Development of 200ppi SOG-LCD

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Abstract

2-inch qVGA (240×320) TFT-LCD with integrated 6-bit source driver is reported. The pixel density is over than 200ppi and the operation frequency is about 2.8MHz. In order to improve TFT characteristics, TS-SLS (Two-Shot Sequential Lateral Solidification) technology has been employed. A 1:6 demultiplexing scheme has been successfully implemented in the source driver owing to the superb characteristics of the TS-SLS TFTs, which resulted in small driver circuit area.

1. Introduction

The SOG (System on Glass) TFT-LCD have been a promising solution for small size LCD module because of their slim module size and low cost. The SOG technology has been developed for future LCD module which enables to spare the silicon driver ICs and to enhance the productivity by reducing the module process steps. Several attempts to integrate the driver circuits on the glass substrate have been reported [1~4].

Compared with the conventional a-Si TFT-LCD with silicon driver ICs on it, the SOG-LCD requires high-performance TFTs such as high field effect mobility (μ_{FE}), low threshold voltage (V_T) and small sub-threshold slope to meet the high speed driving circuits that resulted in good display quality and small dimension.

The well-known SLS (Sequential Lateral Solidification) technique provides sufficient TFT characteristics for the SOG-LCD, because the silicon grains are infinitely large and like a single crystal in one direction as shown in Fig. 1 [5]. However the low productivity of the conventional SLS due to long process time is unacceptable in mass-production.

To meet the requisite of high throughput for mass-production, we report a new laser crystallization technique entitled "TS-SLS" (Two-Shot Sequential Lateral Solidification) technology that is a simplified version of the SLS technology. Employing TS-SLS, the grain size of the TS-SLS poly-Si (polycrystalline silicon) film is at least 6 times larger than that of the conventional ELA. In addition, throughput of the SLS is 2 times higher than that of ELA where the laser beam is irradiated typically with 95% overlap (20 shots per region) due to the intrinsic narrow process margin with respect to the laser energy fluctuation.

