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High-Performance CMOS Inverters Comprising Lateral Large-Grained Low-Temperature Poly-Si TFTs on Transparent Flexible Glass

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1. Introduction

Transparent flexible glass is attractive as a substrate for flexible and ubiquitous electronics, such as information displays, RF-ID, sensors, and solar cells. We have succeeded in fabricating low-temperature (LT) polycrystalline-silicon (poly-Si) thin-film transistors (TFTs) on transparent flexible glass.[1-3] To achieve high speed and low power dissipation circuits on transparent flexible substrates, it is necessary to constitute them from high performance CMOS circuits. In this paper, we demonstrate high performance lateral large-grained (LLG) LT poly-Si TFTs and CMOS inverters fabricated at 550℃ on transparent flexible glass.

2. Experiments

A photograph of 150-μm-thick transparent flexible glass being deformed by pressing on opposite sides of its edges is shown in Fig. 1.

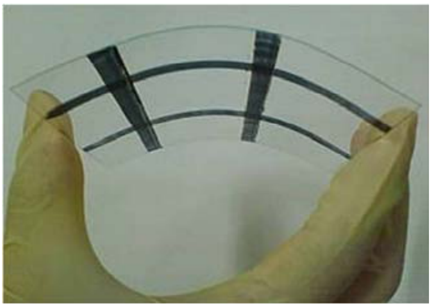

Figure 1. Transparent flexible glass of thickness 150 μm.

Buffer SiO_2 and a-Si were deposited using plasma enhanced chemical vapor deposition (PECVD) on transparent flexible glass 25 × 25 mm^2 in size; the thickness of the buffer SiO_2 was 200 nm and that of the a-Si was 70 nm. To form a high-quality LLG poly-Si film, we used a diode-pumped solid-state (DPSS) continuous-wave (cw) laser lateral crystallization method, CLC, which was developed by A.H., one of the authors of this paper.[4,5] The power output instability of a DPSS cw laser is less than 1 %, superior to that of XeCl and Ar^+ lasers, thus enabling stable and uniform crystallization over a wide area. We used a 532 nm wavelength, second harmonic (2ω) Nd:YVO_4 laser in this experiment. Glass substrates are transparent at this wavelength; therefore, the problem of an increase in their temperature due to the direct absorption of the laser beam during crystallization did not arise. Details of the crystallization method are described in ref. 2). After fabrication of the LLG poly-Si transistor islands, 50-nm-thick SiO_2 gate layer was deposited by PECVD at 325°C using SiH_4 and N_2O gas before Mo was sputtered as the gate metal. Ion implantation (P: 2.0 × 10^{15} cm^{-2} at 10 KeV, BF_2: 2.0 × 10^{15} cm^{-2} at 10 KeV) was carried out to form a source/drain region of n-ch and p-ch poly-Si TFTs, and annealing was carried out at 550°C for 6 h to activate the dopant. A temperature of 550°C is the maximum temperature used in device fabrication processes. A SiO_2 interlayer was then deposited by PECVD, after which electrodes (Mo) were deposited by a sputtering method. Finally, hydrogenation annealing was carried out using a step cooling process.[6] Figure 2(a) shows the transparent flexible substrate after device fabrication, while Fig. 2(b) shows the CMOS inverter, comprised of LLG LT poly-Si TFTs on transparent flexible glass. The width of the p-ch TFT was designed to be three times that of the n-ch TFT, determined from the output characteristics of the TFTs, as shown in Fig. 4(b).

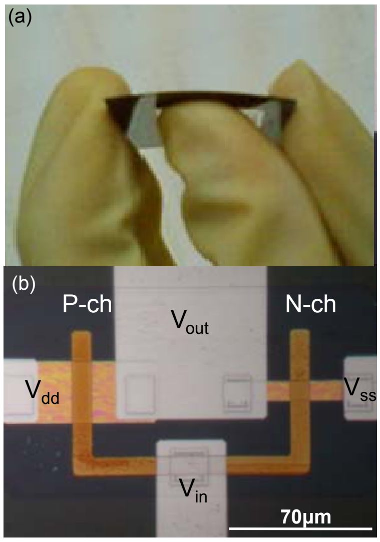

Figure 2. (a) Photograph of transparent flexible glass after device fabrication. (b) CMOS inverter fabricated on transparent flexible glass.

3. Results and discussion

Figure 3 shows an optical microscopic image of the LLG LT poly-Si TFTs fabricated on transparent flexible glass. This photograph of the source/drain region shows that the film was made up of a LLG poly-Si film with an average grain size of 1 × 3 μm^2. This grain size was larger than those found in excimer laser crystallization and metal-induced crystallization poly-Si films.

