論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Control of molecular orientation in organic polycrystalline thin film by liquid crystal and its application in organic electronic devices
著者(和文)	WangYi-Fei
Author(English)	Yi-Fei Wang
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10704号, 授与年月日:2017年12月31日, 学位の種別:課程博士, 審査員:飯野 裕明,梶川 浩太郎,大見 俊一郎,間中 孝彰,石川 謙
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10704号, Conferred date:2017/12/31, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	物理電子システム創造　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
学生氏名： Student's Name	Wang Yi-Fei	指導教員（主）： Academic Supervisor(main)	飯野 裕明
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

As an excellent generation of organic semiconductors, liquid crystal materials not only possessed high charge carrier mobility, but also offered extra advantages in fabrication of organic electronics devices. In contrast with crystal materials, liquid crystal can easily for uniform and molecular flat polycrystalline thin film by solution process. More interesting, with ability to form different molecules orientation through self-assembly, liquid crystal can prepare different oriented semiconductor films for different electronic devices. In the present thesis, liquid crystal was studied as a tool to control molecules orientation in organic polycrystalline thin films.

A general method to fabricate planarly oriented polycrystalline thin film was developed. By using an over-coated film of water-soluble polymer, i.e., PVA as orientation layer and annealing at low ordered liquid crystal phases, the molecules in spin-coated liquid crystal thin films were successfully re-oriented from "hemeotropic" to "planer" orientation. Planer-aligned polycrystalline thin film as thin as ~100nm could be easily processed while maintained good morphology. The role of mesophase behavior and orientation layer to achieve a high quality film was systematically investigated. Liquid crystal materials which have highly ordered smectic phase in combined with a low ordered smectic phase are good candidate to give an efficient re-orientation from perpendicular to planar, and maintain good film morphology without deep cracks and pin-holes. The over-coated polymer layers not only provide surface anchoring to re-orientation, but also played important role to prevent the dewetting of polycrystalline thin film during annealing. A single layer device also fabricated by replace PVA to a conductive polymer PEDOT: PSS. Organic diode with a rectification ratio of 10^3 at ±2V can be easily achieve by a simple blade coating process. This method demonstrated an efficient strategy to fabricate vertical organic electronic devices by using liquid crystal polycrystalline thin film. Thin film obtained by our new developed method can be as thin as 50nm, which is more available for the application in organic electronic devices.

The above method was further developed to an efficient micro-imprinting method. The imprinting template can be directly peeled off after fabrication which enables a more quick and easy process. A novel stamp with micro-patterned surface was designed as micro-imprinting template. The surface of the stamp provided planar anchoring to re-orient the liquid crystal molecules in a spin-coated thin film from "perpendicular" to "planar", while

allowed directly peel off the template after imprinting. In contrast to the previous reported imprinting method to fabricate polycrystalline thin films which relays on a PDMS stamp, the method present here is more advanced. Polycrystalline thin film fabricated has a planar orientation which never been reported before. The thickness of resulted film was less than 200nm which was difficult to obtain by other reported methods. The thickness can be further decrease by optimize the master mold.

Due to the capillarity action of liquid crystals in micro-channel, the dewetting of film during the annealing process was also effectively controlled. Moreover, polycrystalline thin film fabricated by this method show no cracks even the liquid crystal material not have a highly ordered phase. Therefore, this method allowed easier operation and more freedom for selection of liquid crystal materials. Polycrystalline thin film fabricated possessed good charge transport vertical to the substrate. Furthermore, micro-pattern surface was form at the same time of re-orientation, this type of polycrystalline thin film was largely attractive for the applications in optical electronic devices.

The orientation of liquid crystal material also investigated in nanogap structure. Co-planar nanogap organic diodes were fabricated with smectic liquid crystalline organic semiconductors of BTBT and TTP derivatives by a spin-coating their solution at a liquid crystalline temperature. A rectification ratio of the order of 10^6 at ±3 V under ambient condition was achieved, which were 4 orders higher than that of non-liquid crystal derivatives. The high rectification achieved in nanogap diodes fabricated with smectic liquid crystalline organic semiconductors can be attributed to both high crystallinity of the films in the nanogap, which originate from expected stepwise structural relaxation from liquid crystal phase to crystal phase, and well-established molecular orientation of liquid crystal molecules, which inherits the molecular orientation stabilized by both contribution of anchoring energy against electrode side wall and surface energy from free surface. In addition, the liquid crystal materials can form uniform semiconductor thin films full-filled nanogap conformally without dewetting on the electrode surface. Considering high mobility liquid crystalline semiconductors developed in recent years, further improvement of the device performance will be realized in the future.

In summary, by using liquid crystal to control molecular orientation, various processing techniques were developed to fabricate a planarly oriented polycrystalline thin film, which is difficult to realize in previous research. Such concept also beneficial for the new developed nanogap device, in which liquid crystal materials showed obvious advantages to form thin film with well-defined orientation and realize good charge transport in nano-channel. This study repurposed liquid crystals for the fabrication of high quality organic semiconductor thin films.