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Environmentally-friendly fabrication of TIPS pentacene/PMMA blend OFET by ESD method

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Abstract

Although halogenated aromatic solvents with high solubility are often used to form organic semiconductor thin films by solution processing, they are not good for the environment and therefore not compatible with industrial fabrication. In this study, we report environmentally-friendly fabrication of organic field-effect transistors (OFETs) based on small molecule/polymer blend films prepared by electrostatic spray deposition (ESD).

1. Introduction

Organic field-effect transistors (OFETs) can be fabricated in large area by low-cost solution processing, and various methods such as inkjet printing and spin coating have been developed. In the past, we fabricated OFETs based on high-crystalline small-molecule semiconductor thin films prepared by an electrostatic spray deposition (ESD) method, which has the advantage of large-area deposition with high material utilization efficiency and enables application to industrial-scale roll-to-roll processes [1]. In order to obtain organic thin films with high crystallinity, it is necessary to use chlorinated and/or aromatic solvents having high dissolving power such as chlorobenzene and 1,2-dichlorobenzene (o-DCB). However, they have a heavy load on the environment and restrict their use at most factories. In recent years, a solution process using small molecule and polymer blends has attracted much attention as a technique to obtain continuous films with high crystallinity. Further, it is known that an excellent semiconducting small molecule/insulating polymer interface can be obtained due to self-organizing phase separation [2]. Previously, we formed blend films composed of 6,13-bis (triisopropylsilylethynyl) pentacene (TIPS pentacene) and poly(methyl methacrylate) (PMMA) by ESD and obtained continuous crystalline films [3]. However, these solutes were dissolved in a hazardous solvent of o-DCB. In this study, TIPS pentacene/PMMA blend OFETs were fabricated by using only environmentally-friendly solvents and exhibited excellent electrical characteristics due to the well-defined phase separation.

2. Experimental details

TIPS pentacene/PMMA blend films and pristine TIPS pentacene films were deposited on SiO_2/Si substrates by ESD. A schematic of our ESD system is illustrated in Fig. 1. The substrates were subjected to organic washing and UV/O_3 treatment prior to film deposition. Both the blend solution and the TIPS pentacene solution were prepared by using a mixed solvent of butyl acetate and acetone. Finally, source/drain electrodes were formed on these films by a vacuum evaporation method, and a top-contact type OFETs were fabricated. The structure of the fabricated OFET is shown in Fig. 2.

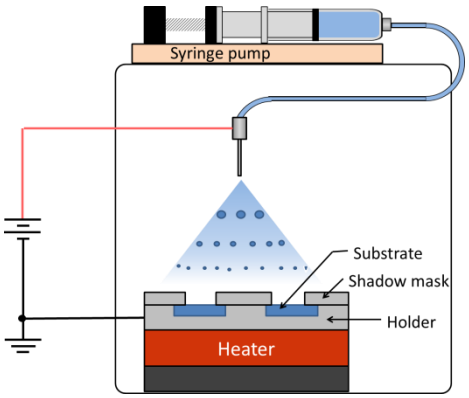

Fig. 1 Schematic of our ESD system.

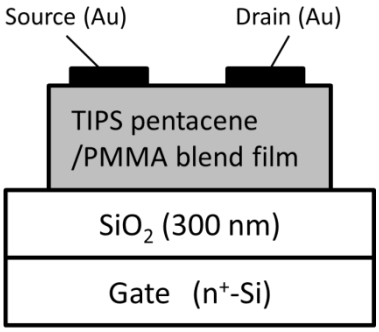

Fig. 2 Schematic of device architecture fabricated in this study.

3. Result

Figure 3 shows polarized microscopic images of the TIPS pentacene film and TIPS pentacene/PMMA blend film formed by the ESD method. As shown in Fig. 3(a), many crystalline nuclei were observed on the pristine TIPS pentacene surface, which is probably due to the poor film connectivity of TIPS pentacene. On the other hand, TIPS pentacene blended with PMMA showed strong birefringence (Fig. 3(b)), indicating the presence of uniaxial molecular ordering. The size of crystalline domains exceeded a few hundred micrometers. This result clearly demonstrates that polymer blending has a significant

influence on crystal growth in solution processing.