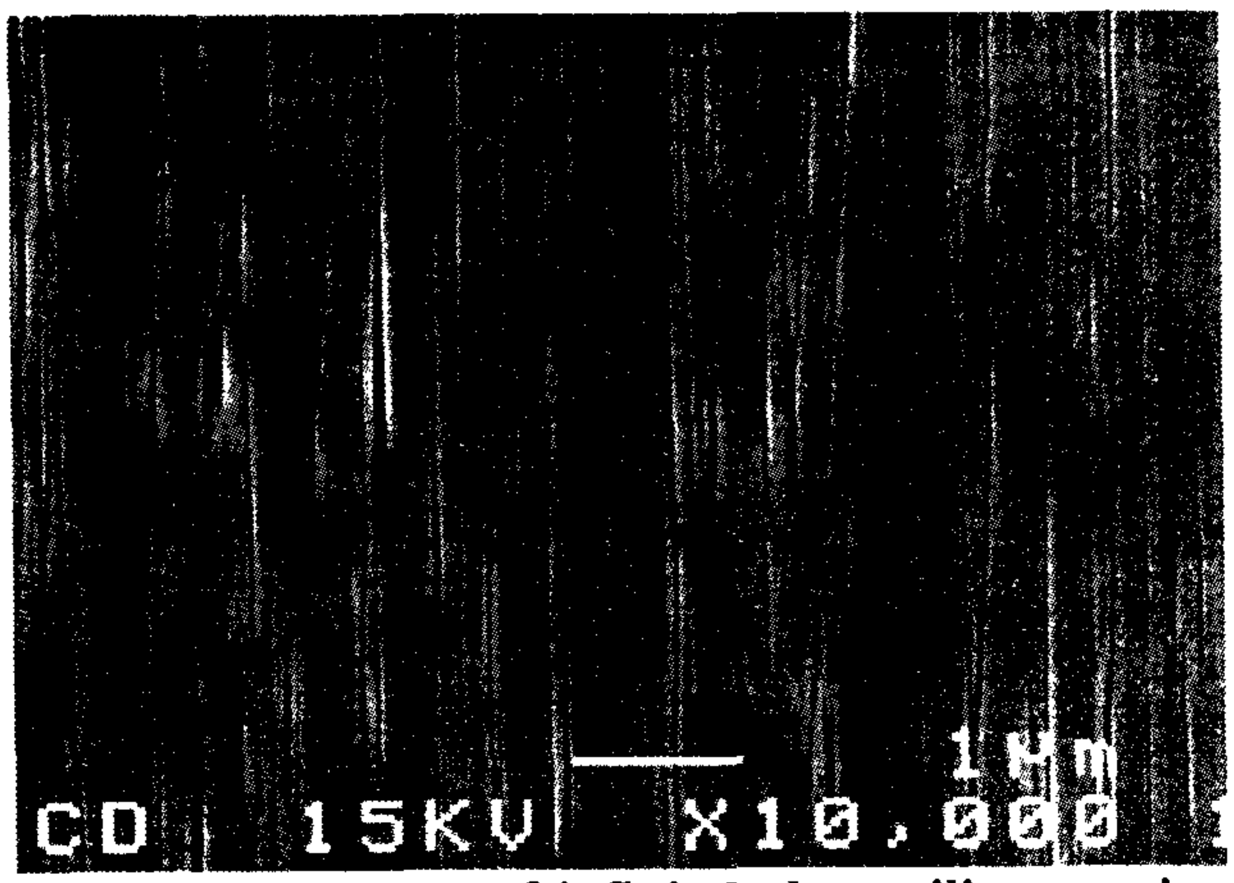

Fig. 1 SEM image of infinitely long silicon grains produced by conventional SLS technique.

A 2-inch qVGA(200ppi) SOG-LCD with integrated 6-bit source driver circuit has been fabricated employing the high-performance TS-SLS TFTs.

2. Panel Driver Scheme

The SOG panel has been designed for 2-inch qVGA portrait, which contains the gate driver, 6-bit source driver and a part of timing generator for demultiplexing. Fig.2 shows the dimensions and the block diagram of the LCD panel. Gamma generator has only two external sources, high and low. In order to obtain a small form factor even with 4μm design rule, we proposed the 1:6 demultiplexing scheme. The 1:6 demultiplexing scheme enables to reduce the circuit area to an acceptable level even with 4μm design rule. However, the data line charging time is also reduced. The 1:6 demultiplexing scheme has been successfully implemented thanks to high performance of TS-SLS TFTs. The timing signals to drive the 1:6 demultiplexer are generated in the panel. The gate driver simply consists of shifter register and a pair of level shifter.

