Pentacene TFTs and Integrated Circuits with PVP as Gate Insulator

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Abstract

In this paper, we have fabricated pentacene thin film transistors (TFTs) using polyvinylphenol (PVP) copolymer and cross-linked PVP as gate insulator on glass and plastic (PET) substrate. Depending on the density of PVP and cross-link material the performance has been changed. We obtained the best device performance with the mobility of 0.32cm2/V·sec and the on/off current ratio of 1.19×106 for the case of 10wt% PVP copolymer mixed with 5wt% poly (melamine-co-formaldehyde). Additionally using pentacene TFTs with the above PVP gate insulator, we fabricated the integrated circuits including inverter which produced the gain of 9.7.

1. Iintroduction

In recent years the use of organic semiconductors in field-effect transistors has gained considerable interest due to their potential application in number of low-cost, large area electronics on flexible substrate, such as active matrix displays, smart cards, price and inventory tags, and large area sensor arrays.1 Most effort of OTFTs application has been put into increasing the mobility of organic semiconductor and the on/off current ratio of OTFT by optimizing existing materials and by applying new materials. According to the reported investigation pentacene is a very promising candidate for organic electronics.2 Several groups have recently demonstrated pentacene TFTs and integrated circuits for alternate to traditional silicon TFTs and ICs. Furthermore, for flexible and inexpensive applications, alternative materials such as organic electrode and organic insulator and low-cost fabrication methods are of interest. Include solution processable polymer gate dielectrics and conducting polymer electrode which can be deposited by spin-coating or printing and may eventually permit the use of large area roll-to-roll processes.3,4,5

Here, for comparison, we have fabricated the pentacene TFT device on two different substrate and two different polymer gate dielectric materials. glass and PET plastic for the substrate on which spin-coated PVP copolymer or cross-linked PVP as gate insulator, and thermal evaporated gold for the gate, source and drain contact electrode.

Additionally using pentacene TFTs with the cross-linked PVP gate insulator, we have fabricated the integrated circuits including inverter and ring oscillator.

2. Experiment

2.1 Test Structure of Pentacene TFTs

Fig. 1 shows the structure of test OTFT fabricated finally inverted staggered structure. PVP as organic insulator was spread through spin-coating and baking covering in part after we patterned ITO on glass. Then we evaporate the pentacene by OMBD and deposite Au as top electrode.

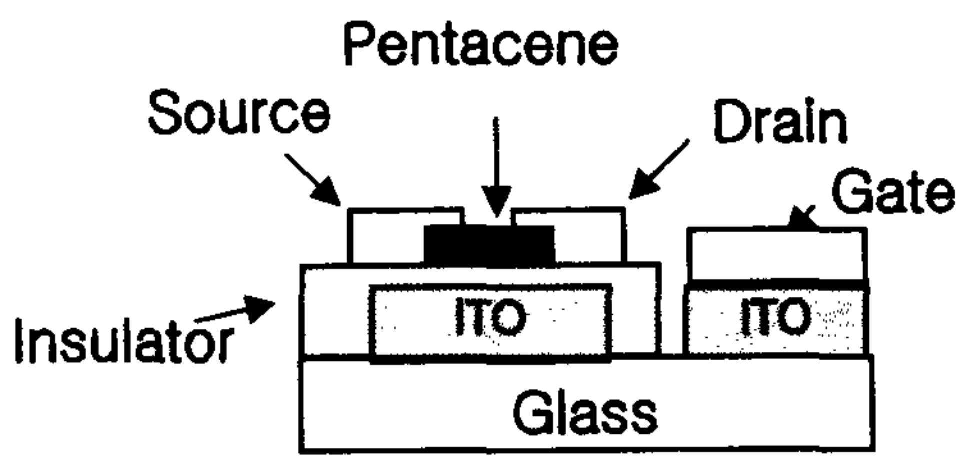

Fig1. Structure of OTFT

PVP copolymer is mixed with PVP (poly-4-vinylphenol) and PGMEA (propylene glycol monomethyl ether acetate) and cross-linked PVP is fabricated mixing PVP after adding poly(melamine-co-formalde hyde) in PGMEA as solvent. Spin-coating condition is 3000rpm, 30sec, and baking condition is that PVP copolymer is 30min in 100℃ and cross-linked PVP is 5min in 200℃ after 10min in 100℃. Each thickness is about 3000Å.

