High-Performance Top-Gate Organic Field-Effect Transistors Based on *n*-Type Polymer Semiconductors

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Introduction

Solution-processable *n*-channel organic field-effect transistors (OFETs) with high electron mobility have attracted growing interest because they enable low-cost production of flexible CMOS-like circuits based on OFETs. It is well known that electron transport in OFETs is strongly influenced by the chemical species of substrates such as hydroxyl groups and film crystallinity, and the hydrophobic treatment of substrates is essential to achieve high performance in bottom-gate *n*-channel OFETs. We have reported that the use of a top-gate configuration enables extraction of high field-effect mobility and better electrical stability in OFETs based on solution-processable *p*-type organic semiconductors without using hydrophobic substrates [1-3]. Here, we report the performance of solution-processed top-gate *n*-channel OFETs using a novel naphthalene diimide-based *n*-type conjugated polymer semiconductor, end-capped poly{[*N*,*N'*-bis(2-decyl tetradecyl)-naphthalene-1,4,5,8-bis(dicarboximide)-2,6-diyl]-*alt*-5,5'-(2,2'-biselenophene)}(ePNDIBS) [4].

Experimental

The structure of *n*-channel top-gate OFETs fabricated in this study is schematically shown in **Fig. 1**. An electron injection layer of Cs_2CO_3 was formed on Au electrodes by spin coating from 2-ethoxyethanol. The ePNDIBS thin films were fabricated by spin coating chloroform-based solutions, followed by annealing at 200 °C. A fluoropolymer insulator CYTOP™ (CTL-809M, Asahi Glass) was spin-coated onto ePNDIBS films and Al gate electrodes were evaporated on CYTOP layers to complete OFET fabrication. The preparation of organic films and FET measurements were performed in a N_2-filled glove box.

Results and discussion

Typical output and transfer characteristics of top-gate ePNDIBS FETs are shown in **Fig. 2**, together with the variation in transfer curves before and after a gate bias stress for 10^4 s. The fabricated top-gate OFET devices exhibit a very stable operation with a negligible shift of threshold voltage and show a high electron field-effect mobilities (average: 0.30 $cm^2V^{-1}s^{-1}$, highest: 0.51 $cm^2V^{-1}s^{-1}$). These values are comparable to or higher than the mobility reported in bottom-gate devices with octyltrichlosilane-treated SiO_2 insulators (0.24 $cm^2V^{-1}s^{-1}$ [4]). The results indicate that a highly ordered microstructure is spontaneously formed at the surface of solution-processed ePNDIBS thin films similarity to regioregular polythiophenes [2,3] and the use of the top-gate configuration is also effective for improving solution-processable *n*-channel OFETs.

References [1] T. Endo *et al.*, Appl. Phys. Express **3**, 121601 (2010). [2] T. Kushida *et al.*, Appl. Phys. Lett. **98**, 063304 (2011). [3] K. Takagi *et al.*, Org. Electron. **15**, 372 (2014). [4] Y. -J. Hwang, N. M. Murari, and S. A. Jenekhe, Polym. Chem. **4**, 3187 (2013).

Acknowledgements This work was financially supported by a Grant-in-Aid for Scientific Research on Innovative Areas "New Polymeric Materials Based on Element Blocks" (No. 24102011) from the MEXT and a Grant-in-Aid for Scientific Research (C) (No. 26420276) from the JSPS, Japan.

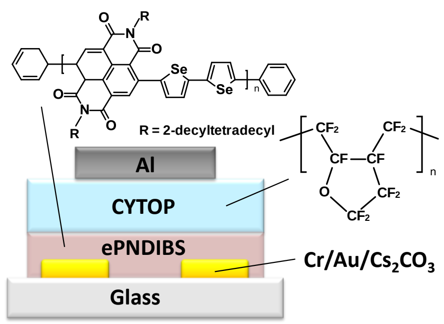

Fig. 1. Device structure of solution-processed top-gate *n*-channel OFET based on ePNDIBS.

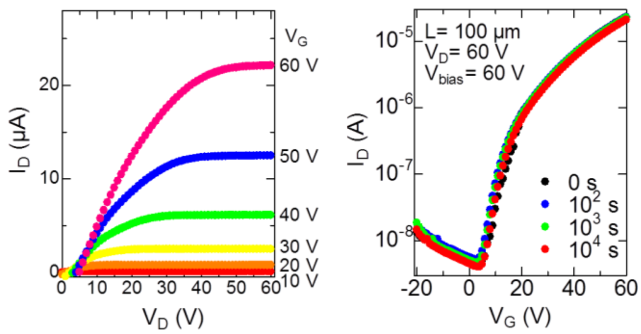

Fig. 2. Output characteristics and the variation in the transfer characteristics of ePNDIBS-based *n*-channel top-gate OFET during the gate bias stress.