

窒素添加LaB₆界面層を用いた単一有機半導体CMOSに関する検討 A Study on Single Organic Material-Based CMOS with N-Doped LaB₆ Interfacial Layer

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1. Introduction

Advantage of Organic Device

- Flexible
- Light weight
- Low cost
- Low temperature process



Flexible display (SONY)

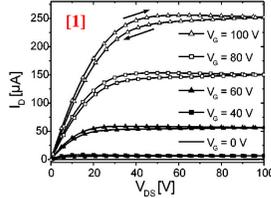
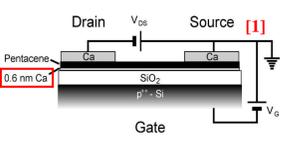
Objective

The Realization of Pentacene-Based CMOS with N-Doped LaB₆ Interfacial Layer

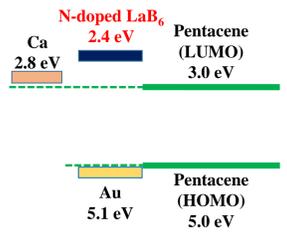
Contents

- The effect of N-doped LaB₆ interfacial layer for Pentacene film
- N-type characteristics in the air

N-OFET with Ca Donor Layer

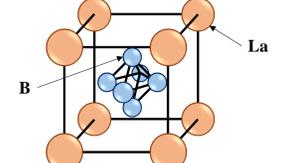


Low Work Function Materials



Nitrogen-doped LaB₆

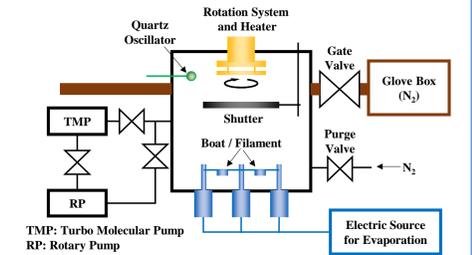
- Work function: 2.4 eV
- Good oxidation immunity by N doping of 0.4wt%



[1] M. Ahles et al., Appl. Phys. Lett., 85, 4499, 2004.
[2] H. Ishii et al., ECS Trans., 66, in press, 2015.

2. Experimental Procedure

Evaporation Chamber for Pentacene

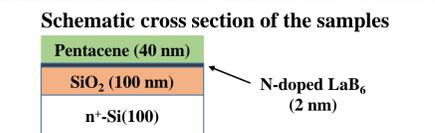
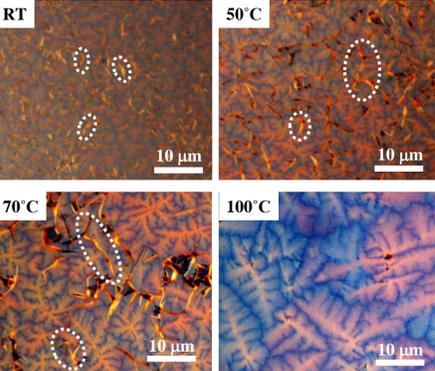


- n⁺-Si(100) substrate
- Cleaning by SPM and DHF
- SiO₂ formation wet oxidation: 1100°C
- N-doped LaB₆ deposition by rotation magnet sputtering [3]
- Interfacial layer (2 nm) RF: 200 W, Ar: 8 Pa
- Contact electrode (50 nm) DC: 200 W, Ar: 0.5 Pa through a shadow mask
- PDA (Forming-Gas Anneal) N₂/4.9%H₂, 400°C/5 min
- Pentacene deposition thermal evaporation purity > 99.995% (ALDRICH) depo. temp.: RT-100°C depo. rate: 0.5 nm/min
- Gate electrode deposition thermal evaporation of Al
- Optical microscopy AFM
- C-V and J-V
- I_D-V_D and I_D-V_G

[3] T. Goto et al., J. Vac. Sci. Technol. A, 27, 4, pp. 653-659, 2009.

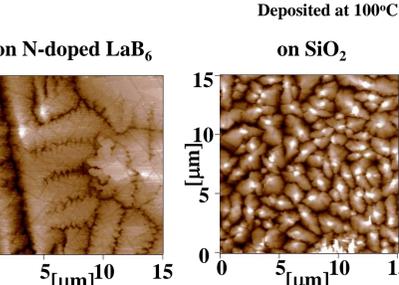
3. Effect of N-doped LaB₆ Interfacial Layer

Surface Morphology of Pentacene Film [4]



- Grain size was increased with increasing temperature.
- Larger grain than 10 μm without lamellar grain at 100°C deposition

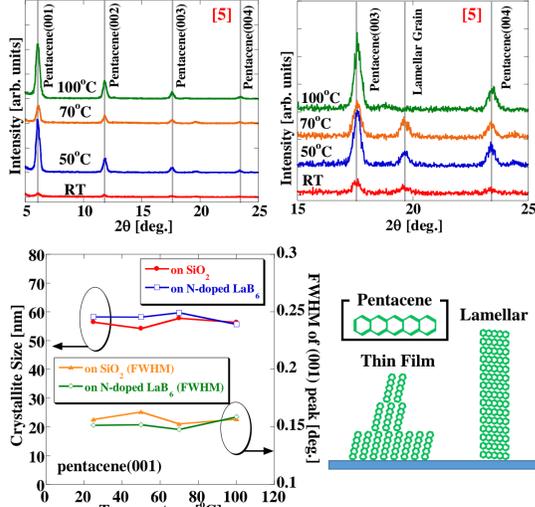
AFM Image of Pentacene Film



- Grain size was dramatically increased on N-doped LaB₆.

