Extended Abstracts of the 2016 International Conference on Solid State Devices and Materials, Tsukuba, 2016, pp313-314

F-6-04(Late News)

Frequency Dependent Electrical Response of Poly(triarylamine) with Triisopropylsilylethynyl-pentance Organic Thin Film for Conduction Mechanisms

Khairul Anuar Mohamad[1], Hoh Hang Tak[1], Afishah Alias[1], Bablu Kumar Ghosh[1], Ismail Saad[1] and Hisashi Fukuda[2]

[1]Universiti Malaysia Sabah,
Jalan UMS 88400, Kota Kinabalu, Sabah, Malaysia
Phone: +60-12-866-2389 E-mail: khairul@ums.edu.my
[2]Muroran Institute of Technology,
27-1, Mizumoto, Muroran, Hokkaido 050-8585, Japan

Abstract

We use the experimental result of electrical response of small-signal measurement to investigate the conduction mechanism in poly(triarylamine) (PTAA) with triisopropylsilylethynyl-pentance (TIPS-PEN) thin films. Binding effects between these two organic semiconductors help to form a better crystalline structure, thus could improve device performances.

1. Introduction

Organic semiconductor raises intense attention in producing thin film devices. These organic semiconductor materials have advantages such as an easy fabrication process, low cost, large area electronic applications and low temperature process. The organic diode is the simple structured diode having low forward-biased voltage drop which is suitable to be applied to fast-swapping action device, also often used as prototypical to demonstrate a close to the ideal behavior of a conventional diode. The electrical response of organic thin films with small-signal measurement of the diode structure provides a method for investigating interface charges between organic semiconductor materials [1]. In this work, we report on the frequency dependent electrical response of poly(triarylamine) (PTAA) with triisopropylsilylethynyl-pentance (TIPS-PEN) composite thin films. We also demonstrate the structural properties of the composite thin films using X-ray diffraction (XRD) technique.

2. Experimental

PTAA and TIPS-PEN were used as received from Lumtec and Osilla, respectively. PTAA and TIPS-PEN were dispersed in chloroform in the PTAA:TIPS-PEN weight ratios of 1:0 (PTAA-only), 10:1 (PTAA with low TIPS-PEN) and 1:10 (PTAA with high TIPS-PEN) to generate 0.1 wt% solutions. PTAA with TIPS-PEN solutions were soaked overnight until all solid materials were dissolved at a room temperature. Glass as a substrate was soaked overnight in Decon90 and ultrasonically cleaned with ethanol, acetone and ditilled water followed by drying with nitrogen gas. Thin films were deposited by spin-coating from same amount of each composite solution, ensuring that the layers have similar thickness. The composite solution was deposited using a syringe with a filter. , The small-signal response of the thin films was measured over a frequency range of 10-100 kHz using a precision LCR meter. The bias voltage was remained at a constant voltage (1 V) with an ac oscillating wave. All measurements were recorded at the room temperature in an ambient condition. Meanwhile, the structural properties of the PTAA with TIPS-PEN were studied using an X-ray diffraction (XRD) spectrometer. X-ray beam was generated by a Cu Kα, using a tube voltage of 40 kV at an electron beam current of 30 mA. The scanning angle was increased in steps of 0.02° over the range of 5-40°.

3. Result and Discussion

The characteristics of the ac response gave important information on the organic semiconductor layer especially conduction process. The conductance was obtained based on the complex admittance equation:

$$Y = \frac{1}{Z} = G + j\omega C = G + j(2\pi f)C \qquad (1)$$

where Y is the admittance, Z is the impedance, G is the conductance, ω is the angular frequency, f is the frequency, and C is the capacitance. Figure 1(a) shows the frequency dependence conductance (G/ω) for PTAA with and without TIPS-PEN at three different weight ratios. These curves were exponentially curved upward and fix-line was obtained by following expression:

$$G = Af^{s} \qquad (2)$$

where A was coefficient and s was the critical exponent. The behavior of the G-f curves was due to the long-range ordering which involving a translational motion with a sudden hopping [2]. The origin of the conductance stayed in the relaxation phenomena. When a mobile charge carrier hopped from origin to a new position, it remains in the state of displacement between two molecules which forming the hopping conductivity [3]. Meanwhile, Figure 1(b) shows the frequency dependence capacitance (C) of the PTAA layers with and without TIPS-PEN with two dispersions was clearly visible. The large amount of capacitance at low frequency was due to the contribution of the interface charges [3]. The capacitance was started accumulative decrease depend on the frequency in the low frequency region which below 100Hz. On the other hand, at a high frequency region (> 100 Hz), the capacitance was almost independent of the frequency. The higher capacitance, bigger amount charge trapped which also narrower the depletion region of the device. As ac voltage was normally oscillating at 50Hz, capacitance got the maximum resonance power and formed a shape peak. However, at high frequency, the interface charge cannot follow the ac wave and yield from the geometrical capacitance value [2].

