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Optical and Electrical Properties of Aligned π-Conjugated Polymer Films Fabricated by Bar-coating method

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Abstract
Uniaxially aligned films of thiophene-based polymers were successfully fabricated by a bar-coating method, and the unique optical and electrical anisotropies were studied. By selecting the solvent for coating and controlling the substrate temperature, the uniform thin films could be obtained. The optical and electrical properties depended on the coating direction, which were discussed by taking the alignment of the polymer main chain into consideration.

1. Introduction

Conjugated polymers with highly extended π-electron system have been widely investigated for organic electronics since organic thin-film layers can be easily formed by solution process due to their high solubility in organic solvents [1]. Controlling the alignment of polymer chains in films is significant to achieve improvements in properties. It is desired to obtain aligned polymer films without any mechanical or thermal damages to organic materials, and various alignment methods have been proposed [2]. Here, a coating method, bar-coating [3-5] was adopted to fabricate thin films of conjugated polymer, because the direction of film formation was uniaxially fixed by the sweep direction of the coating bar, and the conditions of film fabrication, such as the speed of film formation, the solvent, and the substrate temperature, can be adjusted.

In this study, we fabricated uniaxial aligned films of thiophene-based polymers by the bar-coating method and measured their optical and electrical properties. We discuss the anisotropic characteristics by taking polymer alignment into account.

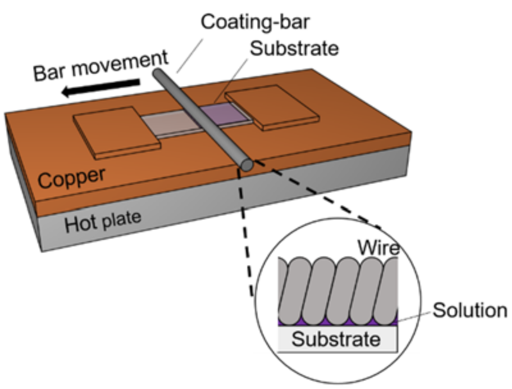

Fig. 1 Schematic diagram of the bar-coating method.

2. Experimental

Thiophene-based polymers, such as, poly(3-hexylthiophene) (P3HT), was used in this study. A thin film of P3HT was fabricated in the following process. A glass substrate was cleaned with a cleaning agent and distilled water by ultrasonication, then treated with UV-ozone. The substrate was placed on a hotplate and the substrate temperature was set at 20-120 °C, and a 9.6-mm-diameter coating bar wound with a 0.05-mm-diameter metal wire was set onto the substrate. A P3HT solution with various solvents, the concentration of which was 10 g/L, was dropped onto the wire bar, then the coating bar was moved in the horizontal direction at a constant speed of 3.3-200 μm/s. The schematic diagram of the bar-coating method is shown in Fig. 1.

The thin film was observed by a polarized optical microscope (Nikon Eclipse LV 100 POL) under crossed nicols. Optical anisotropies of polymer films were measured by polarized absorption. Electrical anisotropies of polymer films were measured by fabricating field-effect transistors (FETs) employing the polymer films as channel layers and measuring their electrical characteristics. Bottom-contacted FETs were achieved by fabricating an aligned polymer film on SiO_2/n-Si substrates with comb-shape-patterned Au electrodes. The bar-sweep direction was perpendicular or parallel to the channel direction of the FETs. The optical and electrical measurements were carried out at room temperature.

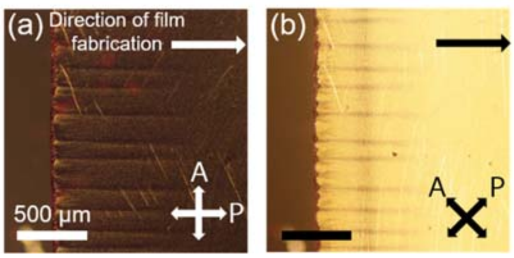

Fig. 2 Typical polarizing micrographs of the bar-coated P3HT thin films observed with crossed polarizers.

3. Results and discussion

Figure 2 shows the typical polarizing micrographs of the thin films observed with crossed polarizers. The observed image of the thin film was uniformly dark when the polarizer was parallel to the bar-sweep direction and became bright when the polarizers were rotated by 45º, which indicates that a uniform and uniaxially oriented thin film with a large area was fabricated.

