P-10-17

Extended Abstracts of the 2010 International Conference on Solid State Devices and Materials, Tokyo, 2010, pp527-528

UV-patternable polymer dielectric for organic thin film transistors

Chung-Ming Wu, Hong-Tai Wang, Shui-Hsiang Su*, and Meiso Yokoyama

Department of Electronic Engineering
I-Shou University, Kaohsiung, TAIWAN (R.O.C.).
E-mail:*shsu@isu.edu.tw

I. Introduction

Organic thin film transistors (OTFTs) have attracted much attention in developing the commercial electronics such as active-matrix organic light-emitting diodes (AMOLEDs).[1-4] The high performance OTFTs required not only the organic active material but also the gate insulator. For application as gate insulator of OTFTs, it requires high dielectric constant, good heat and chemical resistance, high breakdown voltage and long-term stability formability. OTFTs with inorganic dielectric materials, such as SiO_2 and Ta_2O_5, serving as a gate dielectric have demonstrated appreciated electrical performance. However, these dielectrics are not suitable for flexible device application owing to the films deposited in vacuum and patterned by photolithography and etching processes.

On the other hand, several polymeric dielectric materials, such as PVA, PMMA, PVA, BCB, and PI have been widely investigated due to the potential of low manufacturing cost and large area applicability.[5] In order to fabricate OTFTs on flexible substrate and application in commercial electronics, the gate insulator process thirst for low temperature process to prevent the damage the flexible substrate and high resolution pattern of gate insulator without lithography to reduce the complication for fabricating OTFTs. Up to now, however, pattern definition of these polymeric dielectric materials in OTFTs for flexible device applications has many obstacles to be overcome.

In this study, we present a UV-patternable polymer, mr-UVCur06, for use as a gate dielectric in OTFTs fabricated on a flexible PES substrate. The leakage current, pattern resolution, and the electrical property for application on OTFTs are characterized.

II. Experiment

Figure 1 (a) shows schematically the curing reaction of acrylates initiated by UV light, and (b) shows the OTFT configuration examined in this work. The device's structure is PES/indium-tin oxide (ITO)/mr-UVCur06/pentacene/Au (source/drain). Prior to dielectric layer coating, ITO coated PES substrates with a sheet resistance of 20 Ω/square were solvent cleaned by ultrasonic baths in acetone and isopropyl alcohol then in deionized water, followed by UV ozone treatment for ten minutes. The gate dielectric layer, mr-UVCur06, was coated on the substrates by spin-coating, followed with an UV exposure dose of 2400 mJ/cm^2 then an annealing treatment at 100 °C for one hour to cure mr-UVCur06 completely. Organic active layer and source/drain electrode materials were sequentially deposited through a shadow mask by thermal evaporation. Deposition began with 600 Å-thick pentacene as an organic active layer and then 1200 Å-thick Au as source and drain electrodes at a pressure below 5×10^{-6} torr and the evaporation rate at 1-2 Å/s.. The channel length and width of the device was 50 and 500 μm, respectively. The thickness of the evaporation layers was controlled by oscillating quartz monitors and further calibrated by ellipsometric measurements. The electrical characteristics of OTFTs were determined by a Keithley 2400 programmable voltage-current source system. All measurements were in air atmosphere.

III. Results and discussion

The metal-insulator-metal(MIM) structure with mr-UVCur06 as the dielectric is fabricated to investigate gate leakage. The leakage current with the ITO/ mr-UVCur06 (490 nm)/Al structure was measured at a frequency of 100 KHz by applying voltage in a step of 1 V from −50 to 50 V. Fig. 2 show the leakage current was close to 10^{-8} A/cm^2 with the minimum less than 10^{-10} A/cm^2.

The patterning result thus obtained was inspected by an optical microscope and scanning electron microscopy (SEM). As shown in Fig. 3, the line and space are both well defined about 3 μm. For photo-patternable polymeric dielectrics, pattern definition with 3 μm resolution will make it useful for flexible device applications. This result is a demonstration that the dielectric can be patterned by photolithography.

The output (I_{DS} versus V_{DS}) and transfer (I_{DS} versus V_{GS}) characteristic curves of the OTFTs are shown in Figs. 4(a) and 4(b). The field-effect mobility (μ) was calculated from the plot of the square root of the drain current ($I_{DS}^{1/2}$) and gate voltage (V_{GS}) in the saturation regime.

$$I_D = \frac{W}{2L} \times \mu C_i (V_G - V_T)^2 \qquad \text{Eq. (1)}$$

where μ is the field-effect mobility, L and W are channel length and width, respectively, Ci is the insulator capacitance per unit area, and V_T is the threshold voltage. The V_T of the device was determined from the plot of $I_{DS}^{1/2}$ and V_{GS} by extrapolating the measured data to I_{ds}=0. When V_{GS} was swept from +60 to −60 V and V_{DS} was set at −40 V, the μ and I_{ON}/I_{OFF} of the pentacene-base OTFT with the mr-UVCur06 as gate insulator were 0.065 cm^2/V- s and 10^5, respectively.

IV. Conclusion

The OTFTs using a UV-patternable polymer material, mr-UVCur06, as the gate dielectric have been successfully fabricated and characterized. The mr-UVCur06 is not only solution-processed but also directly definable by UV light. The gate dielectric can thus be patternable in the process of forming the dielectric layer by a low-temperature process. The pattern resolution can reach 3 μm and the pentacene-based OTFTs exhibit a on-off ratio around 10^5.

The low-temperature photo-patternable polymer dielectric provides the way for the easy and low-cost fabrication of OTFT array without expensive and complicated photolithography and dry etching processes. These desirable characteristics of mr-UVCur06 should suffice for low cost, large area flexible device applications.