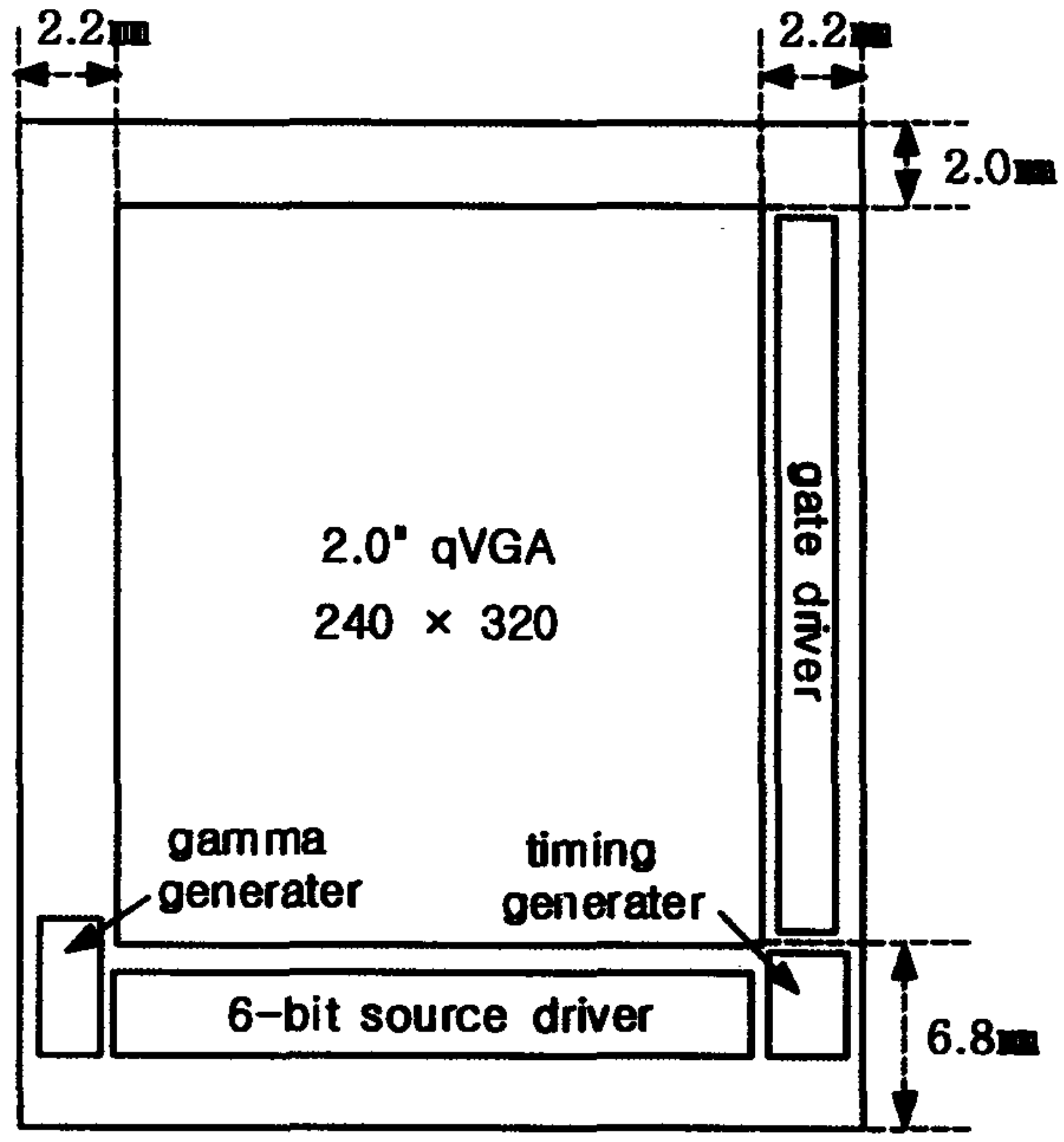

Fig. 2 Dimensions and the block diagram of 2.0-inch qVGA SOG-LCD panel.

The source driver is composed of shift register, latch, 6-bit DAC, gamma voltage generator, buffer amplifier and 1:6 demultiplexer as shown in Fig. 3. The shift register make the parallel 18-bit data inputs sequentially stored in the sampling latch. Clock frequency of the shift register is 2.8MHz for 60Hz frame rate. Schematic of the buffer amplifier circuit is shown in Fig. 4. Push-pull amplifier with differential input stage guarantees sufficient current driving capability under high frequency operation. The biasing block and output stage of the amplifier has been modified in order to reduce the quiescent current. Layout techniques besides the offset-canceling circuit of the amplifier effectively compensate the variations of the TFT characteristics.

Since the source driver circuit is located only in the lower part of the panel where the COG (chip on glass) ICs are located for the conventional a-Si TFT-LCD, the upper and the side bezel size is very slim. The overall panel size is compact enough for commercial products. Compared with the COG-type displays, low module cost along with the competitive form factor and the excellent display quality guarantee the good prospects of SOG-LCDs.

