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# Surface Current Reduction in Organic Thin Film Transistors using Pattern on Pentacene Surface by AFM

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For improve the device characteristics of organic thin film transistor (OTFT) such as high operation frequency, good integration, and enhanced currents, the downscaling method of the channel length L into the sub-micrometer regime was suggested. Reducing the channel length L could be decrease the effect of grain boundaries on transporting holes and electrons in polycrystalline organic films, but, in this case, the surface leakage current due to short channel effect could be increased. In this paper, we proposed a simple method of decreasing the surface leakage current for improve the electrical characteristics such as mobility and on/off ratio by making the patterns between the electrodes using atomic force microscope (AFM) lithography.

## 1. Introduction

Study of organic thin film transistors (OTFTs) has been rapidly growing in the past few years. OTFTs have received considerable attention for their potential to act as low cost. Moreover, all organic TFTs can allow flexible active matrix displays by their integration with organic light emitting diodes or liquid crystal cells on polymeric substrates [1,2]. However, some relevant problems associated with the deposition process and the operational stability are still issued and prevent OTFTs from further applications in future electronics.

The short-channel effect is observed as a parabolic source-drain-current-voltage characteristic with respect to a fixed gate voltage, without a saturation region. The parabolic increase of drain current can be suppressed by the insertion of a high resistive region in the contact, in series with the organic channel, to reduce the net electric field applied to the organic film [3-5]. However, the increased contact resistance results in field-effect mobility, an order of magnitude lower than in long-channel OTFTs. In this paper, we formed line pattern (depth <10nm) on pentacene surface to reduce surface current and increase resistance without channel resistance.

Atomic Force Microscopy(AFM) based nanofabrication methods attract much interest for their ultra-high resolution, easy operation, and low equipment costs. AFM lithography methods are realized by using different interaction forces between the tip and the sample surface, such as physical, chemical and mechanical forces [6]. Because the curvature radius of AFM tip and the distance between the tip and the sample are both on the nano scale, local fields, such as force field and electric field, on the nano scale are generated. These local fields modify the sample surface and construct various nanostructures. AFM mechanical lithography makes scratch and indention on various material surfaces on the nano scale by applying a suitable force, and then nano patterns are obtained by controlling the movement of the tip [7].

## 2. Experimental

Our structure of the fabricated ISM is illustrated in figure 1. Insulator, cross-linked poly(4-vilyphenol) (cPVP) was spin-coated with 350nm thick, which was confirmed by α-step profilemeter. We mixed the polymer PVP and the cross-linking agent poly(melamine-co-formalde-hyde) with the solvent propylene glycol monomethyl ether acetate (PGMEA). And then active layer, pentacene, purified by sublimation, was thermally evaporated under a pressure of $10^{-6}$ Torr. The thickness of the pentacene is 60nm, and the deposition rate was 0.5 Å/sec. The 400nm thick electrodes of gold were prepared. The channel length and width in our OTFTs were 50um and 300um.

Atomic force microscopy and lithography was performed using a PSIA XE-100 instrument. Diamond coated AFM probes (DT-NCHR) in contact mode were used during drew a line on the pentacene film. This AFM probe was also in some cases used for imaging, but most of the AFM imaging was performed in non-contact mode using NCHR or NCLR probes.

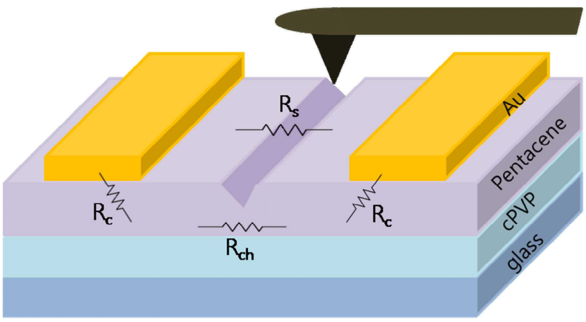


Figure 1. Structure of sample

## 3 Result and Discussion

Established study results, the oxygen defects are very stable and are likely to be caused by pentacene molecules with covalently bound oxygen. The decrease in field-effect mobility is caused by the oxygen-related deep traps. These states are filled upon increasing the gate voltage and the quasi-Fermi level at the interface lags behind the position it has in as-deposited samples [8].

Figure 2(a) show the measured results of current characteristics for the oxidized and non-oxidized pentacene. The current difference for the applied low voltage is a result for process of filling deep trap and is decreased with increasing the applied voltage. Figure 2(b) shows the comparison of current characteristics for the sample using oxidized pentacene with and without patterns (i.e. the lines using AFM lithography) which is shown in figure 3.

