Organic Thin Film Transistor RC Oscillator

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Abstract: *Since organic thin film transistor (OTFT) provide simple and low cost processes, it's application to display has been studied. We developed an RC oscillator using organic thin film transistor (OTFT) and inverters with bootstrapped transistors. Design parameters were optimized by simulations and OTFTs were fabricated for the extraction of the parameters. The oscillator frequency and its dependence on resistance and bias voltage were studied. The frequency of the oscillator were simulated and is acceptable for low-cost microelectronic device and flat panel displays.*

Keywords: Organic Thin Film Transistors; RC Oscillator; Flexible Display.

1. Introduction

Organic thin-film transistors (OTFTs) have been attracting much attention for their potential applications, such as low-end smart cards, and low-cost radio frequency identifications, and especially, driving flat panel display. The high mobility of OTFTs, which is comparable with that of amorphous silicon (a-Si), has been achieved.
The OTFT based on small-molecule organic semiconductor, pentacene, showed the best per-formance with its performance similar to hydro-genated amorphous silicon TFT [1, 2].

Hydrogenated amorphous silicon TFT (a-Si:H TFT) is widely used for the AMLCD (active matrix liquid crystal display). Mobility of a-Si:H TFT is very low around 0.5 cm^2/Vs, however, it provides low cost, low temperature and large substrate process.

Since an organic thin-film transistor (OTFT) can be manufactured by low-cost process such as printing and can be processed on the flexible substrate, intensive studies have been being done. OTFTs have been studied for low-cost circuit on glass or flexible substrates.

After first organic circuits on plastic substrates by Philips Research Laboratories in 1998 [3], much faster organic circuit on rigid or flexible substrates have been reported [4, 5].

Pentacene TFTs typically have a slightly positive threshold voltage, and since pentacene is a p-type semiconductor, devices are typical slightly depletion mode. Therefore, it needs careful appropriate optimization of OTFT circuit parameters.

OTFT ring oscillators on plastic substrates are announced which has 3 kHz oscillation frequency at the gate bias of -20V [6]. However, it is not easy to control the oscillator frequency. Oscillation frequency of RC oscillator can be controlled by adjustment of the capacitance or resistance of the RC oscillator. RC oscillator using a-Si:H TFT which has low mobility is announced [7], where they achieved about 140 kHz oscillation frequency.
In this study, we designed an OTFT RC oscillator and optimized design parameter based on the transfer characteristics of fabricated OTFT. We adopted the bootstrapped inverter for the RC oscillator, the inverter characteristics are also studied.

2. Experiments and Results

An organic TFT with pentacene active layer was fabricated on PES (Polyethersulphone) and with PVP (polyvinylphenol) gate insulator. Figure 1 shows the transfer characteristics of the fabricated organic TFT which is W/L = 16000/10. The OTFT shows slightly depletion mode.

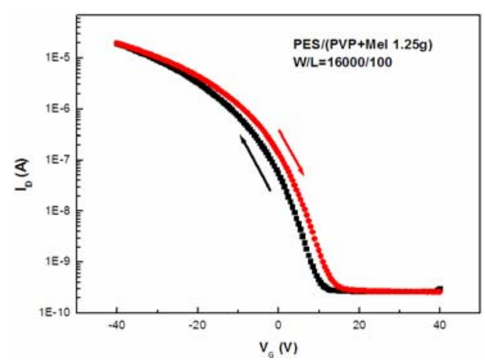

Figure 1. Transfer characteristics of the organic TFT, width/length=16000/10.

Figure 2 shows the schematic of an OTFT bootstrapped inverter. In the bootstrapped inverter made of OTFT, one transistor act as the driver and a second transistor serves as an active load operated in saturation mode.

The gate voltage of load TFT increases over V_{DD} due to the bootstrapping through the capacitor and the parasitic capacitance of the load TFT. Due to the overdrive to the load TFT gate, the high voltage output at the output node can be as high as V_{DD}. For proper operation of the bootstrapping, we optimized each design parameter by circuit simulation. A load transistor with L=10 μm, W= 10 μm and drive transistor with L=100 μm, W= 10 μm and bootstrapping transistor with L=50 μm, W= 10 μm were used for RC oscillator.

Figure 3 shows the simulated DC and AC transfer characteristics of the inverter without bootstrapping at V_{DD} = -40 V.

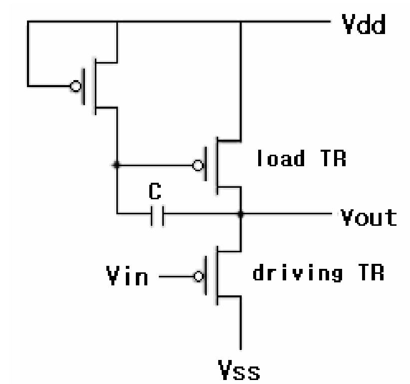

Figure 2. Schematic of a pentacene bootstrapped inverter circuit.

The top figure shows DC voltage transfer characteristics and the under shows output for the square input.

As shown at the top fugue of figure 3, the DC voltage transfer curve is shifted to the right due to the slightly depleted mode of the pentacene OTFT.

Figure 4 shows the circuit diagram of an 3-stage RC Oscillator. The 3-stage RC Oscillator composed of 9 OTFTs including bootstrapping OTFTs, one capacitor and one registor.

The RC oscillator shows 3.38 kHz oscillation frequency and 10 V peak to peak voltage simulated with -40 V power DC voltage. Figure 5 shows the simulated output signals of 3-stage RC Oscillator.