The performance of the n-ch and p-ch LLG LT poly-Si TFTs, with gate length (L) and gate width (W) being

L=W=10 μm, fabricated on transparent flexible glass, is shown in Figs. 4(a) and (b). Table I summarizes their performances.

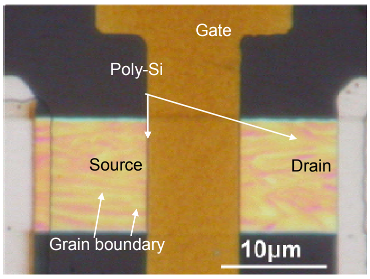

Figure 3. Source and drain region of poly-Si TFT fabricated on transparent flexible substrate.

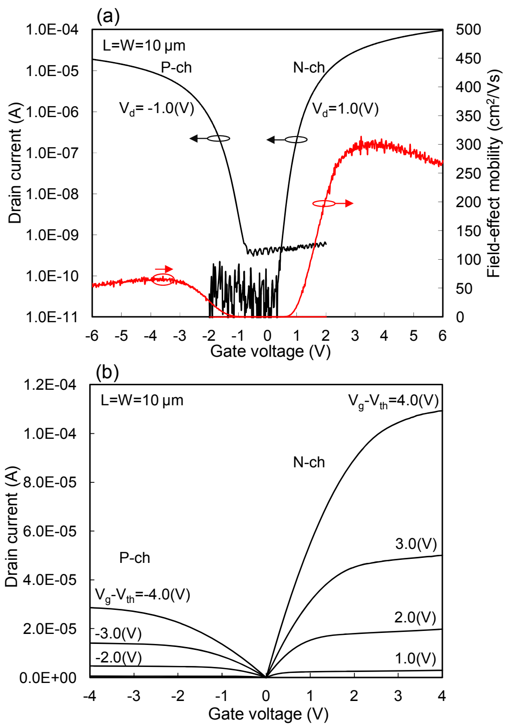

Figure 4. Transfer (a) and output (b) characteristics of LT poly-Si TFTs, with L=W=10 μm, fabricated on transparent flexible glass.

The fabricated n-ch and p-ch TFTs exhibited field-effect mobility of 310 cm^2/Vs and 65 cm^2/Vs, respectively, and subthreshold swing values (s-value) of 220 mV/dec and 280 mV/dec, respectively. The performance of the TFTs fabricated in this study was nearly comparable to that obtained for LLG LT poly-Si TFTs fabricated on a thick glass substrate.

Table I. TFT performance

	Mobility (cm^2/vs)	S (mV/dec)	V_{th} (V)
N-ch TFT	309	220	0.52
P-ch TFT	65	280	-0.88

Figure 5 shows the voltage transfer characteristics of CMOS inverters formed from LLG LT poly-Si TFTs on transparent flexible glass. Inverter operation at V_{dd} = 3.0 V with a voltage gain (dV_{out}/dV_{in}) of 37, a logic swing (V_{OH}-V_{OL}) of 2.9 V, and a switching threshold voltage of 1.65 V was achieved on the transparent flexible glass. The noise margins at V_{dd} = 3.0 V at high level (V_{OH}-V_{IH}) and low level (V_{IL}-V_{OL}) were 1.25 V and 1.30 V, respectively. This was considered sufficient performance for future achievement of high speed and low power dissipation flexible electronics.

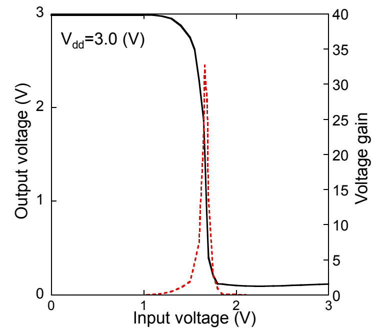

Figure 5. Voltage transfer characteristics of CMOS inverter fabricated at 550℃ on transparent flexible glass.

4. Conclusions

Transparent flexible glass is attractive as a substrate for flexible electronic devices. In this study, high-performance n-ch and p-ch LLG LT poly-Si TFTs were fabricated at 550°C on transparent flexible glass. The fabricated n-ch and p-ch TFTs exhibited field-effect mobilities of 310 and 65 cm^2/Vs, respectively, and subthreshold swing values of 220 and 280 mV/dec, respectively. Furthermore, the performance of the fabricated TFTs was nearly comparable to that of LT poly-Si TFTs fabricated on thick non-alkaline glass. We fabricated CMOS inverters made up of LLG LT poly-Si TFTs on transparent flexible glass, achieving voltage gain of 37, logic swing of 2.9 V, and a switching threshold voltage of 1.65 V at V_{dd} = 3.0 V. This result will lead to high speed and low power dissipation CMOS flexible electronics.

Acknowledgement

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