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High-mobility solution-processed organic thin-film transistors

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Introduction

Organic field effect transistors (OFETs) have been considerably interested due to their ability of application to flexible, large area and low-cost electrical switching components. Although it is mostly argued to use them for relatively slow devices, further applications become possible with the achievement of higher mobility above ~10 cm^2/Vs, which is demonstrated in single-crystal OFETs, in practically mass-producible transistors. Unfortunately, the conventional single-crystal OFETs have not been suited to fabricated large-scale devices. Very recently we developed a method to grow a crystalline film from a solution in an oriented way on a substrate and reported considerable mobility values exceeding a few cm^2/Vs for devices with solution-crystallized 2,7-diocthylbenzoselenopheno[3,2-b]benzo-selenophene (C_8-BTBT) thin films [1]. Apparently, the film consists of crystalline domains spread to the whole channel length, so that molecular steps and terraces are observed in atomic-force-microscope view.

Experiment

Sample preparation

After the surface treatment of vapor depositing decyltriethoxysilane (DTS), a 0.4wt% solution of C_8-BTBT is prepared with a solvent of heptane and a droplet is sustained at an edge of a structure on an inclined substrate, so that the crystalline domain grows in the direction of the inclination through evaporation of the solvent. The structure to support the droplet can be a small piece of a silicon wafer, for example, and can be removed after the growth of the crystalline film. In order to thoroughly remove the solvent, we dried it in a vacuum oven for typically 5 h at 50 C. Source and drain electrodes are then evaporated on the film, so that the channel is parallel to the direction of inclination, i.e., the growth direction. The length and width of the channel are 0.1 and 1.5 mm, respectively. The doped-Si layer acts as a gate electrode, so that electric field is applied to the 500-nm-thick SiO_2 whose dielectric constant is approximately 3.9. Figure 3 shows optical micrograph of the device, where a very homogeneous crystal-like surface is already visible.

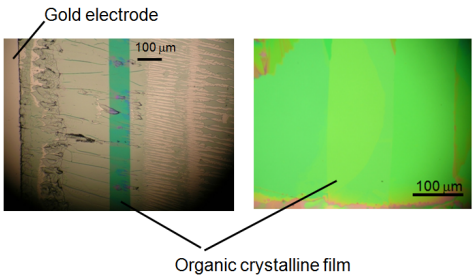

Fig. 1 Optical views of the solution grown crystalline films of C_8-BTBT

Transmission X-ray diffraction

We performed high-energy transmission X-ray diffraction measurement of the solution-crystallized C_8-BTBT films on typically 2-μm-thick parylene substrates. The measurement was configured to elucidate crystallinity of the film, favored direction of the crystal growth, relationship between direction of the crystal and that of favorable carrier transport.

As shown in Fig. 2, obvious Bragg peaks emerged corresponding to the components in the conducting *a-b* plane consistently to the reported crystal structure of the material. The peak patterns indicate that the C_8-BTBT films consist of either one or a few crystal domains, within the sub-millimeter spot of the irradiated X-ray. It turned out that the *c*-axis is vertical to the substrate and that the *a* axis are inclined by approximately 30 degrees to the direction of crystal growth. The growth direction nearly corresponds to that of the highest average transfer integral. Note that the high-mobility transistor performance is measured in the same direction. We conclude that the high performance in the solution-processed C_8-BTBT thin-film transistors are originated from extremely ordered molecular stacking due to the crystallization.

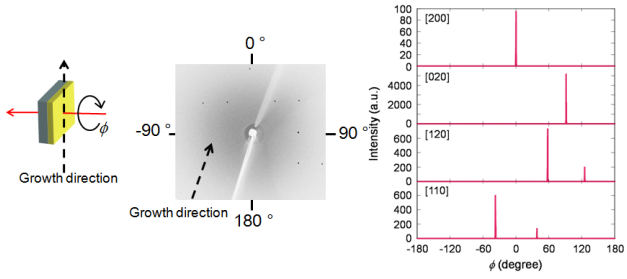

Fig. 2 Optical views of the solution grown crystalline films of C_8-BTBT

References

[1] T. Uemura et al., Appl. Phys. Exp. 2, 111501 (2009).

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