

STRUCTURAL STUDY ON ONE-DIMENSIONALLY ALIGNED POLYFLUORENE THIN FILMS FOR APPLICATION OF POLARIZED ORGANIC LIGHT-EMITTING DIODE

Organic light-emitting diodes (OLEDs) are expected to become the next generation of light sources because of its many advantages such as high efficiency, low power consumption and flexibility. In particular, the possibilities in the field of displays are enormous, and so many researchers are progressively developing OLED displays to generate multicolored light with high efficiency. In addition, the processes for depositing organic materials can lead to the production of large light-emitting areas on flexible substrates at very low cost.

Considerable progress in the field of polymer light-emitting diodes (PLEDs), a kind of OLED in which the materials are composed of emissive polymers, has been made since the report of Burroughes *et al.* [1]. Conventional PLEDs, which are composed of the emissive layer and carrier transport layers with a thickness of about 100 nm sandwiched between the anodes of transparent indium tin oxide (ITO) and the cathodes of metals, are emitting non-polarized light. Figure 1 shows the device configuration of polarized PLEDs. As shown in Fig. 1, PLEDs consisting of an aligned emissive polymer are expected to exhibit polarized emission, because the intrinsic characteristic of conjugated polymers originates from the electrons delocalized along the polymer backbone (main chain). The development of polarized PLEDs is important for their application to liquid crystal display (LCD) backlights: if a polarized light source is employed as a backlight, the LCDs power efficiency could be markedly improved since the light loss through a

polarizer placed in the LCD is approximately zero. Namely, polarized PLEDs are the most advanced devices for next-generation display systems.

According to recent reports [2], polarized PLEDs composed of aligned liquid crystal (LC) emissive polymers on a rubbed alignment layer have been generally developed. One very attractive class of such LC polymers is polyfluorene (PF) because of the following reasons. PF has emerged as an attractive material for PLEDs and can be well aligned on a rubbed polyimide layer via the thermotropic LC state. Once suitable LC polymers have been identified, the main issue to be addressed is the choice of alignment layer. Usually, the alignment layer is positioned between an electrode and an active emitting layer, which causes some problems in terms of device performance. In addition, standard polyimide is a good electrical insulator, leading to poor device performance when it is used for the alignment layer.

Here, we introduce our original technique of "friction transfer." It offers a way for the direct preparation of an aligned polymer thin film without an underlying alignment layer, thus avoiding the disadvantages of the alignment technique described above. When some kind of polymers are squeezed and drawn against a clean surface of metal or glass, the highly aligned polymer film remains on the surface [3]. We have already applied the friction transfer technique to the preparation of aligned thin films of various conjugated polymers. Recently, we have succeeded in preparing highly aligned thin films of thermotropic LC polymer, poly(9,9-dioctylfluorene) (PFO) by this technique (Fig. 2), and found that subsequent thermal treatments of the friction-transferred PFO films are specifically effective for the improvement of molecular alignments and surface morphology [4].

In this study, we have examined the fine structure of the film plane of a friction-transferred PFO thin film by grazing incidence X-ray diffraction (GIXD), beamline **BL13XU**. It clarified the fine structure of aligned polymer thin films, thus leading to improved device performance.

As shown in Fig. 3, the orthogonal ($\phi = 0^\circ$) diffraction pattern of the thin film shows the series of long-period peaks, corresponding to $0k0$ ($k = 2, 4, 6, 8, 10$). These peaks are associated with the crystallographic direction along the alkyl side chains. On the other hand, the parallel ($\phi = 90^\circ$) diffraction

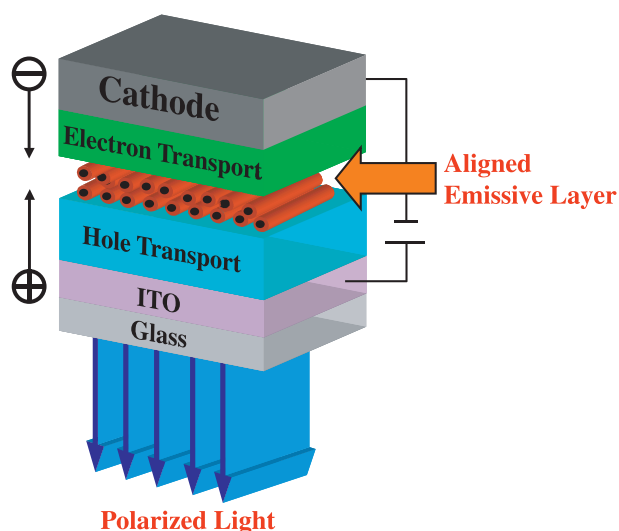


Fig. 1. Device configuration of polarized PLEDs.

