Advanced Touch Sensor with Low-temperature Poly-Si Oxide Thin-film Transistors

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ABSTRACT
We present a novel touch sensor circuit that uses low-temperature poly-Si oxide thin-film transistors, utilizing a pixel-embedded CMOS inverter to amplify the output signal. The circuit demonstrates comparable performance, exhibiting a 4.8V difference between untouched and touched states.

1 Introduction
In recent years, there has been a growing interest in low-temperature poly-Si oxide (LTOPO) TFTs due to their unique combination of extremely low off-state current in a-IGZO TFTs and the high mobility of LTPS TFTs [1]. Notably, the ability to form a CMOS circuit with LTPS (p-type) and a-IGZO (n-type) TFTs has led to a range of circuit structures based on LTOPO, including simple inverters [2], GIPs [1], [3], [4], pixel circuits [5], temperature sensors [6], [7] and amplifiers [8]. The application of LTOPO technology in the circuits has enabled achievements such as high gain [1], [2], [8], faster response and high refresh rates [3], [4], [5], and precise sensing capabilities [6], [7].

In the realm of touch sensors, self-capacitive touch sensors integrated with TFT arrays have gained attention for their precision and touch sensitivity, making them suitable for flexible and portable devices [9]. Various self-capacitive touch sensors have been reported, utilizing different active materials such as LTPS [10], [11], a-Si [12], and a-IGZO [9], [13] TFTs. Many of the previous reports aimed to enhance output characteristics by using external amplifiers, which increased the complexity of the circuit and was less ideal for portable or flexible devices [9].

In this letter, we present an advanced touch sensor circuit based on LTOPO TFTs. The proposed touch sensor operates with a pixel-embedded CMOS inverter, eliminating the need for an external amplifier and yielding comparable results. Utilizing a self-capacitive sensing method, the capacitance difference between distinct states was set to be 5.0pF. Regarding TFT characteristics, p-type LTPS TFTs exhibited a field effect mobility (μFE) of 56.9 cm²/Vs, subthreshold swing (SS) of 0.38 V/dec, and a threshold voltage (VTH) of -0.2V while n-type a-IGZO TFTs demonstrated μFE of 6.30cm²/Vs, SS of 0.46V/dec, and VTH of -0.6V. SPICE simulation of the circuit indicated a comparable 4.8V difference in response to touch and untouched states.

Fig. 1 (a) Cross-sectional view of LTOPO TFTs. (b) Measured and fitted results of (b) LTPS with W/L = 20/4μm, and (c) a-IGZO TFT with W/L = 20/6μm, respectively.

2 Experiment
2.1 Device Fabrication
Figure 1(a) illustrates that LTOPO TFTs are constructed with a combination of self-aligned coplanar p-type LTPS TFTs and dual-gated Back Channel Etch (BCE) a-IGZO TFTs. The fabrication process involves depositing a 100 nm thick a-Si:H layer using plasma-enhanced chemical vapor deposition (PECVD) at 360°C, followed by annealing at 450°C for 2 hours for dehydrogenation. Blue laser annealing (BLA) with a 520µm × 20µm beam was induced for crystallization. A 100nm thick SiO2 layer was used as a top gate insulator for LTPS TFT deposited by PECVD, followed by a 120 nm Mo as a gate layer. An interlayer for LTPS TFTs and a bottom gate insulator for a-IGZO TFTs were created with a stacked SiO2/SiNx/SiO2 (70/100/70nm) layer. A 30nm thick a-IGZO active layer is deposited via reactive sputtering, followed by a 120nm thick Mo layer for source/drain electrodes in both LTPS and a-IGZO TFTs. For n-type TFTs, a 250 nm thick SiO2 top gate insulator and a 150 nm thick Mo top gate layers were deposited. The LTPS TFTs have a 4μm channel length (L), while n-type a-IGZO DG TFTs feature a 1μm offset between...
Fig. 2 (a) Circuit schematic, and (b) timing diagram of the proposed 5T1C touch sensor circuit.