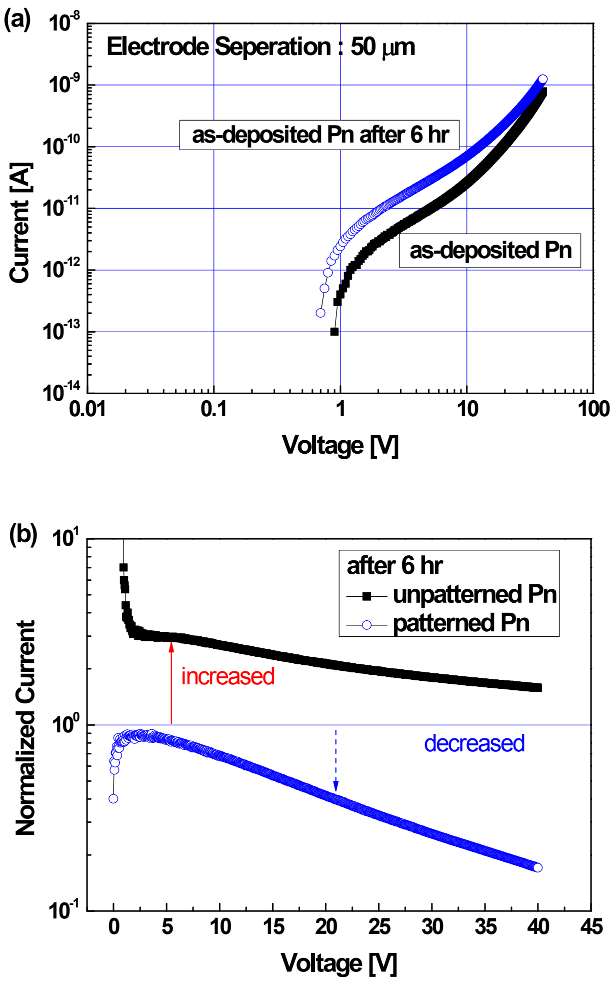


Figure 2. Current vs voltage for leakge current

The slope in the I-V curve for patterned device is larger than without pattern. This phenomenon could be explained the pattern interrupt the current flow near the pentacene surface, as a result, the leakage current was decreased.

## 4. Conclusion

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We proposed the simple method to improve the electrical characteristics of OTFT using the lithography by AFM. We could decreased the surface leakage current by making the lines having enough depth and length on the pentacene surface between electrodes which have the perpendicular direction against electric field for improving the characteristics such as mobility and on/off ratio. Hereafter, additional experiments will be performed to analyze the electrical performance of OTFT for varying the depth, length, and numbers of lines

(a)

(b)

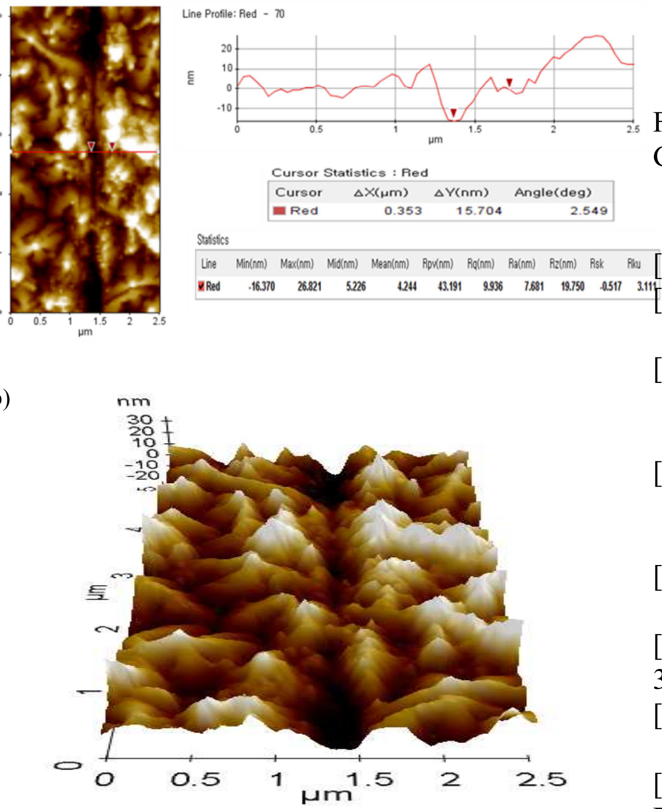


Figure 3. Pentacene topography images and corresponding cross section image(a), 3-D topography image(b).

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## References

[1] G. Horowitz, Adv. Mater. (1998), 10, 365

[2] C. D. Dimitrakopoulos and P. R. L. Malenfant, Adv. Mater. (2002), 14, 99

[3] F. Fujimori, K. Shigeto, T. Hamano, T. Minari, T. Miyadera, K. Tsukagoshi, and Y. Aoyagi, Appl. Phys. Lett. (2007), 90, 193507

[4] L. Wang, D. Fine, T. Jung, D. Basu, H. von Seggern, and A. Dodabalapur, Appl. Phys. Lett. (2004), 85, 1772

[5] J. Collet, O. Tharaud, A. Chapoton, and D. Vuillaume, Appl. Phys. Lett. (2000), 76, 1941

[6] He G H, Yang X H. Microelectronics, (2005), 35, 169~173

[7] Zhu J M, Zhang H J, Zhang D X. Opt Instrum, (2005), 27, 76~79

[8] W. L. Kalb, K. Mattenberger, and B. Batlogg, Physical Review B, (2008), 78, 035334