

Improvement of field-effect mobility of P3HT films by slow cooling in annealing process

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Organic field-effect transistors (OFETs) using polymer semiconductor has the potential to be applied to large area, flexible and low-cost devices. P3HT (poly (3-hexylthiophene-2,5-diyl)) is widely used as a material for OFETs. It is well-known that thiophene-based polymer such as P3HT has liquid crystal phase at high temperature [1]. Therefore, it is expected that slow cooling from a higher temperature than a glass transition point improves crystallinity of polymer films. Although the annealing temperature effect on performance of P3HT OFETs has been reported [2, 3], the effect of slow cooling is unclear. In this study, we investigated influence of slow cooling in annealing process on characteristics of P3HT OFETs.

We fabricated, bottom-contact type of OFETs on a heavily doped p-type Si (100) substrate covered with a 260 nm-thick thermal SiO₂ layer as a gate insulator. The SiO₂ surface was treated with hexamethyldisilazane (HMDS). An Au/Ti layer was deposited through vacuum evaporation and source and drain electrodes were formed by patterning the Au/Ti layer. Finally, a P3HT layer was formed by spin-coating, and it was annealed in a nitrogen atmosphere. It was cooled at a rate of 0.5 °C/min after annealing for 20 minutes. The annealing temperature was varied from 150 °C to 300 °C. The field-effect mobility of P3HT films was estimated from the transport characteristic of an OFET using P3HT. Crystallographic properties of P3HT films were characterized by X-ray diffraction (XRD). Figure 1 shows the dependence of the thermal annealing processes on the field-effect mobility of P3HT films. We found that the field-effect mobility was drastically improved by slow cooling from 250 °C. Figure 2 shows out-of-plane X-ray diffraction patterns of P3HT films. We observed a diffraction peak due to P3HT(100). The peak intensity of a slowly cooled P3HT film is larger than that of a rapidly cooled P3HT film when an annealing temperature was 250 °C. Figure 3 shows in-plane XRD patterns of P3HT films. We observed a diffraction peak of P3HT(010) indicating

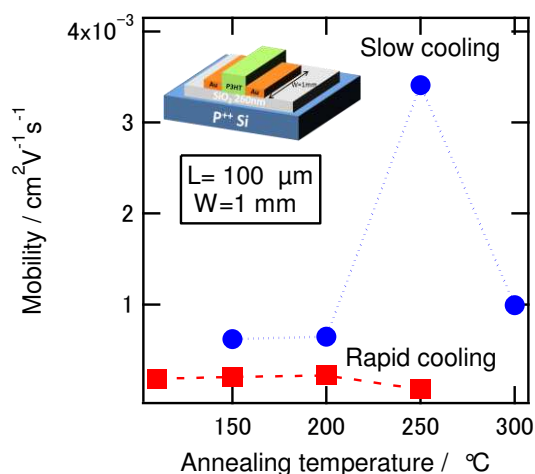


Fig. 1: Slow cooling effect of mobility of P3HT films

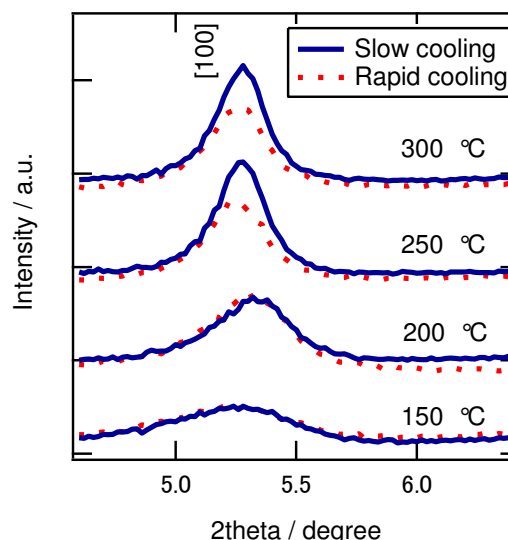


Fig. 2: Out-of-plane XRD patterns of P3HT films

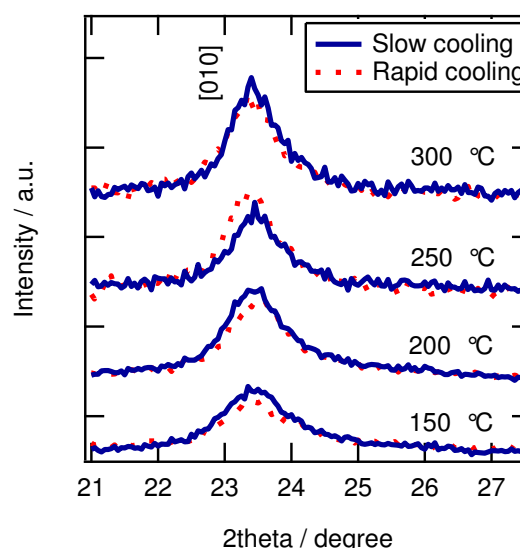


Fig. 3: In-plane XRD patterns of P3HT films

π - π stacking of the thiophene rings. From Fig. 3, we can see that the peak intensity is independent of a cooling process in contrast.

These results indicate that slow cooling from higher than a glass transition point induced to order P3HT crystals along the <100> direction to improve the field effect mobility of P3HT films.

References

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