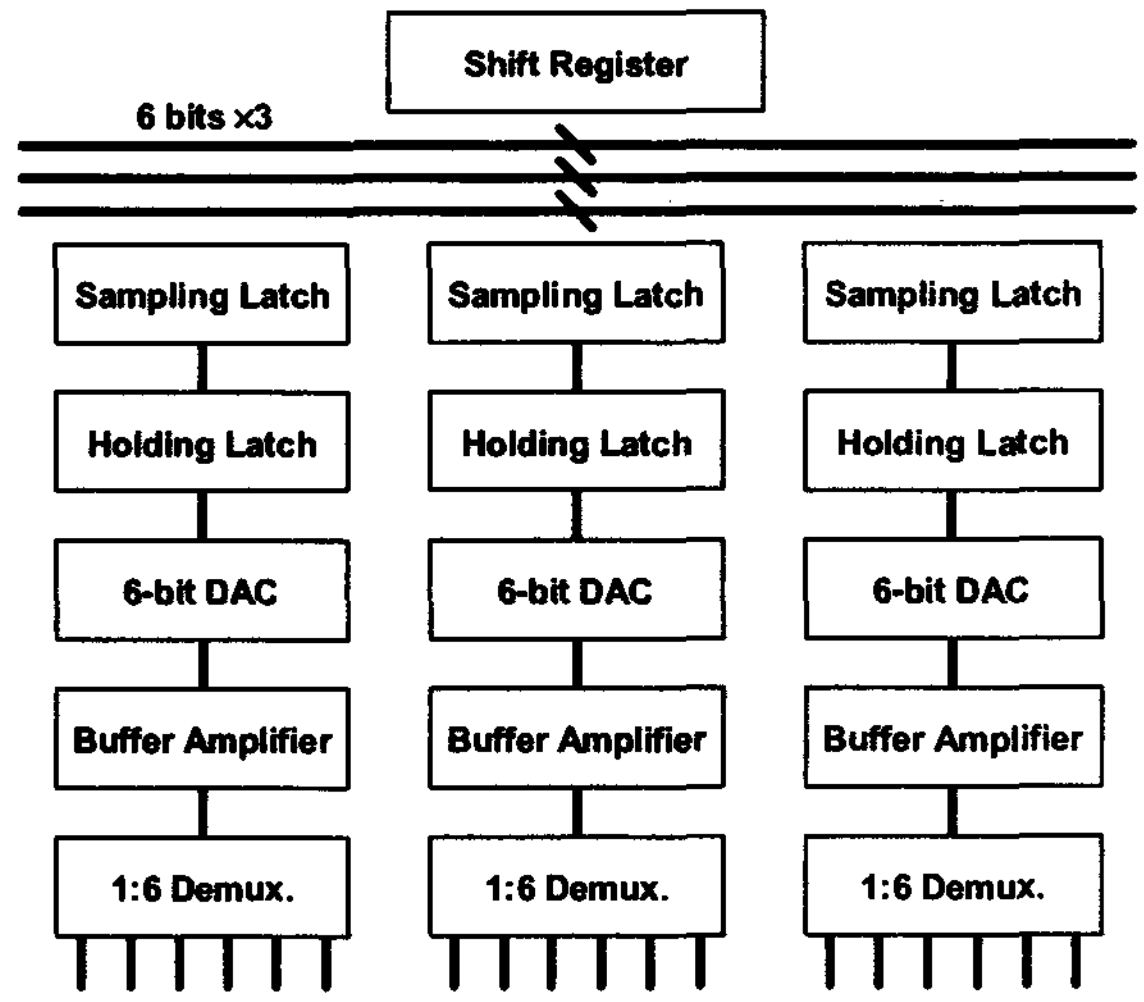

Fig. 3 Block diagram of 6-bit source driver with 1:6 Demux.

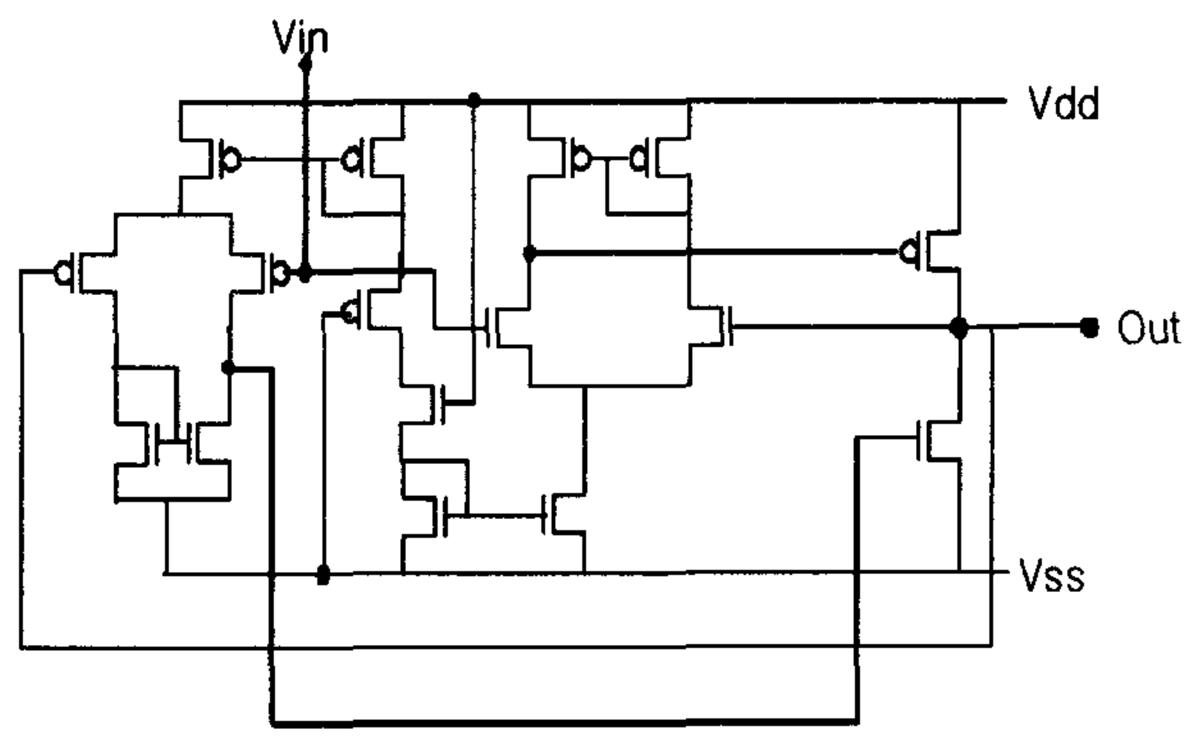

Fig. 4 Schematic of buffer amplifier circuit.

