Extended Abstracts of the 2016 International Conference on Solid State Devices and Materials, Tsukuba, 2016, pp271-272

F-1-06(Late News)

Steep Subthreshold Swing of Pentacene-based OFET with Nitrogen-doped LaB_6 Interfacial Layer

Yasutaka Maeda, Shun-ichiro Ohmi

Tokyo Institute of Technology
Department of Electrical and Electronic Engineering
J2-72, 4259, Nagatsuta, Midori-ku, Yokohama, Kanagawa 226-8502, Japan
Phone: +81-45-924-5473 E-mail: maeda.y.al@m.titech.ac.jp, ohmi@ee.e.titech.ac.jp

Abstract

The subthreshold swing of pentacene-based OFET was dramatically improved by introducing nitrogen-doped LaB_6 (N-doped LaB_6). In this paper, the thickness dependence of N-doped LaB_6 interfacial layer (IL) was investigated. It was found that the 2.2 nm-thick N-doped LaB_6 realized subthreshold swing of p-type OFET such as sub-100 mV/dec. with mobility of 0.088 cm^2/(Vs).

1. Introduction

Organic field-effect transistors, OFETs, have attracted much attention because of their unique properties such as flexible and light weight although the mobility is worse compared to that of Si. Furthermore, some organic materials are available for spincoating, inkjet printing, and imprinting method. Pentacene is well known as p-type organic semiconductor, and its high hole mobility such as 1 $cm^2/(V\cdot s)$ was reported [1]. We have investigated pentacene-based CMOS utilizing nitrogen-doped (N-doped) LaB_6 interfacial layer (IL) which has low work function of 2.4 eV and oxidation immunity [2, 3]. We have demonstrated steep subthreshold swing (SS) of pentacene-based p-type OFETs with N-doped LaB_6 IL [3, 4]. In this paper, the thickness dependence of N-doped LaB_6 IL on device parameters of pentacene-based OFETs was investigated.

2. Experimental Procedure

The back-gate/bottom-contact pentacene-based OFETs were fabricated with the process flow shown in Fig. 1. Heavily doped n^+-Si(100) substrate was cleaned by SPM and DHF. Then, 10 nm-thick SiO_2 was formed on the substrate as gate insulator by wet oxidation. After that, N-doped LaB_6 IL was deposited by RF sputtering. Its sputtering time was varied from 10-30 s with RF power of 30 W and the designed thickness of interfacial layers were 2.2-2.7 nm. Then, pentacene (>99.995%, ALDRICH) film was deposited without any purification by using thermal evaporation at 100°C with deposition rate of 0.3 nm/min. Finally, Au top contact electrode and Al back gate electrode were formed by thermal evaporation (L/W = 100 μm/1000 μm). The fabricated OFETs were evaluated by I_D-V_G and I_D-V_D measurement by Agilent 4156C, and atomic force microscopy (AFM) measurement by Cypher S, Asylum Research.

3. Results and Discussion

The surface morphology of pentacene films on SiO_2 (w/o IL) and on 2.7 nm-thick N-doped LaB_6 IL is shown in Fig. 2. Huge grains were obtained in case of the pentacene deposited on N-doped LaB_6 IL as shown in Fig. 2(b) compared to that on SiO_2 (Fig. 2(a)).

Figure 3 shows I_D-V_G and I_D-V_D characteristics of the fabricated OFET with 2.2 nm-thick N-doped LaB_6 IL. As shown in Fig. 3(a), steep SS of 94 mV/dec. with mobility (μ) of 0.088 cm^2/(Vs) was obtained. Furthermore, threshold voltage (V_{TH}) was -2.1 V and it suggested that this device was normally-off device. It was confirmed from I_D-V_D characteristics as shown in Fig. 3(b). In addition, good saturation characteristics were obtained.

Figure 4 shows the thickness dependence of N-doped LaB_6 IL on device parameters. As shown in Fig. 4(a), steep SS less than 100 mV/dec. was maintained even when the N-doped LaB_6 thickness was 2.7 nm although mobility was decreased by increasing IL thickness. In case of V_{TH}, it was slightly shifted with increasing IL thickness, as well as SS. Therefore, thinner N-doped LaB_6 is necessary to realize steep SS with high mobility.