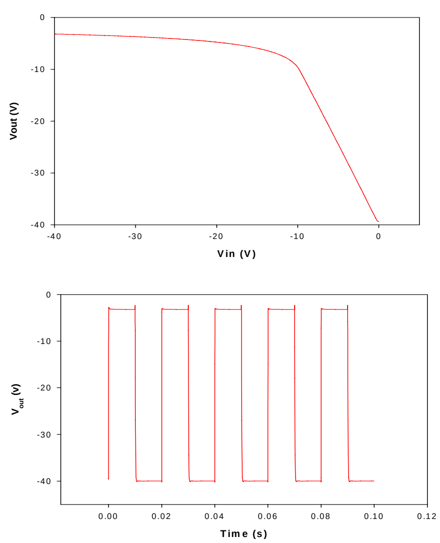

Figure 3. Output waveforms of the oscillator with V_{DD} = -40 V. The top shows DC voltage transfer characteristics and the under shows output for the square input.

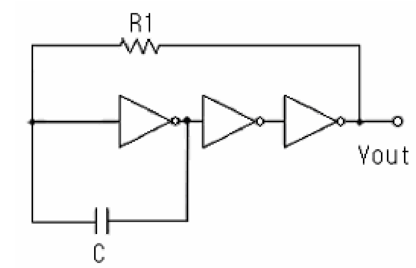

Figure 4. Schematic of a 3-stage RC oscillator.

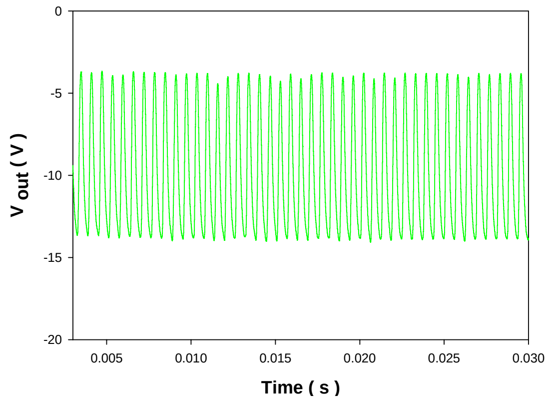

Figure 5. Simulated output waveform of the RC oscillator.

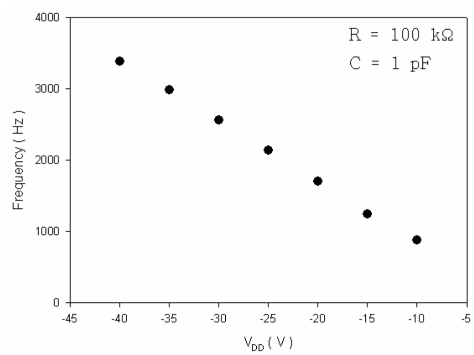

Figure 6. Oscillation frequencies decrease with decreasing V_{DD}.

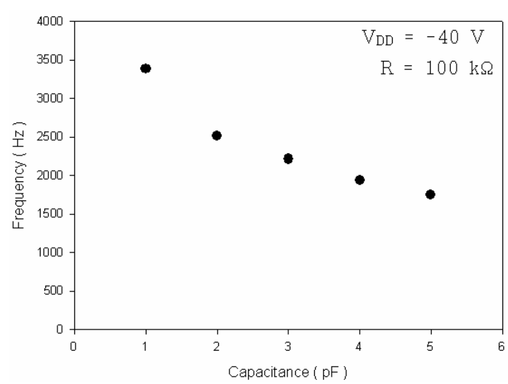

Figure 7. Oscillation frequencies increase with decreasing the capacitance.

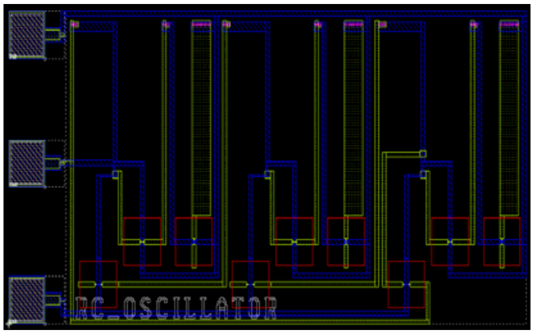

Figure 8. The designed layout of OTFT RC oscillator

Figure 6 shows the dependence of frequencies on V_{DD}. As V_{DD} decreases, the frequencies decrease, therefore, we need stable V_{DD} source for the stable oscillation frequency.

We can adjust the oscillation frequency by varying the capacitance of the RC oscillator. Figure 7 shows the capacitance dependence of the oscillation frequency. The frequency decreases with increasing capacitance due to increased time constant. This means that we can adjust the oscillation frequency by the change of capacitance.

Figure 8 shows the designed OTFT RC oscillator circuit. All dimensions are based on optimized parameters by simulation.

3. Summary

We developed an RC oscillator with OTFTs. And studied its frequency and output waveform. After fabrication of OTFT with pentacene active layer and PVP insulator, we measured the OTFT characteristics which were used for the parameter extraction. With obtained parameters we designed RC oscillator which was optimized through circuit simulation. After optimization of design parameters, we designed mask layout.

The frequency could be controlled by adjustment of the resistance and capacitance. The RC oscillator output frequency increases with decreasing of resistance and capacitance. The performance of the RC oscillator was good enough for low end applications.

Since OTFT circuits provide low cost and flexible processes, OTFT circuit can be a good solution of low end flexible integrated circuit. Therefore, the circuit can be applied to the applications such as pixel circuit, display drivers, low-cost RFID.

4. Acknowledgements

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5. References

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