2. Characteristic of Pentacene TFTs

TFTs' drain current transfer curve is measured by HP4155A from 10V to -40V at intervals of -0.2V. Fig. 2 and fig. 3 shows the transfer curve depending on PVP density and poly (melamine-co-formaldehyde) density with 10wt% PVP.

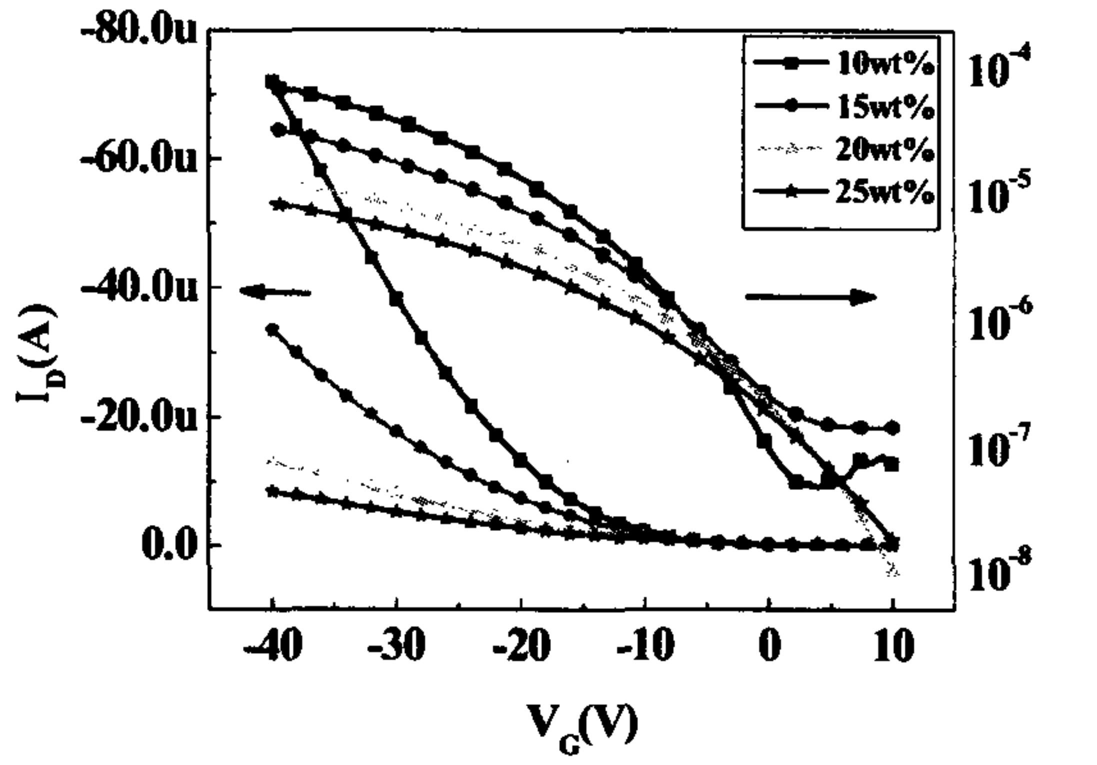

Fig.2 Transfer curves depending on PVP density

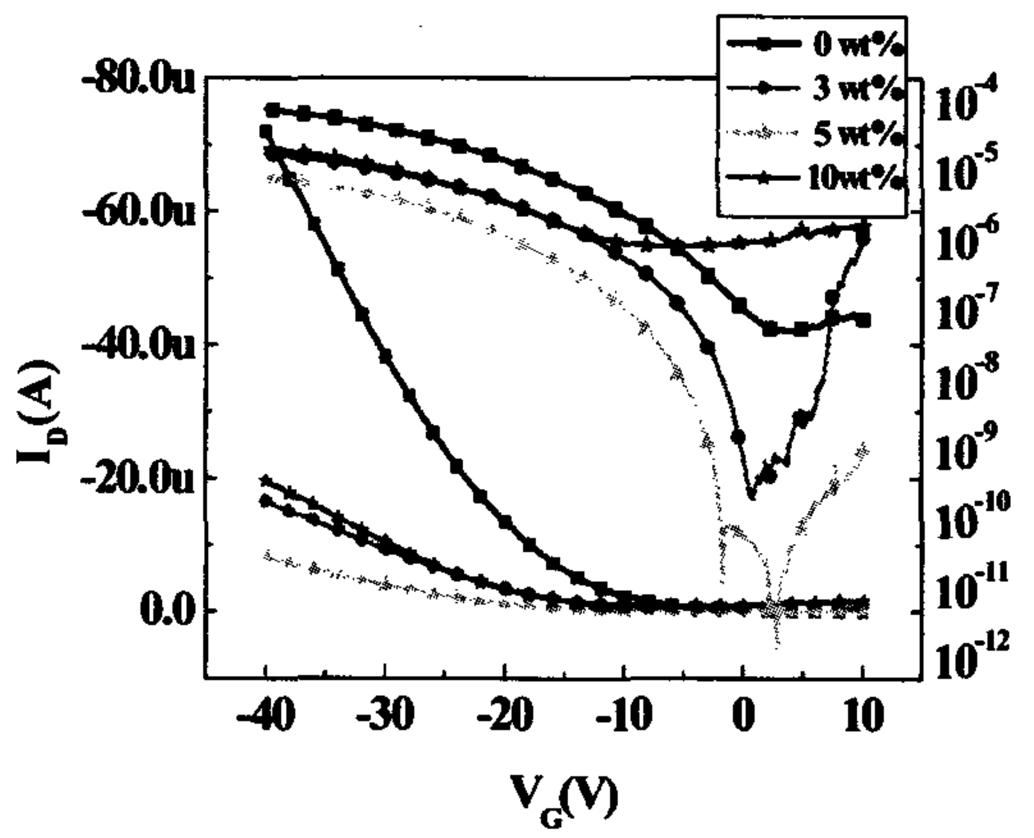

Fig. 3 Transfer curves depending on poly(melamine-co-formaldehyde) density with 10wt% PVPy

We can know that the performance has been changed depending on the density of PVP and poly (melamine-co-formaldehyde). The result of all parameters, 10wt% PVP copolymer and cross-linked PVP mixed 10wt% PVP copolymer and 5wt% poly (melamine-co-formaldehyde) have the best characteristic.

10wt% PVP copolymer's mobility and on/off ratio is 1.65cm^2/V·sec, 1.06×10^3 respectively, and off current was 6.63×10^{-8}A. On the other hand, mobility and on/off ratio of cross-linked PVP are each 0.32cm^2/V·sec and 1.19×10^{6}A, and off current is 1.15×10^{-11}A. Fig 4 and Fig 5 are transfer curve and output curve with cross-linked PVP.