3. TS-SLS Technology

The process scheme of the TS-SLS technique is shown in Fig. 5. Laser pulses are irradiated sequentially on an a-Si film while the substrate is continuously moving loaded on a translational stage. Meanwhile a mask with patterned windows screens the laser pulse so that only the a-Si in selective area is completely melted and crystallized as shown in the first figure of Fig. 5. Right after the laser irradiation, lateral growth of silicon grains starts from the edge of the molten region to the center of it [5]. The length of the silicon grains is typically 1.5μm, and it can be extended up to 4μm when the pulse duration of the laser is increased. When the second laser pulse is irradiated through the same mask with the stage translation as far as the width of the patterned window, the residual a-Si regions between the poly-Si regions are also exposed by the laser pulse as shown in the second figure of Fig. 5. As a result of the second laser irradiation, the residual a-Si region is completely melted and crystallized continuously from the silicon grains that have been previously crystallized by the first laser shot.

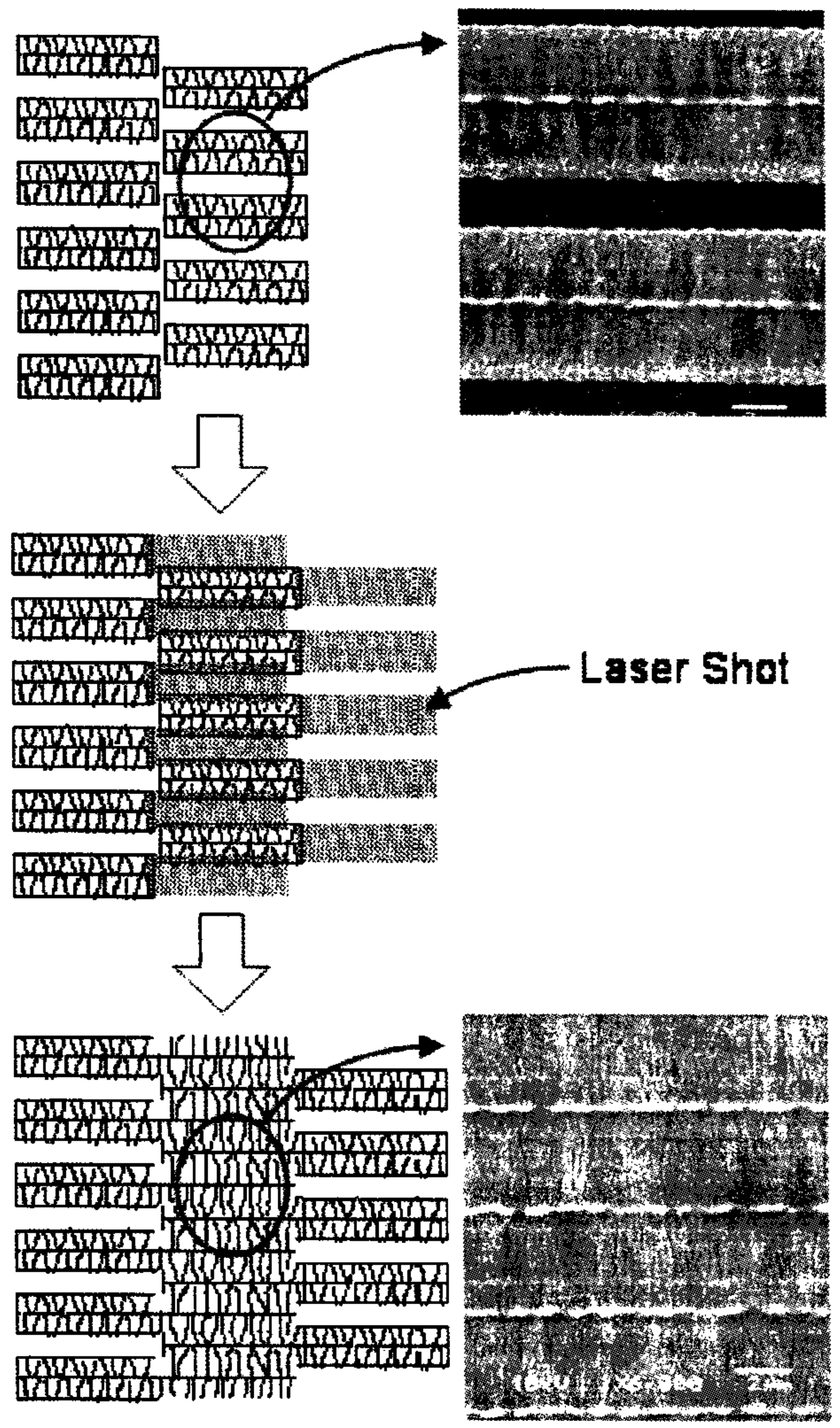

Fig. 5 Process scheme of TS-SLS technology.

