

## Effect of Anisotropic Gate Dielectric Layer fabricated by Obliquely Evaporated Silicon Dioxide on Pentacene-Based Field-Effect Transistor

H.-R. Kim, J.-J. Jung, Y.-J. Lee, and J.-H. Kim<sup>\*</sup>

Department of Electronics and Computer Engineering, Hanyang University  
17 Heangdang-Dong, Seongdong-Gu, Seoul 133-791, Korea

L.-M. Do

Basic Research Laboratory, Electronic and Telecommunications Research Institute  
161 Gajeong-Dong, Yuseong-Gu, Daejeon 305-700, Korea

### Abstract

We investigated anisotropic conduction effects of pentacene-based organic thin film transistor on an anisotropic insulator fabricated by obliquely evaporated silicon dioxide. It was observed that the obliquely evaporated gate dielectric layer affected the crystallized grain size as well as the molecular ordering. The mobility of the pentacene film in parallel to the oblique incidence of the e-beam evaporation was about 8 times higher than that in perpendicular one. As the inclination angle of e-beam evaporation was increased, the mobility was decreased due to the decreased grain size induced by increased surface roughness.

### 1. Introduction

Organic thin film transistors (OTFTs) have drawn much attention for flexible electronics such as smart cards, flexible displays, and several types of low cost and low-end electronics[1]. Recent intensive studies improved the electrical performances of the pentacene-based OTFTs in mobility comparable to that of hydrogenated amorphous silicon transistors[2].

Since the electrical conduction of OTFTs is highly affected by the molecular ordering, crystalline orientation, and the crystallized grain size of the organic semiconductors, there were several efforts to modify interfacial properties between the evaporated pentacene molecules and the insulator surface. In general, highly oriented polymeric layers by mechanical rubbing[3,4] or irradiation of polarized UV light[5,6] were used for the purpose. But, the electrical performance of OTFTs on the organic insulators are not satisfactory yet, comparing with those on the inorganic insulators, especially in terms of leakage current and the driving gate voltage.

In this paper, we investigated anisotropic conduction effects of pentacene-based OTFT on an anisotropic insulator fabricated by obliquely evaporated silicon dioxide. The molecular ordering effect and the grain size effect depending on the surface anisotropy and the surface roughness were discussed with the results of the field-induced mobility and the surface morphology.

### 2. Experimental Results and Discussion

Fig. 1 shows our bottom gate transistor structure where an n-type silicon wafer was used as a gate electrode. For comparison, conventional OTFT with an isotropic silicon dioxide surface was prepared by thermally grown oxidization with about 1400 Å thick on the heavily doped silicon wafer. The effects of the anisotropic inorganic interface were investigated by further evaporating silicon dioxide obliquely with an e-beam method on the thermally grown oxidized surface. The thickness of the additional dielectric layer was about 1000 Å. On the inorganic dielectric layer, a pentacene layer was deposited by 300 Å thick with a deposition rate of 0.4 Å/s under the base pressure of  $1 \times 10^{-7}$  Torr. As source and drain contacts, gold was thermally deposited on top of the pentacene film, where the channel length and width were 100 μm and 1 nm, respectively. Two types of samples were prepared, where the channel direction was parallel or perpendicular to the oblique incidence of the e-beam evaporation.

Fig. 2 shows the  $I_D$ - $V_{DS}$  characteristics of OTFTs with the anisotropic insulator layer when the inclination angle of the e-beam evaporation was 40° with respect to the channel direction. It was observed that the mobility of the pentacene film in parallel one was higher than that in perpendicular one, with the values of  $2.1 \times 10^{-3}$  cm<sup>2</sup>/V·s and  $2.7 \times 10^{-3}$  cm<sup>2</sup>/V·s, respectively. The induced mobility anisotropy was about 8. Such results mean that the pentacene molecules, composed of  $\pi$ -electron conjugated systems are aligned in a direction perpendicular to the evaporation direction of the silicon dioxide, which resulted in the enhanced mobility of Fig. 2 (a) through the increased  $\pi$ -electron orbital overlap. The on/off ratios were similar in both samples with about  $10^4$ .

