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Improvement in Electronic Stability under Bending Stress in Flexible Organic TFT using Polymer Semiconductor

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Abstract

We report on the electronic stability of flexible organic TFT devices under bending stress. We measured decrease of drain current of the devices with increase of strain amount. The drain current of a pentacene (low molecular) TFT decreased by nearly 60% under a tensile strain of 1.5%. In contrast, a PBTTT-C16 (polymer) TFT showed smaller changes in drain current under same strain conditions (1.5%). These results indicate that a polymer semiconductor provide for higher electronic stability under bending stress.

1. Introduction

Organic thin-film transistor (OTFT) is known as a promising device for flexible electronics, which can be fabricated on a plastic film substrates with low-temperature printing processes. In flexible devices, the stability of the transistor characteristics under bending stress is very important, therefore several studies have assessed the changes in electrical characteristics under applied bending stress [1-3]. However, the mechanism of the changes in device performance has not yet been understood. The investigations for electrical stability were carried out for organic TFT devices using a conventional pentacene organic semiconductor [4,5]. To fully understand the mechanism of performance changes under bending stress, various semiconductors should be investigated, for example polymer semiconductors or solution-processable small molecular semiconductors.

In this study, we have investigated the electrical stability under bending stress for the flexible organic TFT devices using small molecule and polymer semiconductors. In particular, we focused on the electrical stability of the organic TFT devices with printed source and drain electrodes.

2. Results and Discussion

A cross sectional device image and photograph of the flexible organic TFT devices are shown in Fig. 1. The organic TFTs were fabricated on the PEN film substrates (Du Pont, Teonex®, 125 μm) fixed to a glass. A cross-linkable PVP solution consisting of a mixture of Poly (4-vinyl-phenol) (PVP) (Aldrich, 436224) and melamine resin (Aldrich, 418560), using 1-Methoxy-2- propyl acetate (PEGMEA) (Kanto chemicals, 01948-00) as a solvent, was spin-coated on the PEN film for planarization. After a 30 nm Al metal layer was deposited as gate electrode, a 300 nm layer of cross-linkable PVP was spin-coated as gate insulator onto the substrate and annealed at 130ºC for 1 hour. Next, source and drain (S/D) electrodes were formed from a silver nanoparticle ink with inkjet printer (Fuji film Dimatex, DMP-2831) onto the gate insulator (W/L = 500/ 60 μm). The printed silver nanoparticle electrodes were sintered at 150ºC for 1 hour. Finally, pentacene and poly(2,5-bis(3-hexadecylthiophene-2-yl)thieno[3,2-b]thiophene) (PBTTT-C16) (Merck) were formed on the gate insulator as semiconductor layer. Pentacene layer was thermally evaporated through a shadow mask. PBTTT-C16 solution (0.03 wt%) of toluene (Kanto chemicals, 40500-05) was drop-casted, and then annealed at 150°C for 30min under dry nitrogen atmosphere.

The transistor characteristics and stability under bending stress were measured in dry nitrogen using a semiconductor parameter analyzer (4200-SCS,

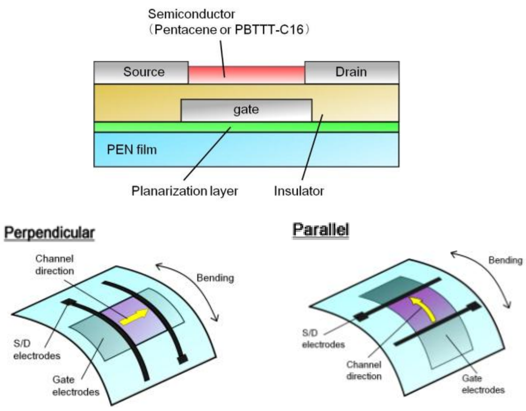

Fig.1 Top: Schematic structure of the flexible organic TFT. Bottom: Direction of the tensile strain to the channel direction.