The whole area of the a-Si substrate can be crystallized by further repetition of the laser irradiation with moving substrate. Since the SLS process uses the complete melting of a-Si film, it has wider process window than the conventional ELA (eximer laser annealing).

TS-SLS requires only two laser shots per region to complete the crystallization of the a-Si film. But the grain size of the TS-SLS poly-Si film is limited to 4μm, while the lateral grain growth with the conventional SLS process has no limit if the throughput is not an issue. Although the grain size is small, the grain size of the TS-SLS poly-Si film is at least 6 times larger than that of the conventional ELA. In addition, throughput of the SLS is 2 times higher than that of ELA where the laser beam is irradiated typically with 95% overlap (20 shots per region) due to the intrinsic narrow process margin with respect to the laser energy fluctuation.

SEM images in Fig. 5 show the microstructures of the Secco-etched TS-SLS poly-Si films after the 1st and the 2nd laser irradiation. By the first laser irradiation, the grains are nucleated at the interface of the molten silicon and the solid a-Si. The nucleated grains grow toward the center of the molten silicon region. After the 2nd laser irradiation, the lateral grain growth is initiated from the silicon grains previously crystallized by the 1st laser shot and continuously solidifies.

Fig. 6 shows the typical transfer characteristics of TS-SLS TFTs. The channel width and length of the TFT are 20μm and 6μm respectively. N-channel TFT has 1μm long LDD (lightly doped drain) to reduce the off current and to enhance the reliability while p-channel TFT has no LDD. μ_{FE} and V_T of n-channel TFT are 207cm^2/Vs and 0.94V respectively. μ_{FE} and V_T of p-channel TFT are 106cm^2/Vs and -1.09V. Still the performance of TS-SLS TFT is superior to that of the conventional ELA TFT, it can be further improved by process optimization. Fig. 7 shows the output waveform of the last stage of the shift register and the clock waveform. Thanks to the superb characteristics of the TS-SLS TFTs, the signal delay between the clock signal and the shift register output is sufficiently small.

