Extended Abstracts of the 2008 International Conference on Solid State Devices and Materials, Tsukuba, 2008, pp. 810-811

I-6-1

Effect of regioregularity and alkyl chain length on the depletion layer width formed at the interface of Al and Poly (3-Alkylthiophene)

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1. Introduction

In this work we present bias dependent Photoluminescence (PL) based study of depletion layer formed at the Al and Poly-alkylthiophene (PAT) interface. The effect of varying the alkyl chain length (R= 4, 6, 12) as well as the regioregularity of the PAT films on the depletion layer width will be discussed in detail.

2. Experimental Methods

Glass samples (for Absorption and emission spectra) having an area of 3 cm^2 were cleaned in ultrasonic bath with acetone and iso propanol. The surface of these glass samples were then made hydrophobic by silanizing with 1,1,1,3,3,3-Hexamethyldisilazane (HMDS) for 90 minutes [1]. Later these samples were spin coated with chloroform solution of PAT @ [1500 (30s), 3000 (10s)] r.p.m. For the purpose of Bias dependence PL, ITO coated glass samples were etch patterned in HCl solution using Zn dust and then were subsequently spin coated from Chloroform solution of PAT as described above, further more a 30 nm thick Top Al electrode was coated using the Physical Vapor Deposition (PVD) technique. The active cell area was found to be 40 mm^2. Keithley 6517A electrometer was used for the bias application. PL measurements were done under ambient air conditions using Hamamatsu photonic multi channel analyzer PMA 11. A 300 mW, class 3B, He-Cd laser, 442 nm by Kimmon Electric Company was used as an optical pumping source. Thicknesses of PAT films were measured using Dektak surface profiler.

3. Results and Discussions

In this work we report a novel technique of estimating the depletion layer thickness by using bias dependent PL quenching (Q_{PL}) [2-5], as in eq. (1).

$$Q_{PL} = \left(\frac{I_{PL}(0) - I_{PL}(V)}{I_{PL}(0)} \right) \quad (1)$$

PL emission occurs from the bulk of the semiconductor, due to the radiative decay of intermediate species called excitons. In a sandwiched cell, viz. ITO/PAT/Al, we have demonstrated a direct relationship between PL quenching Q_{PL} and the depletion layer width $W(v)$ as given by eq. (2), [5]. In this report we try to analyze the effect of Regioregularity and the alkyl chain length on the depletion layer width.

$$W(V) = W_0 + \frac{1}{\alpha} \ln \left| \frac{-A + \sqrt{(A+2B)^2 + 4BQ_{PL}}}{2B} \right| \quad (2)$$

Figure 1 shows the absorption spectra of PAT Films (R= 4, 6, 12). It was observed that the absorption peak was slightly red shifted for PAT 6 and PAT 12 films. Also the emergence of shoulder peaks with increasing alkyl chain length suggests formation of

well stacked structures in these films. Better stacking results in higher microcrystalline domains in these films. It was also observed that the absorption coefficients at the peak wavelengths are larger for PATs with shorter alkyl chain lengths. This is primarily because the strength of absorption coefficient α relates to the density or compactness of the π electron backbone, while side chains simply make the film bulky [6]. The absorption spectra of rrnd PAT 6 films show a large blue shift as compared to rr PAT 6, mainly due to lesser degree of effective π conjugation in these films.

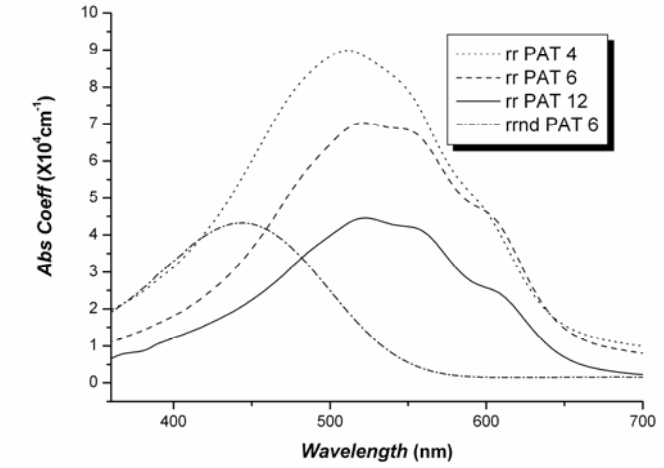

Fig. 1 Absorption spectra of rr and rrnd PAT films

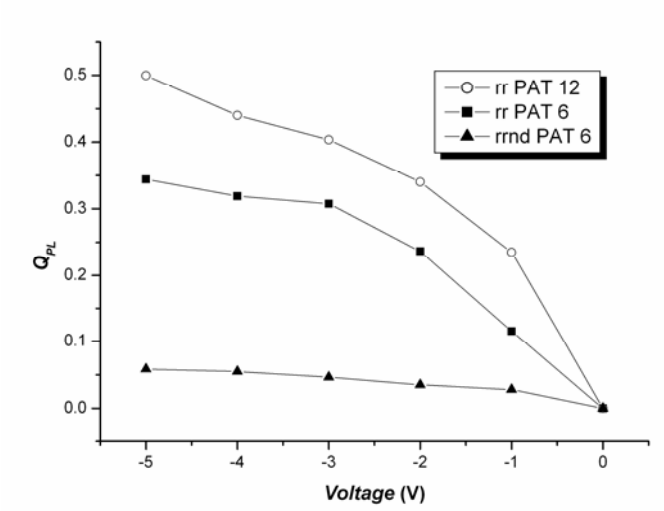

Fig. 2 Bias dependent PL quenching for rr PAT 6 , rr PAT 12 and rrnd PAT 6

Fig. 2 shows the PL quenching against the reverse bias, and as can be seen higher levels of PL quenching occur in PAT 12 films as compared to PAT 6, which might also be due to the well stacked crystalline domains in PAT 12 films, or might be due to the difference in their charge carrier densities. However, it is worthwhile to note that Q_{PL} was significantly low in the rrnd PAT 6 compared to rr PAT 6, mainly owing to the increased trap density in the rrnd PAT 6 films.

4. Conclusion

We would finally like to conclude that (i) the presence of long alkyl chain length leads to well stacked films and thus leads to easier injection of charge carriers into these films. (ii) The regio random P3HT also does not have well defined crystalline domains owing to larger trap densities in these films and therefore gives lesser PL quenching [7]. The depletion widths for various PAT films along with their diode characteristics as well as Field effect Characteristics will be discussed in detail during the presentation.

Acknowledgements

The present study was supported by research fund from Kyushu Institute of Technology and by grant in aid for science research in priority area “Super Hierarchical structures” from Ministry of Education, Culture, Sports, Science and Technology, Japan. One of the authors (V.S.) would further like to thank HNF (Heiwa Nakajima Foundation) for their financial support.

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