4. Conclusion

In this paper, the thickness dependence of N-doped LaB_6 IL on device parameters was investigated. SS and V_{TH} were almost independent of IL thickness. However, mobility was increased with decreasing IL thickness. As a conclusion, thinner IL could provide good SS of sub-100 mV/dec. and higher mobility.

Acknowledgement

The authors thank Prof. Emeritus H. Ishiwara and Mr. M. Suzuki of Tokyo Institute of Technology, the late Prof Emeritus T. Ohmi, Associate Prof. T. Goto, and Dr. Y. Fujisaki of Hitachi, Ltd. for useful discussion for this research. This research was partially supported by JSPS KAKENHI (15K13969).

Reference

[1] S. Lee, *et al.*, Appl. Phys. Lett., **88**, 162109, 2006.
[2] H. Ishii, *et al.*, ECS Trans., **66**, 41, pp. 23-28, 2015.
[3] Y. Maeda, *et al.*, IEICE Trans. Electron., **E99-C**, pp. 535-540, 2016.
[4] Y. Maeda, *et al.*, AWAD2016, **A2-3**, pp. 98-101, 2016.

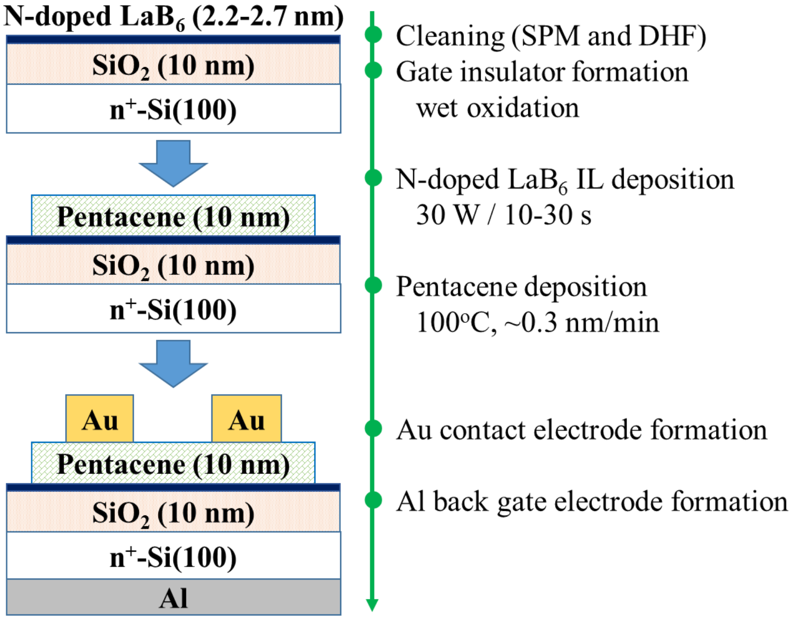

Figure 1 Experimental procedure of OFETs fabrication.

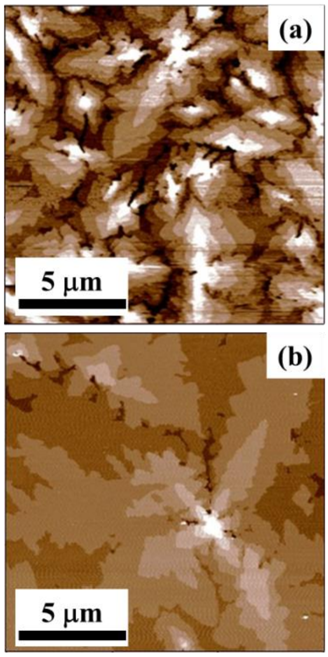

Figure 2 Surface morphology of pentacene film on (a) SiO_2 and (b) 2.7 nm-thick N-doped LaB_6 IL.