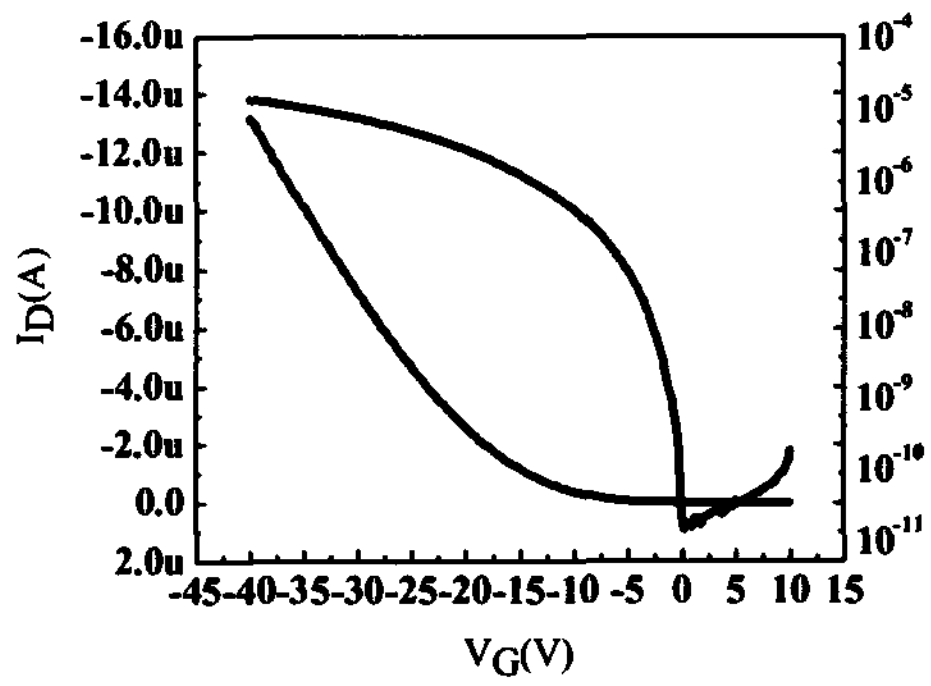

Fig.2 Transfer curve of Pentacene TFT with cross-linked PVP

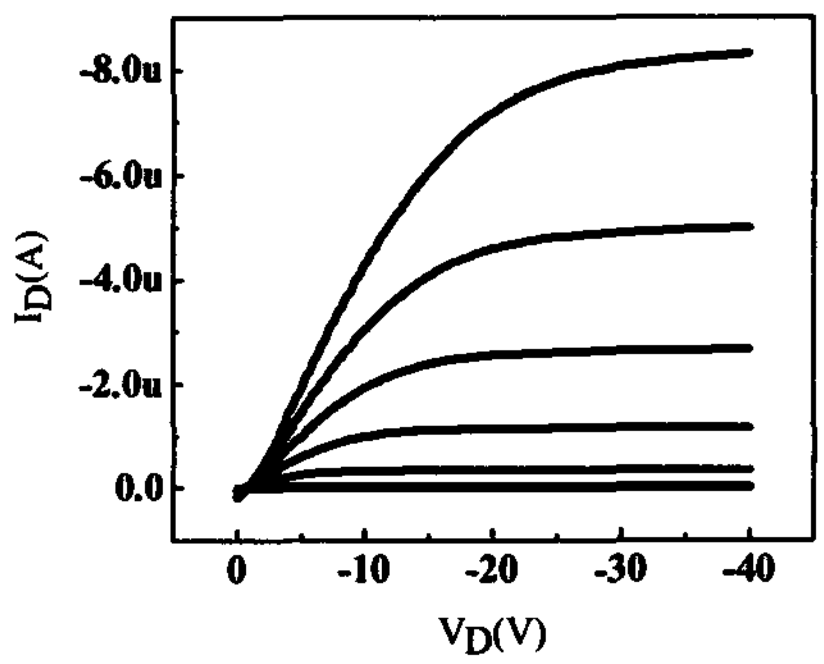

Fig.5 Output curve of Pentacene TFT with cross-linked PVP

2.3 Integrated Circuits

Fig. 6 is actually made circuit on plastic (PET) that is involving fabricated inverter and 5-stage ring-oscillator using cross-linked PVP gate.

