (5.31 – 5.47 eV) and Cr (4.5 eV). It is found to be important to choose appropriate materials for source and drain electrodes to improve both carrier injections.

Figure 4 shows transfer characteristics of the fabricated devices. The drain current of the device B was smaller than that of the device A. Hole injections into MEH-PPV from Al electrodes are less efficient than those from Cr electrodes, since the work function of Al is smaller than that of Cr and Au. It was found that the carrier injection process played an important role in determining the device characteristics. The drain current of the device A and C were almost the same each other at high gate voltage ranges, indicating hole injection, transfer and extraction processes are the same. On the other hand, there is a significant difference at low gate voltage. For the device C, the drain current was decreasing with the gate voltage and exhibited a minimum value at the gate voltage of -20 V, beyond which it increased with the gate voltage. Figure 5 shows FET characteristics of the device C at low gate voltages. A nonlinear increase of the current was observed at the gate voltage of 0 V, which is often observed for ambipolar FETs. This current is contributed by injected electrons from the drain electrode and indicates a formation a quasi-ambipolar state.

4. Summary

We fabricated light-emitting field-effect transistors based on MEH-PPV. The emission intensity can be controlled by the gate voltage applied. It is revealed that the work function of the electrodes affect greatly on the FETs. The balance between the number of holes and electrons injected was improved by using Al electrodes. It is important to choose appropriate materials for source and drain electrodes to inject both carriers efficiently.

References

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Table I. The electrodes of the device prepared.

	source	drain
Device A	Au / Cr	Au / Cr
Device B	Au / Al	Au / Al
Device C	Au / Cr	Al

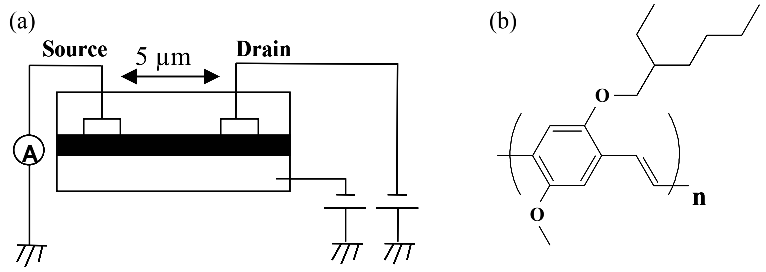

Fig. 1 Schematic view of the device prepared and molecular structure of the MEH-PPV (b).

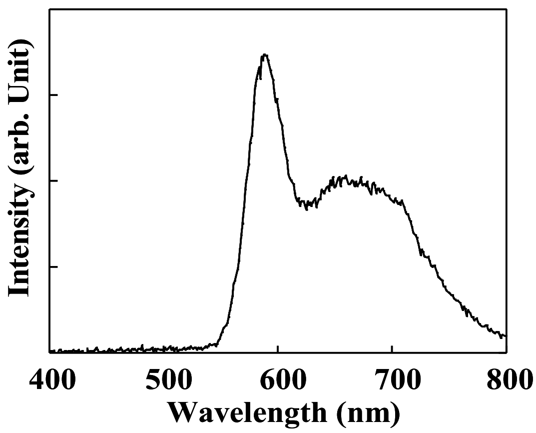

Fig.2 Luminescent spectra of the device C at the source and gate voltage of -100 V.

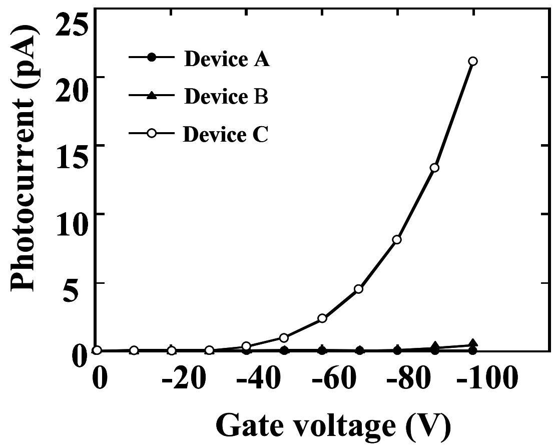

Fig.3 Emission intensity of device prepared. Drain voltage was set at -100 V.

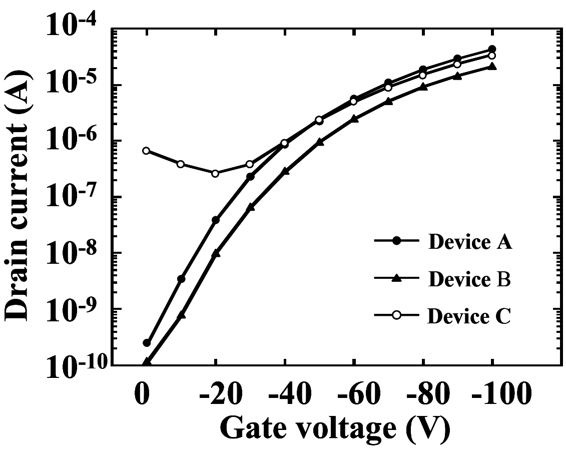

Fig.4 Transfer characteristics of the device prepared at the drain voltage of -100V.

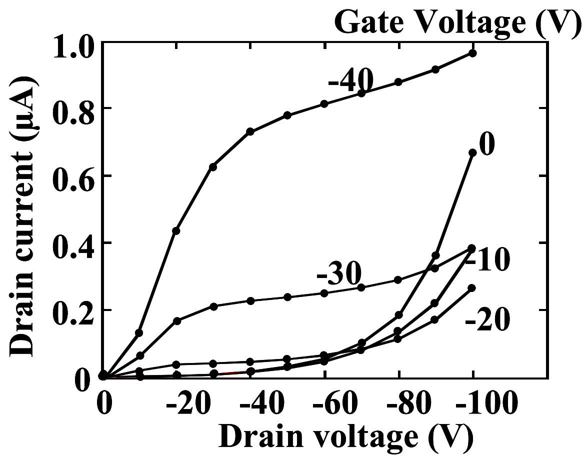

Fig.5 FET characteristics of the device C.