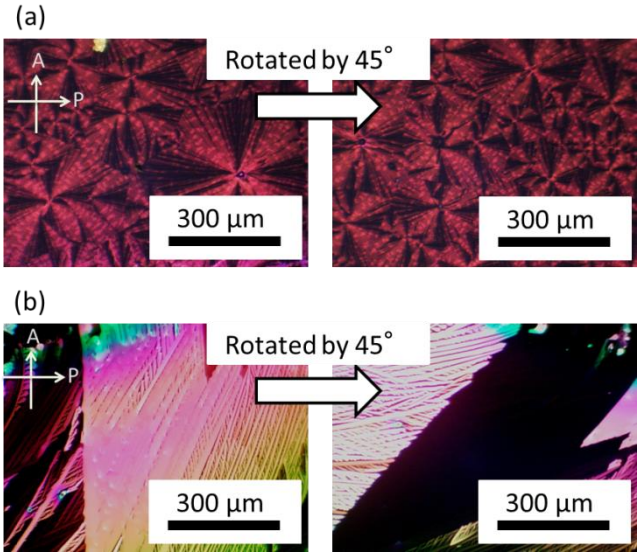

Fig. 3 Polarized microscopic images of (a) pristine TIPS pentacene film, (b) TIPS pentacene/PMMA blend film.

The cross-sectional morphology of the blend film was characterized by a field-effect scanning electron microscope (in-lens type FE-SEM S-5200, Hitachi). As shown in Fig. 4, the blend film was well-separated into two layers, top TIPS pentacene layer and bottom PMMA layer. Phase separation was sufficiently induced due to the difference in surface energy of TIPS pentacene and PMMA and the difference between properties of acetone and butyl acetate.

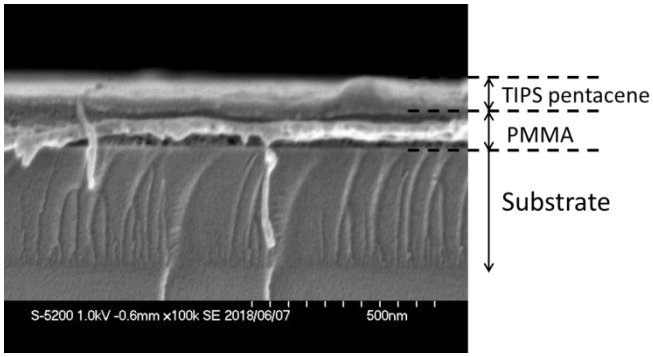

Fig. 4 Cross-sectional SEM image of TIPS pentacene/PMMA blend film.

Figure 5 shows the output and transfer characteristics of the blend OFET. The field-effect mobility in the saturation region exhibited a very high value of 0.88 cm^2/Vs. This result is probably due to obtaining the continuous film with high crystallinity and the well-defined phase-separated interface between TIPS pentacene and PMMA. However, the threshold voltage is very large. This might be caused by poor adhesion between TIPS pentacene and PMMA, which is now under investigation.

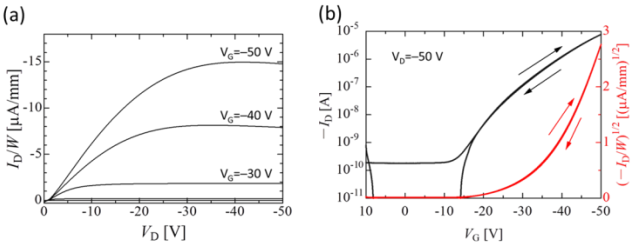

Fig. 5 (a) Output and (b) transfer characteristics of TIPS pentacene/PMMA blend OFET. Channel length and width are 0.1 mm and 1.0 mm.

4. Conclusions

We fabricated OFETs based on TIPS pentacene/PMMA blend films prepared by ESD with the use of only environmentally-friendly solvents and demonstrated excellent electrical characteristics due to obtaining the continuous film with high crystallinity and the well-defined phase-separated interface between TIPS pentacene and PMMA.

Acknowledgements

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