The polarized absorption spectra of the thin film are shown in Fig. 3. When the polarization direction of the incident light was parallel or perpendicular to the bar-sweep direction, the absorbance based on the π-π* transition of P3HT was minimum or maximum, respectively. The absorbance should become maximum if the polarization direction of the incident light is parallel to the direction of the π-conjugation [6-8]. Therefore, it is considered that the polymer main-chain was perpendicular to the bar-sweep direction. A typical dichroic ratio at peak absorption wavelength was estimated to be approximately 1.48.

Figure 4 shows transfer characteristics of the FETs with oriented P3HT films. The bar-sweep direction was perpendicular (⊥) or parallel (//) to channel direction of FETs. The field effect mobilities in each channel were evaluated to be 2.9×10^{-3} and 4.4×10^{-3} $cm^2\cdot V^{-1}\cdot s^{-1}$ in parallel and perpendicular directions, respectively. It is considered that the anisotropic carrier mobilities in the oriented P3HT films are based on alignment of polymer chains.

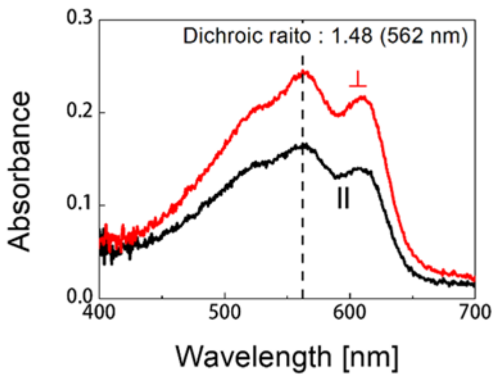

Fig. 3 Typical polarized absorption spectrum of oriented P3HT films.

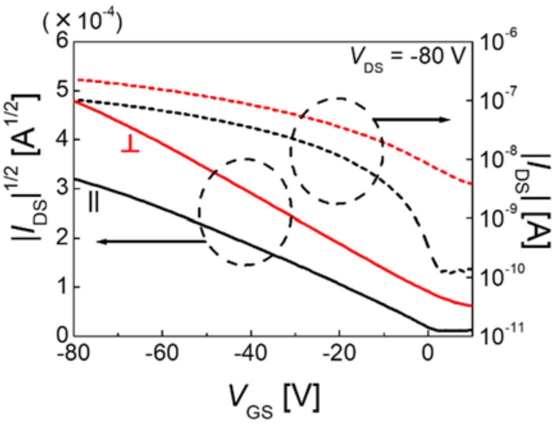

Fig. 4 Typical transfer characteristics of the FETs with oriented P3HT films.

4. Conclusions

We obtained aligned P3HT films by bar-coating method, and demonstrated the optical and electrical anisotropies of the aligned films. The bar-coating method should be appropriate for fabricating uniform and oriented thin films of π-conjugated polymers.

Acknowledgements

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References

[1] K. Yoshino, Y. Ohmori, A. Fujii and M. Ozaki, Jpn. J. Appl. Phys. **46** (2007) 5655.

[2] N. Yamasaki, Y. Miyake, H. Yoshida, A. Fujii and M. Ozaki, Jpn. J. Appl. Phys. **50** (2011) 020205.

[3] D. Khim, H. Han, K.-J. Baeg, J. Kim, S.-W. Kwak, D.-Y. Kim and Y.-Y. Noh, Adv. Mater. **25** (2013) 4302.

[4] M. Ohmori, T. Uno, M. Nakatani, C. Nakano, A. Fujii and M. Ozaki, Appl. Phys. Lett. **109** (2016) 153302.

[5] M. Ohmori, M. Nakatani, H. Kajii, A. Miyamoto, M. Yoneya, A. Fujii and M. Ozaki, Jpn. J. Appl. Phys. **57** (2018) 03EH10.

[6] K. Yoshino, M. Onoda and R. Sugimoto, Jpn. J. Appl. Phys. **27** (1988) L2034.

[7] M. Onoda, Y. Manda and K. Yoshino, Jpn. J. Appl. Phys. **29** (1990) 1490.

[8] T. Higashi, N. Yamasaki, H. Utsumi, H. Yoshida, A. Fujii and M. Ozaki, Appl. Phys. Express **4** (2011) 091602.