Extended Abstracts of the 2010 International Conference on Solid State Devices and Materials, Tokyo, 2010, pp505-506

Extraction of Energy Density Profile of Bulk and Interface Trap States in Pentacene

Seung-Hyeon Jeong and Chung-Kun Song

Dept. of Electronics Eng., Dong-A University
840, Hadan-dong, Saha-Gu, Busan, 604-714, Korea
Phone: +82-51-200-7711 E-mail: cksong@dau.ac.kr

1. Introduction

Organic thin film transistors(OTFTs) are attracted much attention because of their potential applications requiring flexibility, low temperature processing, and low cost [1-2]. However, the trap charge properties in bulk or interface between organic semiconductor and organic dielectric, which are important to performances such as mobility, threshold voltage, sub-threshold slope, are not clearly identified yet.

In this paper, we analyzed the bulk trap density in pentacene using the temperature dependent space charge limited current (TDSCLC) and the interface trap density between pentacene and poly-4-vinyphenol (PVP) using the temperature dependent transfer characteristics (TDTC).

2. Experimental

We fabricated the top contact OTFT for extraction of bulk and interface trap density. For gate electrode, the 1000Å thickness Al was evaporated onto glass substrate. And PVP layer for gate insulator was spin-coated and baked for 20min at 200℃. The 450Å thickness pentacene for organic semiconductor was evaporated on PVP insulator. Finally, the 450Å thickness Au was used for source and drain electrode.

We used Agilent 4156C precision semiconductor parameter analyzer to measure the I-V characteristics with various temperature in dark box and vacuum. After we measured I-V characteristics at one of various temperature, we gave enough time for the temperature stabilization.

3. Results and discussion

The bulk trap density was extracted by eq. 1 [3].

$$h(E) \approx \frac{1}{kT}\frac{\varepsilon_i \varepsilon_0 V}{qL^2}\frac{2m-1}{m^2}(1+C) \quad (1)$$

Where C = (2 - 3m)B + d ln(1+B)/d lnV, B = -[d m/d lnV]/[m(2m - 1)(m - 1)], m = d lnJ/d lnV, ε_i is the dielectric constant of gate insulator, and L is the distance between two electrodes.

The interface trap density was extracted by eq. 2 [4].

$$N(E) = \frac{1}{q}\frac{d}{dE_a}\left[\frac{\varepsilon_i}{\varepsilon_s l} C_i U_g \left(\frac{dE_a}{dU_g}\right)^{-1}\right] \quad (2)$$

Where U_g = abs(V_g-V_{FB}), E_a is the activation energy, C_i is the capacitance of gate insulator.

As shown in Fig. 1, the J-V curves were measured with various temperature from 303K to 423K.

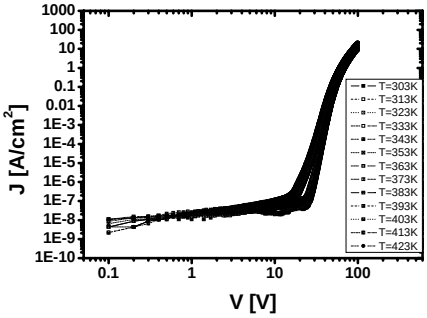

Fig. 1 The J-V characteristics with respect to the various temperature.

We extracted the activation energy in the J-V curves, then we extracted energy distribution of bulk trap density in the pentacene using the TDSCLC. The extracted bulk trap density is shown in Fig. 2.

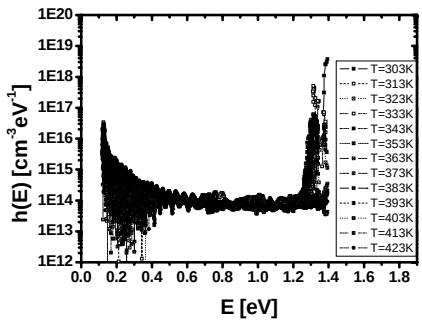

Fig. 2 The bulk trap energy density profile of pentacene ex-

tracted by TDSCLC.

The bulk trap density was existed the exponential tail state. At the high temperature(383K~423K), the bulk trap density at the deep level(E≈1.3eV) was decreased due to annealing effect.

As shown in Fig. 3, the transfer characteristics were measured with various temperature from 303K to 423K.

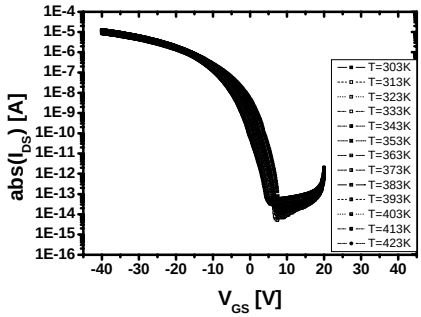

Fig. 3 The transfer curves of OTFT with respect to the various temperature.

We extracted the activation energy from the relationship between the conductivity and the temperature. Then, we applied the TDTC to analyze the interface trap density between pentacene and PVP. The extracted interface trap density is shown in Fig. 4.

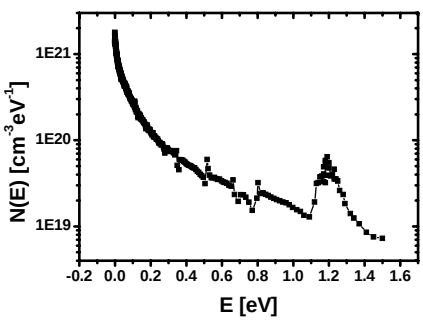

Fig. 4 The interface trap energy density profile extracted by TDTC.

As shown in Fig. 4, the interface trap density was varied from 10^{21} $cm^{-3}eV^{-1}$ to 10^{18} $cm^{-3}eV^{-1}$ as the Fermi energy level moved along the band gap. There were the strong interface trap density at E=0.3, 0.5, 0.8, 1.2 eV.

4. Summary

We extracted bulk trap energy density profile of pentacene and interface trap energy density profile between pentacene and PVP. The bulk trap at 1.3 eV was reduced as temperature increased due to the annealing effect. A strong peak of interface trap density at 1.2 eV. The origin is under investigation.

Acknowledgements

This research was supported by a grant (F0004021-2009-32) from Information Display R&D Center, one of the Knowledge Economy Froniter R&D Program funded by the Ministry of Knowledge Economy of Korean government.

References

[1] G. H. Gelinck, H. E. A. Huitema, E. V. Veenendaal, E. Cantatore, L. Schrijnemakers, J. B. P. H. V. D. Putten, T. C. T. Geuns, M. Beenhakkers, J. B. Giesbers, B. Huisman, E. J. Meijer, E. M. Benito, F. J. Touwslager, A. W. Marsman, B. J. E. Van rens, and D. M. De leeuw, Nature Mater., **3**, 106 (2004)

[2] Fadlallah, G. Billiot, W. Eccleston and D. Barclay, Solid-State Electronics, **51**, 1047 (2007)

[3] O. Zmeškal, F. Schauer, and S. Nešpůrek, J. Phys. C : Solid State Phys., **18**, 1873 (1985)

[4] W. L. Kalb, K. Mattenberger, B. Batlogg, Phys. Rev. B, **78**, 035334 (2008)