Flexible and printed organic TFTs and integrated circuits

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1. Introduction

Flexible electronic devices fabricated with printing technology are attracting significant attention because of their potential for reduced manufacturing costs and environmentally friendly production. Organic thin-film transistor (OTFT) devices are favored for next generation printed electronics applications such displays, RFID tags and sensors.

We are advancing printing fabrication processes for OTFT on plastic films using various printing techniques and developments of solution-processable organic semiconductors. We will report briefly on fully-printed OTFT devices and their applications to the flexible display, RFID Tags and biosensors.

2. Printed OTFT Array

Two types of silver nanoparticle inks (JAGLT-01 (DIC) and NPS-JL (Harima Chem.) were used for gate electrode and source-drain electrodes, respectively. Cross-linked polyvinylphenol (PVP) and poly-p-xylene (parylene-C) were use for gate dielectric layer. Three types of organic semiconductors were used for the active layer of the OTFT devices. Inkjet printing and dispensing methods were largely employed for electrodes, bank and organic semiconductor layer. Channel length and width of the printed OTFT device with a bottom-contact and bottom-gate configuration were 20 -90 μm and 1000-2000 μm, respectively. At first, a PEN film was bonded on a glass plate by using adhesive, then the PEN surface was planarized with a polymer solution. Teflon banks were formed around source-drain electrodes in advance of dropping organic semiconducotor (OSC) ink with a dispenser. Fully-printed OTFT arrays (30x30) for backplane were successfully fabricated on PEN film substrates.

The printed OTFT devices where the new OSC was used showed excellent p-type electrical performance, with a maximum mobility of about 2 cm^2/Vs, and an average mobility of 1.1 cm^2/Vs. The subthreshold swings were small and current on/off ratios were over 10^8. Uniformity of the device performance within the panel was excellent. Especially, the deviation of threshold voltages was significantly small which is ideal for display applications.

We also fabricated an ultra-thin OTFT array using a parylene-C film, which was extremely flexible. Although the thickness was only 1μm, the OTFT devices worked very well. This device can be suitable for biosensors conformable to human body.

3. Integrated Circuits

In this study, we tried to fabricate a pseudo-CMOS inverter by using only p-type printed OTFT devices. The pseudo-CMOS inverter consists of four p-type transistors. Gate-drain and gate source overlap was reduced to decrease the parasitic capacitance. The fabricated inverter with channel length of 20 μm showed a typical transfer curves with a high gain of 35 at 20 V. Logic circuits such as NAND and NOR circuits based on the pseudo-CMOS with a channel length of 40 μm were also successfully fabricated; the NAND circuit exhibited a gain 32 and a noise margin of 4.4 V, and the NOR circuit exhibited a gain of 50 and a noise margin of 5.9 V at 15 V. Using the pseudo-CMOS inverters a three-stage ring oscillator was also fabricated on a PEN film. Oscillation at a frequency of 400 Hz and a delay time of 0.4 ms at 40 V were observed, which are among the best results obtained to date for fully-printed ring-oscillators.

Furthermore, a more complicate circuit (1-bit flip-flop) using the pseudo-CMOS was fabricated. The logic circuit exhibited ideal output response according to a true table. The output voltage of 15 V was stably maintained after the input signal (Set) was applied. The signal decay time was 3.5 ms at 20 V.

References:

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