However, the mobility was smaller than that of the conventional OTFT, as shown in Fig. 3. The mobility of the pentacene on the thermally grown silicon dioxide was  $2.0 \times 10^{-3}$  cm<sup>2</sup>/V·s. The on/off ratio was also better with the value of about  $10^6$ .

Above results can be explained by considering the grain boundary effects including the molecular ordering effects on the OTFT performances. As shown in Fig. 4, the surface roughness of the dielectric layer fabricated by oblique evaporation was higher

than that of the thermally grown one. Thus, the pentacene grains can not be grown to a larger size, which resulted in the reduced mobility of the OTFTs with the aligned molecular ordering. Figs. 5 (a) and (b) show the AFM images of the pentacene surface on the thermally grown isotropic silicon dioxide layer and the obliquely evaporated anisotropic silicon dioxide layer, respectively.

### 3. Summary

In this paper, we investigated the electrical performances of the pentacene based OTFT on the obliquely evaporated silicon dioxide surface. On our anisotropic interface, the molecular ordering effects of the pentacene molecules could be obviously obtained. However, since the surface roughness and resultant grain boundary were also increased as the inclination angle of the evaporation increased, it is assumed that the optimization of the fabrication process has to be required.

### References

- [1] C. D. Dimitrakopoulos, et al., *Adv. Mater.*, Vol. 14, (2002), P. 99-117.
- [2] S. E. Nelson, et al., *Appl. Phys. Lett.*, Vol. 72, (1998), P.1854-1856.
- [3] M. E. Swigger, et al., *Appl. Phys. Lett.*, Vol. 79, (2001), P.1300-1302.
- [4] Y. Kato, et al., *Appl. Phys. Lett.*, Vol. 84, (2004), P. 3789-3791.
- [5] W.-Y. Chou, et al., *Adv. Funct. Mater.*, Vol. 14, (2004), P.811-815.
- [6] W. Y. Chou, et al., *Chem. Mater.*, Vol. 16, (2004), P. 4610-4615.

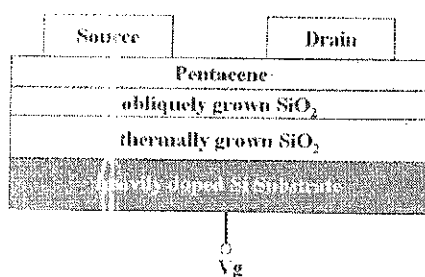


Fig. 1. Structure of pentacene-based TFT with an anisotropic inorganic dielectric layer.

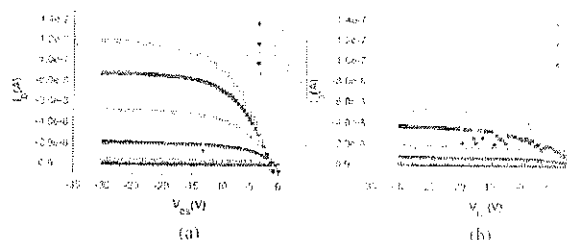


Fig. 2.  $I_D - V_{DS}$  characteristics of OTFTs where the oblique incidences of the silicon dioxide evaporation are (a) parallel and (b) perpendicular to the channel direction.

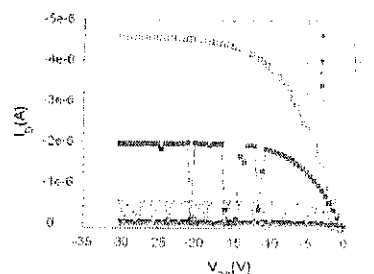


Fig. 3.  $I_D - V_{DS}$  characteristics of OTFTs with thermally grown silicon dioxide layer.