pattern shows no $0k0$ peaks. This indicates that the b -axis is orthogonal to the friction direction. Instead of $0k0$ reflections, the series of the $00l$ reflection appeared. The c -axis of PFO is parallel to the friction direction. Moreover, we observed that changes in the scattering intensity at the fixed scattering angle 2θ indicate the distribution of arrangement of the reflecting plane to the friction direction. The half-width of the distribution of the PFO parallel 008 reflection was estimated to be 2.94° . This result shows that the polymer chains are well-ordered in the friction direction. To quantitatively estimate a molecular orientation of polymers, we introduce an aligned fraction factor f_{20} for uniaxial oriented polymer thin films. The aligned fraction calculated from the X-ray diffraction data is described below:

$$f_{20} = (3 \langle \cos^2 \theta \rangle - 1) / 2$$

Here, θ indicates an angle between a polymer chain and c -axis of unit cell. The fraction of the c -axis in thin films is 0.999, which is extremely large (a fraction at perfect alignment is 1.0 by definition). Almost perfect alignments are accomplished in the PFO thin film.

In conclusion, we have succeeded in preparing almost perfect alignments of polymer in PFO thin films by a friction transfer combined with thermal treatment. Already, we have reported the performance of polarized PLEDs prepared by friction transfer [5]. Aiming to develop high performance and stable

polarized PLEDs, we are going to confirm the relationship between the aligned structure and the device performances.

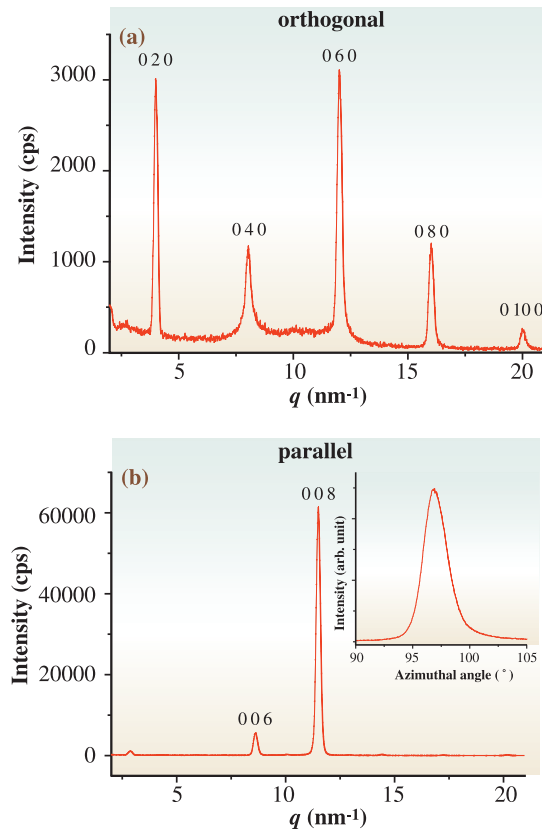


Fig. 3. In-plane GIXD profiles of PFO thin films with scattering vectors (a) orthogonal to the friction direction and (b) parallel. The inset shows the rocking scan of 008.

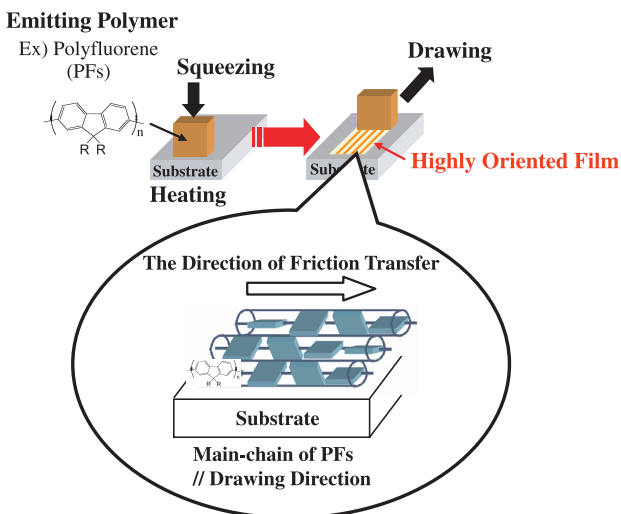


Fig. 2. Schematic illustrations of the friction transfer technique and the aligned polymer structure in PFO thin films.

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