T2R2 東京科学大学 リサーチリポジトリ
Science Tokyo Research Repository

論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Study on Thin Film Transistors using Liquid Crystalline Organic Semiconductor and Silver Electrodes
著者(和文)	KangSabina
Author(English)	Sabina Kang
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12619号, 授与年月日:2023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,間中 孝彰,大見 俊一郎,田口 大,長谷川 達生
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12619号, Conferred date:2023/12/31, 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

Powered by T2R2 (Science Tokyo Research Repository)

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子　系 電気電子　コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
学生氏名： Student's Name	Sabina Kang	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 ）

Organic field effect transistors (OFETs) have been investigated for many years due to their potential applications in flexible, large-area, and low-cost electronics. 2-Decyl-7-phenyl-[1]benzothieno[3,2-b][1]benzothiophene (Ph-BTBT-10), which is one of the liquid crystalline organic semiconductors, is easy to fabricate uniform films by spin coating technique and the resulting uniform thin films exhibit high mobility even though polycrystalline films. Thus, this material is suitable for practical applications with solution processes. Most reports of Ph-BTBT-10 OFETs used gold source-drain (S/D) electrodes due to their outstanding properties. Unfortunately, the high cost of gold has overshadowed its applications in low-cost electronics. Therefore, it is aimed at fabricating high-performance and low-cost OFETs using Ph-BTBT-10 OFET and silver S/D electrodes.

Ph-BTBT-10 OFETs using silver S/D electrodes in the top contact configuration were investigated and exhibited intriguing results of the performance not depending on the work function of the metal electrodes, which silver and gold are 4.6 eV and 5.0 eV, respectively. Ph-BTBT-10 OFET with silver S/D electrodes exhibited comparable carrier mobility (8.2 cm^2/Vs) to those with gold S/D electrodes (11.9 cm^2/Vs). For the contact resistance, a value less than 0.5 kΩcm was obtained, which is an order of magnitude lower than OFETs with gold S/D electrodes (2.7 kΩcm). Therefore, the possible reasons why Ph-BTBT-10 OFETs with silver S/D electrodes perform superior to those with gold S/D electrodes despite the energy level mismatches were discussed. It was assumed that silver electrodes may easily penetrate into the Ph-BTBT-10 semiconductor layer upon the deposition of silver electrodes. So, cross-section analyses were conducted through time-of-flight secondary ion mass spectrometry, scanning electron microscope, and X-ray reflectometry analysis to clarify the mechanism. It can be concluded that silver electrodes penetrated Ph-BTBT-10 layer more deeply compared to gold electrodes according to observation. This affects decreasing access resistance, which is one of the dominant elements of contact resistance in the bottom-gate top-contact configuration. Furthermore, the results indicated that the interface area between Ph-BTBT-10 layer and silver electrodes is larger than that between Ph-BTBT-10 layer and gold electrodes. As a result of this larger interface area, the carrier injection area is increased and Ph-BTBT-10 OFET with silver S/D electrodes achieves a small contact resistance.

Bottom-contact configuration is feasible for industrial applications such as photolithography and solution processes. However, it suffers from lower performance because the poor contact condition between organic semiconductors and S/D electrodes contributes in large part to the contact resistance. Ph-BTBT-10 OFETs with silver S/D electrodes showed very low OFET mobility (0.1 cm^2/Vs) and high contact resistance (630 kΩcm) because the work function of silver has a large energy level misalignment with the highest occupied molecular orbital (HOMO) level of Ph-BTBT-10 (-5.6 eV). Therefore, it is required to enhance the carrier injection, silver S/D electrodes were modified by self-assembled monolayer (SAM) treatment with pentafluorobenzenethiol (PFBT) and tetrafluoro-(trifluoromethyl)-benzenethiol (TTFP), respectively. Ph-BTBT-10 OFETs with SAM-treated silver S/D electrodes achieved mobility of an average of 1.5 cm^2/Vs and the contact resistance two orders of magnitude lower than OFETs with pristine silver S/D electrodes. Also, Ph-BTBT-10 OFETs with TTFP-modified silver S/D electrodes showed deep work function (6.0 eV) and small contact resistance (2.1 kΩcm), it can be expected to utilize a deeper HOMO level of organic semiconductors. Bottom-contact OFET is a practical structure for the application of solution processes since silver nanoparticles can damage the organic layer when electrodes are fabricated in the top-contact structure. Therefore, based on these conventional process results, solution-processed silver S/D electrodes were investigated.

Solution-processed silver S/D electrodes by using silver nanoparticles were applied to Ph-BTBT-10 OFETs. First, the inkjet printing process which has the advantage of the drop-on-demand method was conducted. Although relatively non-wavy dot line patterns were obtained by adjusting conditions between silver nanoparticles and surfaces, it was difficult to control fabrication conditions and obtain fine patterns. To achieve fine patterns, differential surface properties of hydrophobic and hydrophilic were utilized. To pattern electrodes, three concepts were investigated: hydrophobic and hydrophilic SAMs, fluorinated polymer (CYTOP) layer with oxygen plasma, and hydrophobic photoreactive SAM. The basic concept is silver nanoparticles can be controlled to be fabricated only on hydrophilic surfaces. After hydrophobic treatment of the underlayer, the designated area for S/D electrodes is conducted in hydrophilic properties, consequently, silver S/D electrodes will be patterned. Fine patterns were achieved through CYTOP layer with oxygen plasma and photoreactive SAM. However, the residue of CYTOP on the channel area impeded the fabrication of Ph-BTBT-10 semiconductor layer due to issues with hydrophobicity and thickness. For photoreactive SAM, the SAM layer is thin, and photoreactive protecting groups of SAM on the channel area can be removed as UV exposed after fabricating silver S/D electrodes, and additional UV/ozone cleaning improved the uniform formation of Ph-BTBT-10 thin film. As a result, Ph-BTBT-10 OFETs with solution-processed silver S/D electrodes were successfully fabricated and operated. Ph-BTBT-10 OFETs with TTFP-treated silver S/D electrodes by fabricating solution process showed the mobility of 0.18 cm^2/Vs.

Ph-BTBT-10 OFETs with silver S/D electrodes showed meaningful results as next-generation organic electronics: superior performance to OFETs with gold S/D electrodes in the top contact configuration; the possibility of utilization for display, showing the mobility of over 1cm^2/Vs in the bottom contact configuration with SAM. Furthermore, this approach is also expected to realize an ultra-low-cost all-solution process. These results envision that Ph-BTBT-10 OFET with silver S/D electrodes is a promising candidate.

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。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

注意：論文要旨は、東工大リサーチリポジトリ（T2R2）にてインターネット公表されますので、公表可能な範囲の内容で作成してください。

Attention: Thesis Summary will be published on Tokyo Tech Research Repository Website (T2R2).