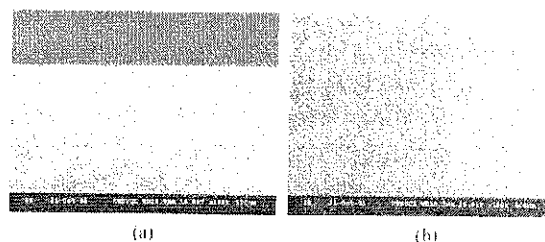


Fig. 4. (a) Cross section and (b) surface SEM images of the obliquely evaporated silicon dioxide dielectric layer.

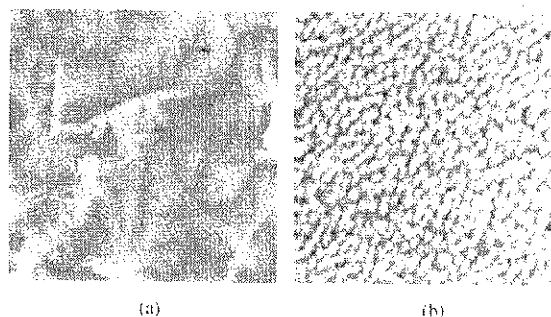


Fig. 5. AFM images of the pentacene surface on (a) the thermally grown isotropic silicon dioxide layer and (b) the obliquely evaporated anisotropic silicon dioxide layer.



제13회

# 한국반도체학술대회

The 13<sup>th</sup>  
Korean Conference on  
Semiconductors

2006. 2. 23(목) 발표논문(上)

2006. 2. 23(목)~24(금)

라마다프라자 제주호텔

**주관** 한국전자통신연구원  
한국반도체산업협회  
한국반도체연구조합

**주최** 한국물리학회 반도체분과회  
한국재료학회  
대한전기학회 전기재료연구회  
대한전자공학회 반도체재료 및 부품연구회  
대한전자공학회 SoC 설계연구회  
반도체설계교육센터(DSEC)

**후원** 삼성전자, 하이닉스반도체, 동부이남반도체,  
매그나칩반도체, 피케이엘, 한국램리서치,  
ASML Korea, 케이던스코리아, 시놉시스 코리아,  
한국애질런트테크놀로지스, 광전자주식회사,  
한국멘토, 해빛정보, 성원EDWARDS, 실리콘웍스,  
윙플러스 비전, 마이더스 시스템, 세미코리아,  
제주대학교 나노박막재료연구실,  
IEEE Electron Device Society Korea Chapter,  
IEEE ED/SSC Seoul Chapter