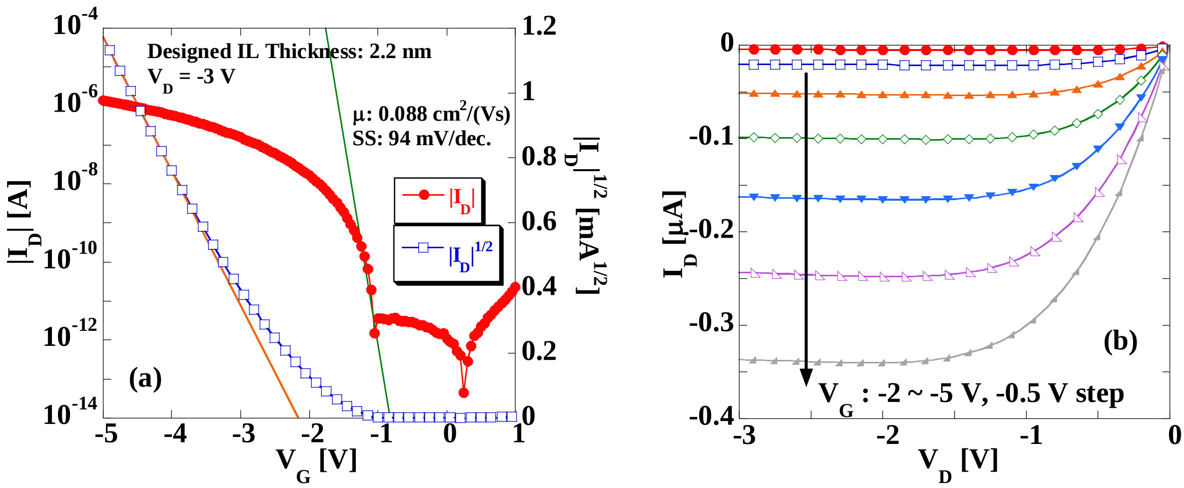

Figure 3 (a) I_D-V_G and (b) I_D-V_D characteristics of fabricated OFET with 2.2 nm-thick N-doped LaB_6 IL.

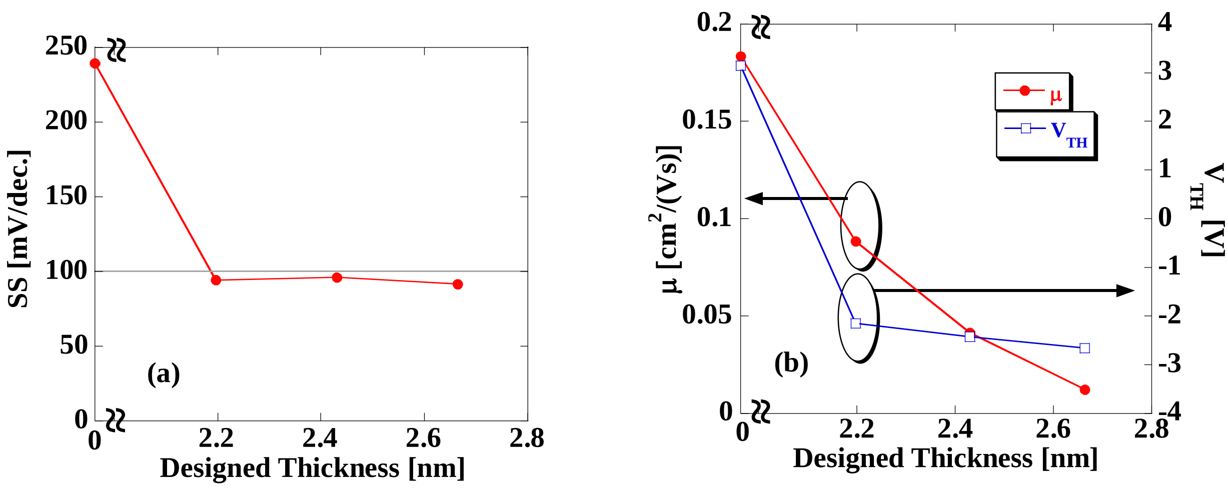

Figure 4 Thickness dependence of IL thickness on device parameters. (a) SS, and (b) mobility and V_{TH}.