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Development of a Printed Dielectric Layer for Organic Transistors

Toshihide Kamata, Sei Uemura, Manabu Yoshida, Kouji Suemori, Satoshi Hoshino, Noriyuki Takada and Takehito Kozasa

National Institute of Advanced Industrial Science and Technology,
1-1-1 Higashi, Tsukuba, Ibaraki 305-8565, Japan
Phone: +81-29-861-4516 E-mail: t-kamata@aist.go.jp

1. Introduction

It has been recognized that one of the most attractive point of organic transistors is its high productivity by use of solution process. Namely, many organic semiconductors are soluble in a solvent and its film can be prepared by printing. In this characteristic, many researchers investigate printable organic semiconductor films for development of organic FETs. However, not only an active layer but also a dielectric layer and an electrode should be prepared by printing for raising productivity of transistors in the industry. Therefore, we have paid attention to the dielectric layer and been investigating several printable dielectric materials.

On the other hand, a function of organic FETs is not governed only by the semiconductor layer. A lot of functions are controlled by the properties of a dielectric layer also. If we can use a functional dielectric material in the FET dielectric layer, new FET performance would be developed. In this study, we introduce our several examinations for developing a new function in the printed organic FET by using printed dielectric layers.

2. Memory Effect

If we can get a good printable ferroelectric material for a dielectric layer of organic FETs, a ferroelectric FET (FeFET) memory can be prepared by printing. Poly-L-glutamate is one of the representative polypeptide with a α-helix structure, and is known to show the ferroelectric phase due to its rigid rod-like structure [1,2]. Therefore, the memory effect can be expected on a printed device using poly-L-glutamate layer. The FeFET was fabricated using pentacene as an active layer and poly(α-methyl-L-glutamate) [PMLG] as a dielectric layer. The PMLG layer was prepared by a dip coating method from the DCE solution. By using this coating technique, well ordered PMLG film could be obtained, in which its molecular axis

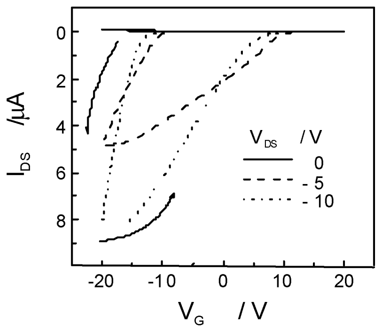

Fig.1 The transfer characteristics of pentacene FET fabricated with PMLG gate dielectric.

oriented in parallel with the substrate surface. The transfer characteristics of the prepared pentacene FET show large hysteresis behavior (Fig.1). In order to study the origin of the hysteresis, the PMLG molecular weights dependence on the hysteresis was investigated with a.c and d.c. current-voltage properties, spectroscopic measurements and morphology observation. When the PMLG with large molecular weight (M.w. 64,000) was used, no hysteresis was observed in the transfer characteristics. On the other hand, the devices fabricated with low molecular weight PMLG (M.w. 10,000 and 27,000) showed large hysteresis behavior. From the results of the ac current-voltage properties, it is suggested that motion of the main-chain dipole of PMLG is take place only in the film of low molecular weight PMLG. In the case of high molecular weight PMLG, molecular aggregation of the PMLG and morphology changes in the

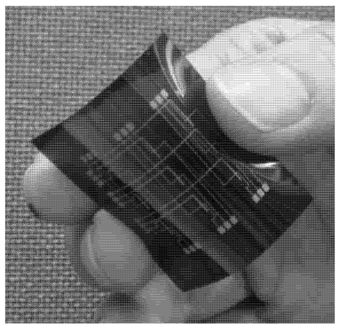

Fig. 2 Printed FeFET memory array on a plastic film

film were observed by applying voltage. From these results, we concluded that the memory effect was caused by the motion of the main-chain rather than the side-chain without any morphological change. By using these techniques, we have developed printed memory array on a plastic film, and demonstrated its memory operation (Fig.2).

3. Photo Switching Effect

It is well known that the capacitance of the dielectric layer of FET gives serious influence to the FET performance. If the capacitance could be controlled by any external signal, the FET performance would be controlled by the signal. Therefore, we have investigated to use a printable photo sensitive polymer as a dielectric layer for the organic FET to control the FET performance by the irradiated light.

Poly(N-vinylcarbazole) (PVK) is a well known photo conductive polymer. We have tried to use it as a gate dielectric to control the organic FET performance by light irradiation. Here, we have prepared a pentacene FET with a PVK dielectric and examined photo controllability of the FET performance. Unfortunately, resistivity of PVK film is too small as a gate dielectric layer. Therefore, we have inserted a blocking layer of polyvinylphenole (PVP) between the PVK and pentacene layers. 2,4,7-Trinitro-9-fluorenone (TNF) was used as a photo sensitizer for the PVK.

Blue (430nm) or red (635nm) light was irradiated from the ITO electrode side on the FET. Fig.3 shows transfer characteristics of the FET before and after light irradiation. Evaluated field effect mobility μ_{FET} and threshold voltages V_ts are listed in Table 1. Under dark condition, this device shows p-channel field effect transistor's behavior, although μ_{FET} is very small. By irradiating blue light, subthreshold characteristic was remarkably improved, and large drain current could be observed. Consequently, mobility was remarkably improved as shown in table 1. Gate capacitance was also increased by blue light irradiation. Such improvement was also observed in the case of red light irradiation. However, off current was also increased by the red light irradiation. These results indicate that these characteristics correspond to the difference of light absorption layer as shown in UV-vis absorption spectra (Fig. 4). Red light (630nm) is absorbed in pentacene layer, and then the conductivity of pentacene is increased and I_{ds} is very high at even zero bias voltage. On the other hand, blue light was absorbed in PVK layer. From these results, we concluded that the blue light induced carrier generation in the PVK layer. The generated photo carrier induced capacitance increase and improved mobility. On the other hand, red light induced carrier generation in the pentacene layer. Then the output current was improved but also off current was also increased.

References

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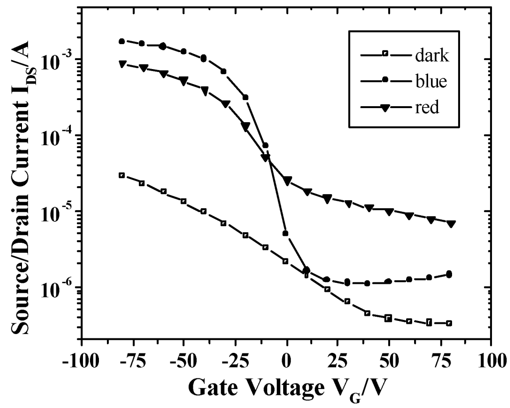

Fig. 3. Transfer characteristics of phototransistor under dark and blue or red light irradiation.

Table 1 Summary of parameter of FET with PVK layer

	dark	red	blue
V_t [V]	25.28	8.61	2.43
μ_{FET} [$cm^2V^{-1}s^{-1}$]	0.023	1.8	6.55

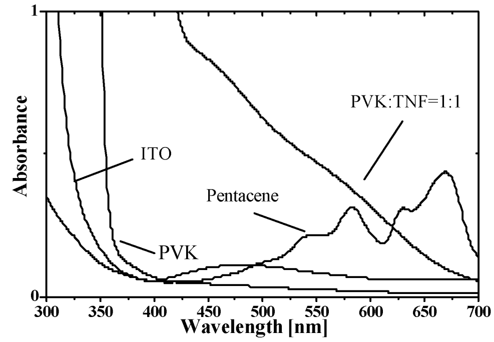

Fig. 4. UV-vis spectrum of each layer.