<http://kcs.cosar.or.kr>

042-412-7464

PT1-49	<b>A Compact and Low Loss Single-Pole Six-Throw RF MEMS Switch</b> .....	305
	저자 : 이재우, 재형환, 강성원, 최철익 소속 : 한국전자통신연구원 기반기술연구소 Microsystem팀	
PT1-50	<b>Micro-Bridge Thermopile Sensor</b> .....	307
	저자 : Kum-Pyo Yoo <sup>1</sup> , H. M. Byun <sup>1</sup> , Woo-Suk Choi <sup>1</sup> , and Nam-Ki Min <sup>2</sup> 소속 : <sup>1</sup> Department of Biomicrosystem Technology, Korea University, <sup>2</sup> Department of Control and Instrumentation Engineering, Korea University	
PT1-51	<b>ZnO TFT Fabricated at Low Temperature for Application of Active-Matrix Display</b> .....	309
	저자 : Chi-Sun Hwang, Sang-Hee Ko Park, and Hye Yong Chu 소속 : Basic Research Laboratory, Electronics and Telecommunications Research Institute	
PT1-52	<b>Capacitance-Voltage Characteristics of MIS Capacitors Using Organic Materials</b> .....	311
	저자 : J. Park, S. P. Jang, H. S. Kim, K. W. Bong, and J. S. Choi 소속 : Department of Electrical, Information and Control Engineering, Hongik University	
PT1-53	<b>Activation of Doped Polycrystalline Si Thin Films using Field-Aided Rapid Temperature Annealing toward Active Matrix Organic Light-Emitting Diodes</b> .....	313
	저자 : B. S. So <sup>1</sup> , Y. H. You <sup>1</sup> , B. K. Lee <sup>1</sup> , N. Y. Kang <sup>1</sup> , T. Y. Kim <sup>1</sup> , H. J. Kim <sup>1</sup> , Y. H. Kim <sup>1</sup> , D. H. Shin <sup>2</sup> , S. R. Ryu <sup>2</sup> , and J. H. Hwang <sup>1</sup> 소속 : <sup>1</sup> Department of Material Science&Engineering, Hongik University, <sup>2</sup> Viatron Technologies	
PT1-54	<b>Effect of Anisotropic Gate Dielectric Layer Fabricated by Obliquely Evaporated Silicon Dioxide on Pentacene-based Field-Effect Transistor</b> .....	315
	저자 : H.-R. Kim <sup>1</sup> , J.-I. Jung <sup>1</sup> , Y.-J. Lee <sup>1</sup> , J.-H. Kim <sup>1</sup> , and L.-M. Do <sup>2</sup> 소속 : <sup>1</sup> Department of Electronics and Computer Engineering, Hanyang University, <sup>2</sup> Basic Research Laboratory, Electronic and Telecommunications Research Institute	
PT1-55	<b>A New Pixel Design of Active-Matrix Organic Light-Emitting Diode Display Using Amorphous Silicon Backplane</b> .....	317
	저자 : 최재원, 강문호, 김영승, 오재환, 허지호, 배병성, 정진 소속 : 경희 대학교 차세대 정보 디스플레이 연구센터	
PT1-56	<b>Highly Efficient DC-DC Converter Employing P-Type Poly-Si TFTs for Integrated Gate Drivers in Active Matrix Displays</b> .....	319
	저자 : Hye-Jin Lee, Woo-Jin Nam, Jae-Hoon Lee, Hee-Sun Shin, and Min-Koo Han 소속 : School of Electrical Engineering, Seoul National University	
PT1-57	<b>Electric-field Activation of Screen Printed Carbon Nanotube Emitters</b> .....	321
	저자 : H. J. Lee <sup>1</sup> , Y. D. Lee <sup>1</sup> , W. S. Cho <sup>1</sup> , J. K. Kim <sup>2</sup> , S. W. Hwang <sup>3</sup> , and B. K. Ju <sup>1</sup> 소속 : <sup>1</sup> Display and Nano System Laboratory, Korea University, <sup>2</sup> Korea Institute of Science and Technology, <sup>3</sup> Department of Electronics and Computer Engineering, Korea University	
PT1-58	<b>TFT-LCD 3차원 시뮬레이션에서의 광 경로에 대한 고려</b> .....	323
	저자 : 최경욱, 김기범, 박우상 소속 : 인하대학교 전자공학과	
PT1-59	<b>Polymer SAW Sensor for Detecting Chemical Warfare Agents</b> .....	325
	저자 : B. S. Joo <sup>1</sup> , J. H. Lee <sup>1</sup> , S. M. Lee <sup>1</sup> , Y. H. Hong <sup>2</sup> , J. S. Huh <sup>2</sup> , and D. D. Lee <sup>1</sup> 소속 : <sup>1</sup> School of Electrical Engineering and Computer Science, Kyungpook National University, <sup>2</sup> Department of Digital Electronic Engineering, Kyungwoon University, <sup>3</sup> Department of materials Science and Metallurgy, Kyungpook National University	

## VLSI CAD 분과

PT1-60	<b>Cross-talk을 고려한 Gate-level Delay Calculation의 Accuracy 향상을 위한 Time-varying Output Resistance Model</b> .....	327
	저자 : 이종섭, 배태원, 김영현 소속 : 포항공대 전자공학과 CAD and SoC Design Laboratory	
PT1-61	<b>A Simple Stopping Criterion for Turbo Codes</b> .....	329
	저자 : Byoung Sup Shim <sup>1</sup> , Tae Hyung Kim <sup>2</sup> , and Hwan Yong Kim <sup>1</sup> 소속 : <sup>1</sup> Wonkwang University, <sup>2</sup> Iksan National College	