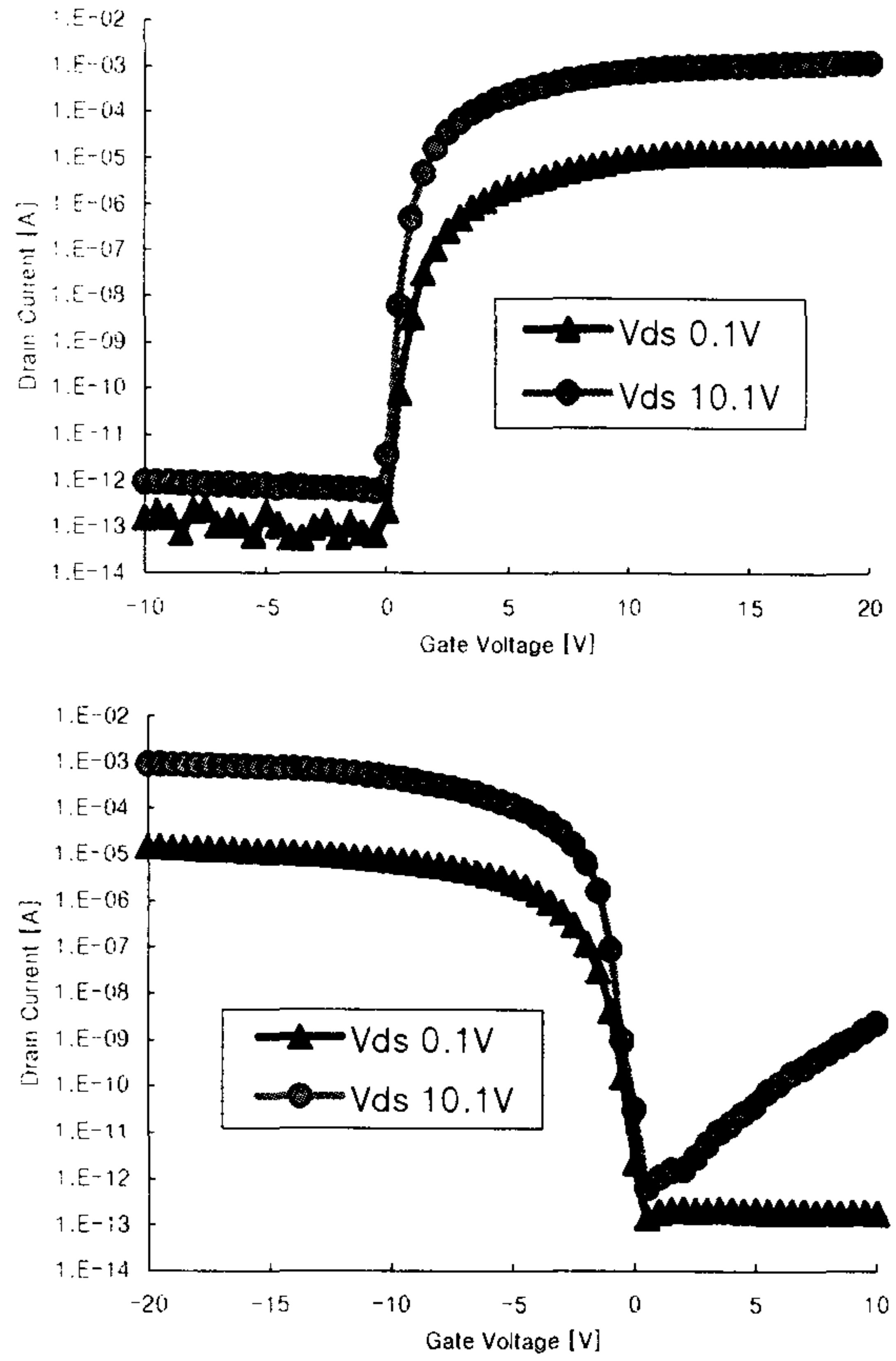

Fig. 6 Transfer characteristics of n-channel SLS TFT with LDD and p-channel SLS TFT. W/L=20μm/6μm