High quality Pentacene film can be formed on N-doped LaB₆

XRD Pattern of Pentacene Film



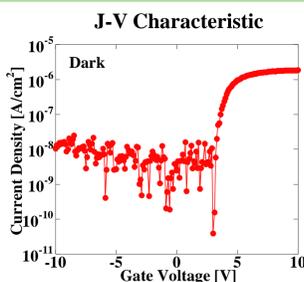
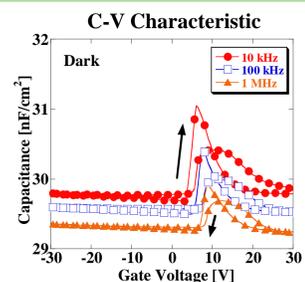
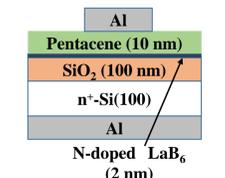
- Keep the crystallite size about 60 nm
- The molecules have low tilt angle in lamellar grain.

[4] Y. Maeda et al., AWAD2015, 3A-3, pp. 225-229, 2015.
[5] Y. Maeda et al., The 75th JSAP autumn meeting, 17a-A5-4, p. 12-004, 2014.

4. N-Type Characteristics of Pentacene-Based OFET

MOS Diode Characteristics [6]

Schematic cross section of the diode

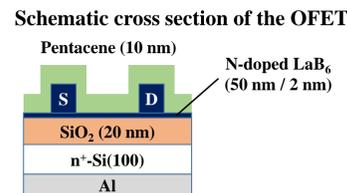
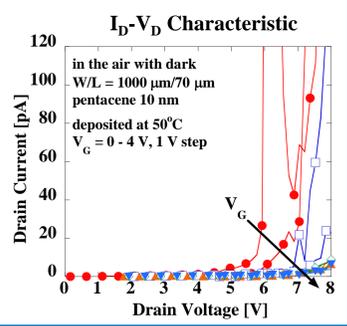


- Accumulation in positive bias was obtained.
- J-V characteristic also showed n-type characteristic.

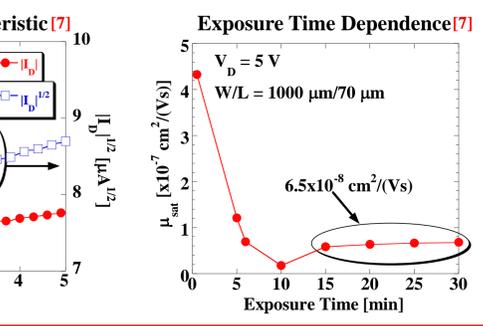
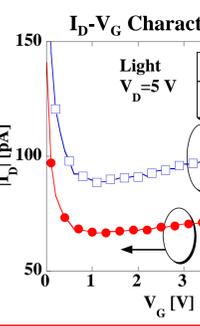
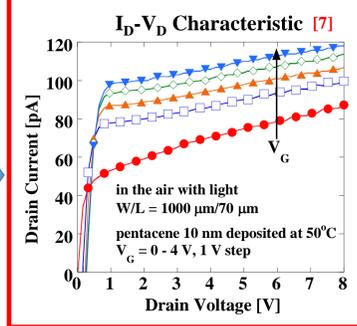
Electron current was obtained in the air with light by using N-doped LaB₆ film

OFET Characteristics

Dark



Light



- There is no n-type characteristic in dark.
- By light exposure, small amplification and saturation characteristics were observed.
- Although there is light exposure time dependence, the electron mobility of 6.5x10⁻⁸ cm²/(Vs) can be obtained.

[6] Y. Maeda et al., The 61st JSAP spring meeting, 19p-E5-20, p. 12-052, 2014.
[7] Y. Maeda et al., AWAD2014, 5B-3, pp. 186-189, 2014.

5. Conclusion

In this paper, N-doped LaB₆ with low work function of 2.4 eV and good oxidation immunity was investigated for Pentacene-based device. It was found as below.

- Deposition on N-doped LaB₆ at 100°C
 - Pentacene grain size: larger than 10 μm
 - The lamellar grain can be suppressed.
- MOS diode with N-doped LaB₆ layer
 - C-V and J-V showed n-type.
- OFET with N-doped LaB₆ interfacial layer
 - Electron current was observed in the air
 - It is still necessary to be assisted by light exposure.
 - The extracted electron mobility was 6.5x10⁻⁸ cm²/(Vs).

For the future step, the effect of N-doped LaB₆ interfacial layer in p-type Pentacene-based OFET and the passivation layer for Pentacene film in n-type OFET will be investigated. In addition, Pentacene-based CMOS with N-doped LaB₆ interfacial layer will be fabricated.

Acknowledgement

The authors thank Prof. Emeritus H. Ishiwara, Prof. H. Funakubo, and Mr. M. Suzuki of Tokyo Institute of Technology, and Dr. Y. Fujisaki of Hitachi, Ltd. for useful discussion for this research. The N-doped LaB₆ film depositions were carried out at fluctuation free facility of New Industry Creation Hatchery Center, Tohoku University. This research was partially supported by Asahi Glass Foundation and JSPS KAKENHI Grant Number 15K13969.