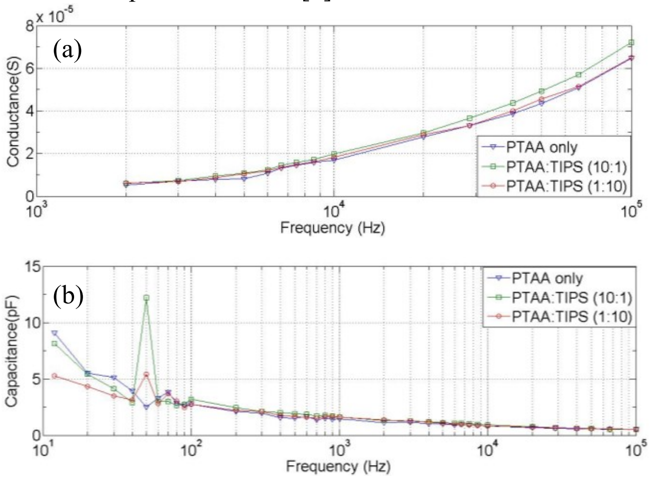

Fig. 1 Frequency dependence of (a) conductance (G/ω) and (b) capacitance (C) measured at a constant voltage for PTAA-only and PTAA with TIPS-PEN at constant speed (3000 rpm)

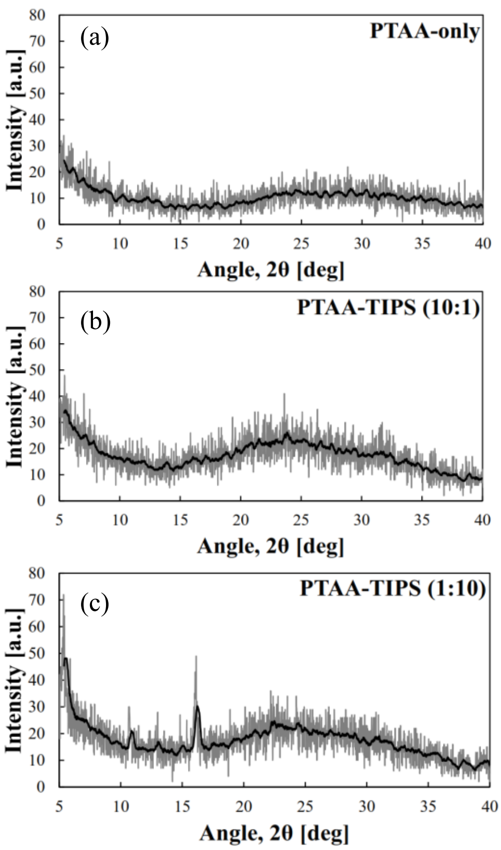

Fig. 2 Out-of-plane XRD patterns of (a) PTAA-only, (b) PTAA-TIPS-PEN (10:1) and PTAA-TIPS-PEN (1:10) composite thin films.

Figure 2 shows the XRD shows the XRD patterns of PTAA with and without TIPS-PEN by spin-coating on glass substrate. PTAA-only thin film exhibits an amorphous layer, whereas the PTAA with a small amount of TIPS-PEN show higher intensity peaks than those of the PTAA-only films indicate a transition from amorphous towards a well-organized molecular structure. As a large amount of TIPS-PEN in PTAA film exhibits a series of (00*l*) diffraction peaks of TIPS-PEN. Binding effect between PTAA and TIPS-PEN molecules could contribute to the improvement of the crystalline structures [4].

4. Conclusions

The frequency dependence of conductance and capacitance of the PTAA with (different weight ratios) and without (PTAA only) were presented. The frequency dependence characteristics of the ac response gave important information on the organic semiconductor layer especially conduction process. XRD patterns showed an improvement crystalline structure of the PTAA thin film due to the binding effect between PTAA and TIPS-PEN molecules. The ac impedance and current-voltage characteristics of these thin films will be discussed later.

Acknowledgements

The author would like to thank Artificial Intelligence Research Unit (AiRU) at Universiti Malaysia Sabah for the facilities provided.

References

[1] M. Ullah, D. M. Taylor, R. Schwodiauer, H. Sitter, S. Bauer, N. S. Sariciftci and T. B. Singh, J. Appl. Phys. **106** (2009) 114505.
[2] H. Dogan, N. Yildirim, I. Orak, S. Elagoz and A. Turut, Physica B Condens. Matter. **457** (2015) 48.
[3] A. Cherif, S. Jomni, H. Saghrouni, W. Belgacem, K. Khirouni and L. Beiji, J. Alloys. Compd. **685** (2016) 28.
[4] M. H. Chung, J. H. Kwon, T. Y. Oh, S. J. Lee, D. H. Choi and B. K. Ju, Thin Solid Films **518** (2010) 6289.