Keithley Instruments Inc.). The flexible organic TFT devices were stressed with a tensile strain perpendicular and parallel to the channel direction.

The transfer characteristics of pentacene TFT and PBTTT-C16 TFT are shown in Fig. 2. Each of the on/off ratio exceeded 10^5 and the field effect mobilities estimated in the saturation regime were 0.1 cm^2/Vs in pentacene TFT and 0.06 cm^2/Vs in the PBTTT-C16 TFT, respectively.

Fig. 3 shows the change in the drain current as a function of the strain amount at the interface of organic semiconductor layer and gate insulator layer arising from the film bending. It was confirmed that the drain current returned before bending by to release up to flat to the OTFT (Fig 3a, b). The strain amount calculated from the bending radius of 4 mm was 1.6%. In the pentacene TFT, the drain current decreased significantly with increase of strain amount. The drain current was decreased by nearly 60% at the strain of 1.5% (Fig3 a). In addition, the performance of the pentacene TFT, which was bent in the direction of parallel to the drain current direction, showed further decrease compared to that in the perpendicular direction. In contrast, the decrease in drain current for the PBTTT-C16 TFT under bending was smaller, less than 20% (Fig.3 b).

From these results, we should consider that the contact resistance at the interface of organic semiconductor and printed S/D electrodes is the main cause of the change in the drain current when applying bending stress. Actually, according to Kumaki et al., the contact resistance of a flexible OTFT fabricated by thermal evaporation process increased under the bending stress [6]. In this study, we can say similar things, and the increase of the contact resistance caused the decrease of drain current under bending stress.

These results indicate that organic TFT devices using polymer semiconductors possess better electronic stability under bending stress.

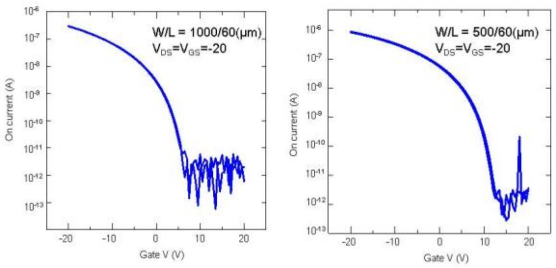

Fig.2 Transfer characteristics (I_{DS}-V_{GS}) of the flexible organic TFTs.
Left: pentacene. Right: PBTTT-C16.

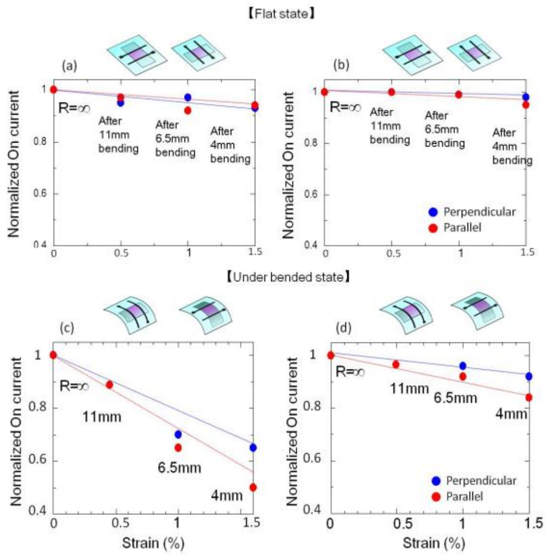

Fig.3 Top: The change in the drain current after bending. The drain current returned before bending from after bending at each radius.
(a): pentacene. (b): PBTTT-C16.
Bottom: The change in the drain current of the organic TFT under bending stress.
(c): pentacene. (d): PBTTT-C16

3. Conclusion

We have investigated electronic stability under bending stress of organic TFT devices with printed S/D electrodes. A significant decrease in drain current was observed in the pentacene TFT devices under bending stress. In contrast, the polymer TFT device showed smaller changes in the drain current under the same amount of bending stress. These results indicate that the polymer semiconductors provide for better electronic stability in the OTFT devices under bending stress.

Acknowledgements

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