

論文 / 著書情報
Article / Book Information

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Title(English)	Study on Near-infrared Photodetectors with a Liquid Crystalline Phthalocyanine Derivative for Biomedical Applications
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種別(和文)	論文要旨
Type(English)	Summary

論文要旨

THESIS SUMMARY

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

In recent years organic electronics have attracted notable research attention due to advantages such as large-area fabrication, solution processability, mechanical flexibility, stretchability and skin conformity, low-temperature, and low-cost fabrication, among others. The possibility of changing the semiconducting and material properties of organic polymers and small molecules by making modifications to their chemical structure has driven the research and development in the field of light emitting diodes, solar cells, and photodetectors. Liquid crystalline organic semiconductors are unique materials that show one or more mesophases between crystalline and liquid phases. By making use of the mesophase, it is possible to change the orientation of molecules, crystalline order, and grain size of the thin film even after thin film fabrication. Liquid crystalline materials with large π -conjugated systems can self-organize into single domain thin films by taking advantage of the presence of the liquid crystalline mesophase. As a result, boundaries between randomly oriented grains in the crystalline phase, which create large barriers for charge carrier and exciton transport, can be avoided. Moreover, solution processed liquid crystalline thin films have been reported to be a good precursor for films having excellent morphology and uniformity.

In this study, solution processed near-infrared organic photodetectors were realized with a liquid crystalline phthalocyanine derivative, 1,4,8,11,15,18,22,25-octaoctyl-phthalocyanine (8H₂Pc), exhibiting maximum external quantum efficiency of 60%, responsivity of 0.4 A/W, and shot-noise-limited specific detectivity of 3×10^{12} Jones at 760 nm. The performance of these bulk heterojunction organic photodetectors was superior to the ones prepared with a soluble phthalocyanine derivative without any liquid crystalline phase, 1,4,8,11,15,18,22,25-octaoctyloxy-phthalocyanine (8OH₂Pc), suggesting the advantage of using liquid crystalline materials in photodetector applications. The better performance was attributed to the well intermixing of the donor and acceptor materials in the bulk heterojunction, creation of grains of tens of nm, and smooth surface morphology of the solution processed active layer. It was suggested that these advantageous bulk heterojunction conditions were achievable due to the weak intermolecular interaction and self-organizing nature of the liquid crystalline material. Careful interface engineering of diode electrodes proved to be very effective in lowering dark current levels and increasing reproducibility.

Furthermore, one of the principal challenges of organic devices, poor air stability, was addressed and two different approaches to resolve the issue were demonstrated: inverted architecture photodiodes with a stable cathode and encapsulation of the device with epoxy glue and glass substrate. While the inverted photodiodes showed slower degradation of performance compared to conventional ones, epoxy glue and glass encapsulated photodiodes showed excellent stability and reliability with only 7% degradation in responsivity after 22 days of fabrication.

By thermal annealing at the liquid crystalline temperature of 8H₂Pc, it was demonstrated that the molecules could be redirected from the edge-on orientation to the face-on orientation even after the deposition of the thin film. This reorientation of molecular direction significantly improved the device performance and photo current output of the photodetectors with neat 8H₂Pc active layer. The effect of thermal annealing at liquid crystalline and isotropic phases was also explored for the bulk heterojunction active layers and phase separation and change in grain size and purity of the donor and acceptor materials were observed. Annealing at isotropic temperature resulted in the face-on orientation of the disc-like molecules of 8H₂Pc but created large area grains in the order of tens of μm. On the other hand, annealing at liquid crystalline temperature achieved the effect of face-on orientation without creating such large grains. These changes could also be controlled by varying the duration of thermal annealing and the cooling rate of the samples from liquid crystalline phase to crystalline phase temperature. In addition, taking advantage of the solution process for the fabrication of the active layer, flexible and wearable organic photodetectors were prepared on plastic substrates of 25 μm thickness. The flexible devices exhibited external quantum efficiency of 9% and 5% at 740 nm under no strain and at bending radius of 7.5 mm, respectively, indicating good mechanical flexibility and durability.

Finally, the practical utility of the near-infrared photodetectors was demonstrated by measuring the photoplethysmogram signal of a human subject in real-time in ambient conditions. By irradiating near-infrared light of 740 nm on the index finger of the subject, the systolic and diastolic peaks of the heartbeat could be detected in the filtered spectrum and an average heartrate of 66 bpm could be extracted. The accuracy of these results shows the prospect of these devices for use in hospitals and clinics in practical applications for the benefit of patients and elderly generation. The flexible devices realized in this study may also be used in commercial products such as smartwatches or portable health monitors which will allow the users to have more freedom and comfort while monitoring their physical activities or health conditions.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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