Acknowledgement

The authors would like to thank the National Science Council of the Republic of China, for financially supporting this research under Contract No. NSC98-2218-E-214-001 and 98-2221-E-214-003-MY3. The authors would also like to thank the MANALAB at ISU, Taiwan.

Reference

[1] Huiping Jia, Erich K. Gross, Robert M. Wallace, Bruce E. Gnade, Organic Electronics 8, 44–50 (2007)

[2] B. Lucas , A. El Amrani, M. Chakaroun, B. Ratier, R. Antony, A. Moliton Thin Solid Films 517 6280–6282 (2009)

[3] Jae-Hong Kwon , Sang-Il Shin , Jinnil Choi , Myung-Ho Chung , Hochul Kang , Byeong-Kwon Ju Solid-State Electronics 53 266–270 (2009)

[4] Jae Bon Koo , Seong Yeol Kang, In Kyu You, Kyung Soo Suh Solid-State Electronics 53 621–625 (2009)

[5] D.J. Gundlach, T.N. Jackson, D.G. Schlom, and S.F. Nelson, Appl. Phys. Lett.,74, p.3302, (1999)

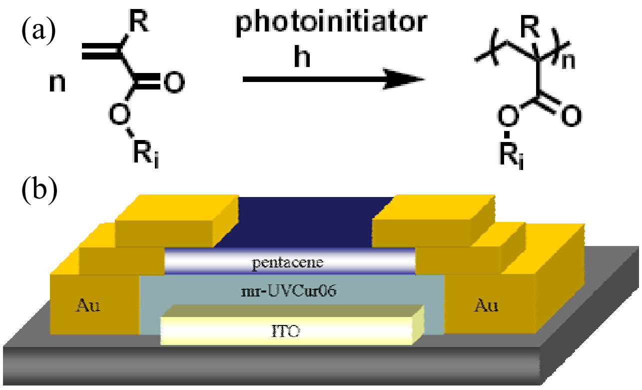

Fig 1. (a) Free-radical polymerisation of (meth)acrylates initiated by UV exposure (acrylates R=H, methacrylates R=CH3, Ri various functional groups). (b) Schematic cross section of a pentacene-base OTFT with low-temperature processable photosensitive polymerization.

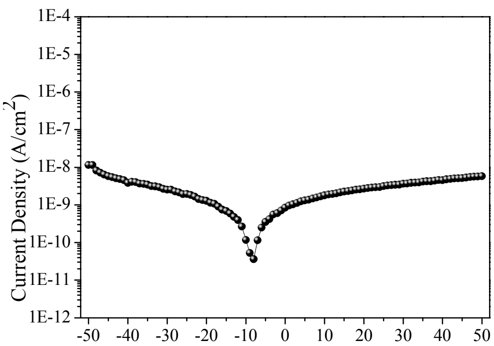

Fig. 2. Leakage current density of MIM with mr-UVCur06 as a dielectric. The voltage was varied from −50 to 50 V.

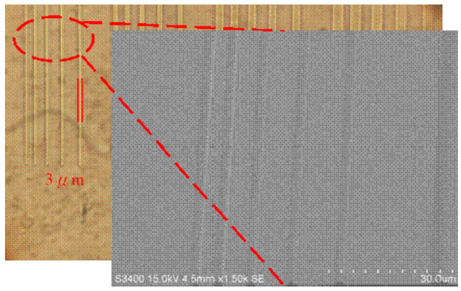

Fig. 3. Optical microscopy image and cross-sectional SEM image for a pattern with 3 μm line/space resolution.

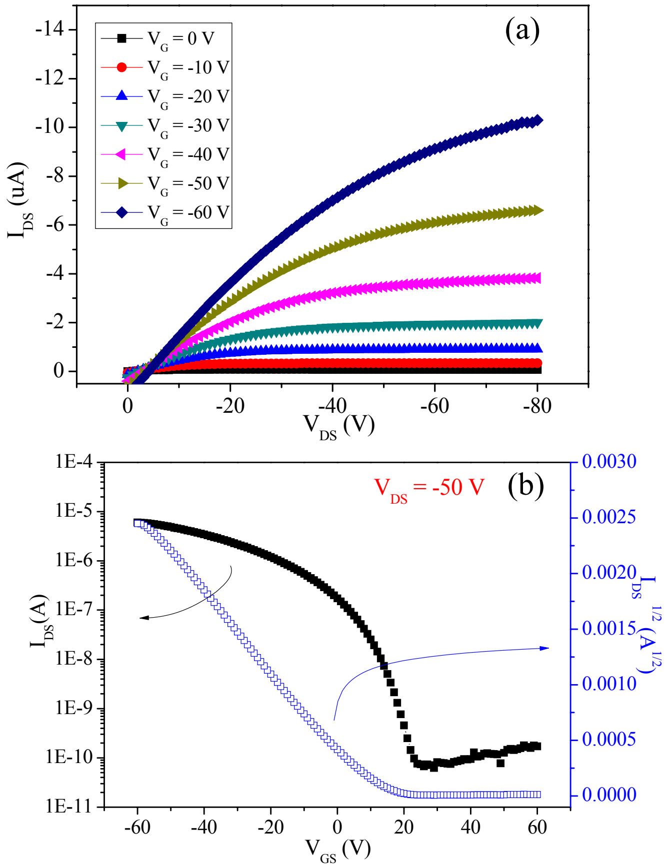

Fig. 4(a). The output characteristics of I_{DS} versus V_{DS} of OTFTs. (b) The transfer characteristics of I_{DS} versus V_{GS} and the square root of the I_{DS} versus V_{GS} of OTFTs with mr-UVCur06 as gate dielectric.