Fig. 6 Integrated Circuit on the PET

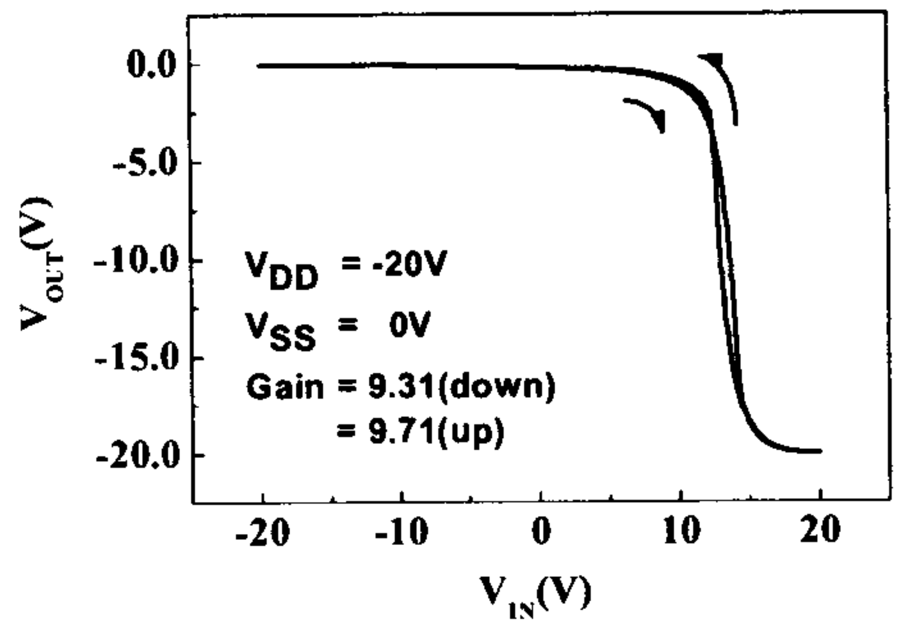

Fig.8 Transfer Characteristic of Inverter on Plastic.

At first, We deposite Ti/Au as bottom electro and spread cross-linked PVP. After then, we etch bottom electrode for open of inter-connect using RIE and deposite top electrode through lift-off. This processing needs lithography processing using PR and acetone. So, we should use cross-linked PVP. The last process is evaporating the pentacene using OMBD.

[Figure 7] and [Figure 8] are showing characteristics of inverter fabricated on the glass and plastic substrate respectively. When we measure the characteristic of inverter using HP4155A, we impress VDD=-20V, VSS= 0V and set 100ms both hold time and delay time. The gain of inverter fabricated on the glass was 5.56 and gain of inverter fabricated on the PET was 9.71. The threshold voltage was +8V and +14V respectively.

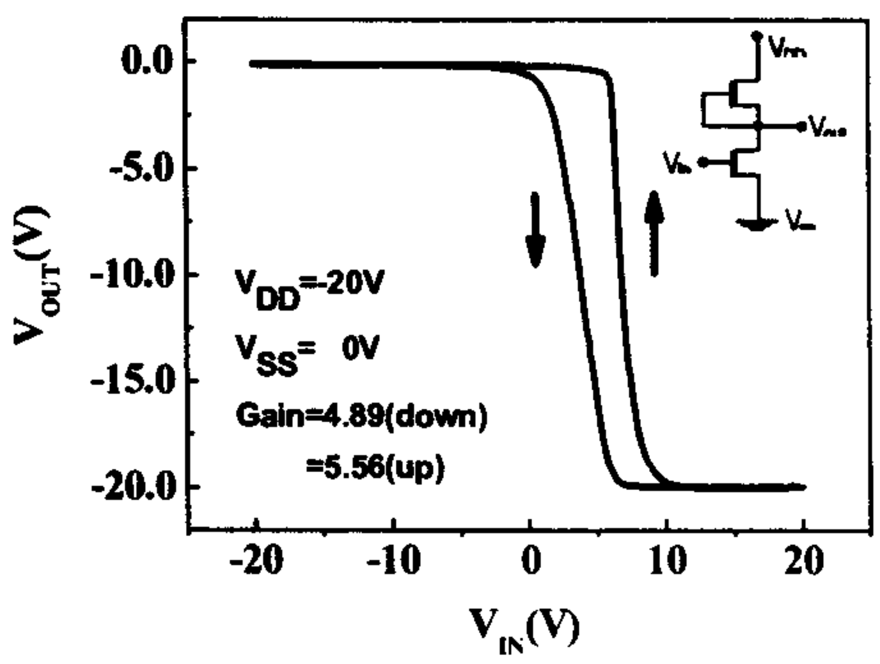

Fig. 7 Transfer Characteristic of Inverter on Glass

3. Results

In this paper, we fabricate pentacene TFT using PVP copolymer and cross-linked PVP as gate insulator on glass substrate. In case of PVP copolymer gate, mobility and current on/off ratio is 1.65cm2/V·sec, 1.06×103A and another case is 0.248cm2/V·sec, 1.45×105A.

We also make integrated circuit which is including inverter and ring oscillator using cross-linked PVP on glass and plastic substrate and attain inverter property 5.56, 9.71 separately.

Acknowledgment

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4. Rferences

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