![Circuit schematic and timing diagram](image)

Table 1. Specifications of components comprising of 5T1C touch sensor

<table>
<thead>
<tr>
<th>Components</th>
<th>Specifications</th>
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<th>Specifications</th>
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<tbody>
<tr>
<td>T1</td>
<td>10μm / 4μm</td>
<td>C_{Touch}</td>
<td>5.0 pF</td>
</tr>
<tr>
<td>T2</td>
<td>10μm / 4μm</td>
<td>V_{th}</td>
<td>2V</td>
</tr>
<tr>
<td>T3</td>
<td>10μm / 4μm</td>
<td>p-Scan</td>
<td>V_{pp}: 0 to -10V</td>
</tr>
<tr>
<td>T4</td>
<td>10μm / 4μm</td>
<td></td>
<td>PW: 10μs</td>
</tr>
<tr>
<td>T5</td>
<td>30μm / 6μm</td>
<td></td>
<td></td>
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source/drain electrodes and the channel, with a 6μm channel length and 4μm TG length. BG and TG of a-IGZO TFTs are electrically tied.

2.2 Simulation

Transfer curves of the TFTs are presented in Fig. 1(b) and (c). The LTPS TFT exhibits a field effect mobility (μ_{FE}) of 56.9 cm²/Vs, subthreshold swing (SS) of 0.38 V/dec, and a threshold voltage (V_{th}) of -0.2 V. The a-IGZO TFT showed μ_{FE} of 6.30 cm²/Vs, SS of 0.46 V/dec, and V_{th} of -0.6 V. These results are well-matched by Silvaco SPICE simulation, as shown in Fig. 1(b) and (c).

Table 2. Comparison of proposed TFT touch sensor with the former publications

<table>
<thead>
<tr>
<th>#</th>
<th>C_{Touch} Range</th>
<th>ΔV_{out}</th>
<th>Type</th>
<th>Amplification</th>
</tr>
</thead>
<tbody>
<tr>
<td>[12]</td>
<td>0.2pF ~ 1.0pF</td>
<td>0.4V</td>
<td>a-5I</td>
<td>LTPB</td>
</tr>
<tr>
<td>[9]</td>
<td>-</td>
<td>7V</td>
<td>a-IGZO</td>
<td>Internal</td>
</tr>
<tr>
<td>[13]</td>
<td>0 ~ 0.55pF</td>
<td>0.7V</td>
<td>a-IGZO</td>
<td>Internal</td>
</tr>
<tr>
<td>[14]</td>
<td>1.3 ~ 10.6pF</td>
<td>0.7V</td>
<td>ZnO</td>
<td>External</td>
</tr>
<tr>
<td>This work</td>
<td>0pF ~ 5pF</td>
<td>4.8 V</td>
<td>LTPB</td>
<td>Internal</td>
</tr>
</tbody>
</table>

The output signal of the proposed circuit primarily consists of two distinct periods: the resetting period and the sensing period. During the resetting period, a high voltage from the scan signal is introduced, and the circuit exhibits varying responses depending on its current state. Simulation results depicting the behavior of the proposed circuitry are presented in Figures 3(a) and 3(b), which illustrate the Q node and output node, respectively. In the resetting period, the Q node is initially charged with a low voltage. This causes T2 to activate, allowing the scan signal to be transmitted to the output node, thereby resetting the output node to a high voltage level. In the touched state, the voltage at the Q node is maintained until the sensing period. During this time, the scan signal is allowed to pass through T3, effectively bringing the output node to a low voltage. Conversely, in the untouched state, the Q node returns to a high voltage level during the sensing period, resulting in the output node remaining at 0V. The simulation results reveal a substantial up to 4.8V difference in the behavior of the output node between these two states. Furthermore, Figure 3(c) showcases simulation results with six touch sensor units connected adjacently. These results confirm that the behavior of one unit does not impact its neighboring unit, indicating the circuit's suitability for array applications.

Table 2 provides an overview of specifications from previous publications, encompassing details such as the
amplification method implemented, the output voltage difference achieved, and the touch capacitance range. The table shows that the proposed touch sensor performs comparably to those with additional amplifier components.

4 Conclusions

In this study, we introduced a touch sensor circuit utilizing 5 transistors and 1 capacitor, built on LTPO TFTs with pixel-embedded amplifier. The circuit exhibited output characteristics with a 4.8V difference, and notably, it was achieved without requiring external amplifiers, aligning with previous research findings. Furthermore, the circuit demonstrated the absence of interference with adjacent units, highlighting its suitability for array-based applications.

References