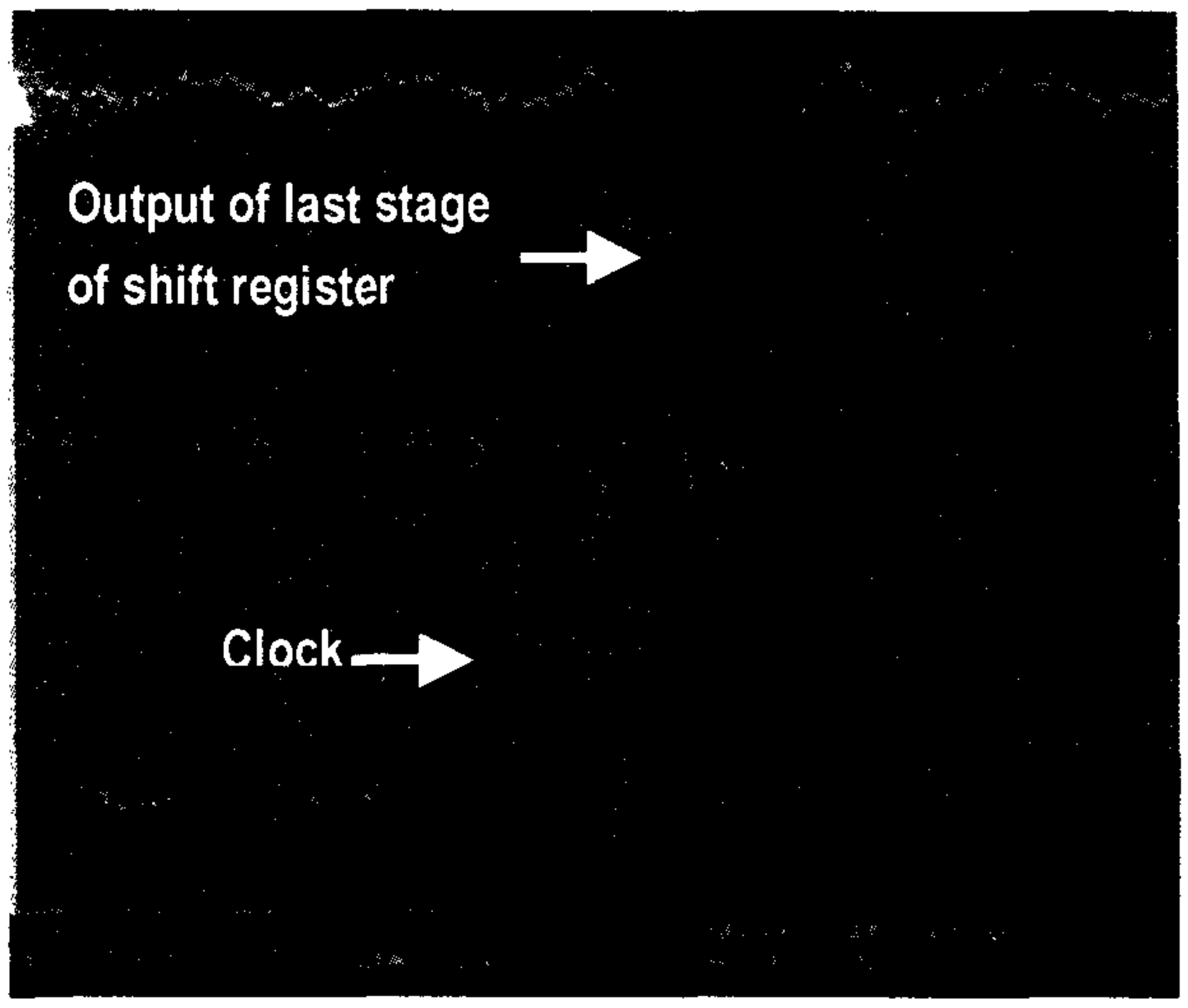

Fig. 7 Output waveform of shift register for 2.8MHz clock.

4. Panel Characteristics

Fig. 8 is a display image of 2-inch qVGA SOG-LCD panel with 6-bit source driver integrated. High quality display image has been successively implemented with small driver circuit area (32mm×4.5mm) owing to the superb performance of TS-SLS TFT and 1:6 demultiplixing driving scheme.

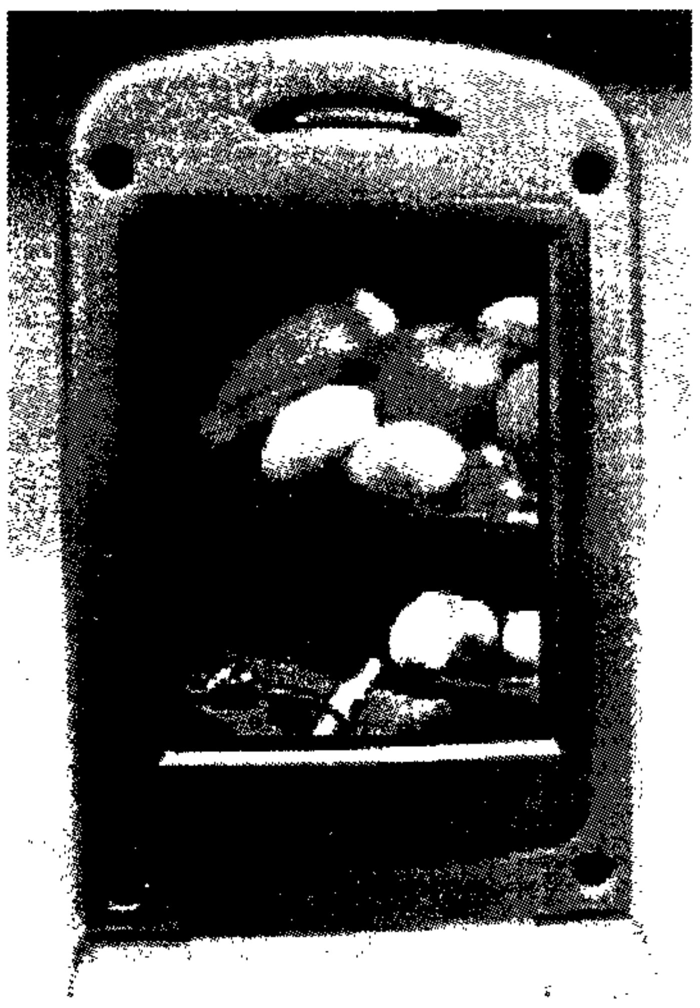

Fig. 8 Display image of 2-inch qVGA SOG-LCD.

5. Conclusion

2-inch qVGA SOG-LCD with integrated 6-bit source driver has been developed. This is the highest resolution SOG display (200ppi) ever reported. Source driver with 1:6 demultiplexing driving scheme has been successfully implemented owing to the high performance of TS-SLS (Two-Shot Sequential Lateral Solidification) TFT, which resulted in small driver circuit area (32mm×4.5mm) with 4μm design rule.

6. References

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