Device Design Considerations and Uniformity Improvement for Low-Temperature Poly-Si TFTs Fabricated by Sequential Lateral Solidification Technology

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Abstract

In this paper, we proposed the novel device and process design to enhance the uniformity of low-temperature poly-Si TFTs fabricated by sequential lateral solidification (SLS). The proposed design schemes can avert the conventional two-shot SLS process-induced issues. Moreover, different design considerations between conventional excimer laser crystallization and the SLS process were also proposed and discussed.

1. Introduction

High performance low-temperature poly-Si (LTPS) TFTs are adapted in large-area electronics, including active-matrix LCDs (AMLCDs) and organic light-emitting diodes (AMOLEDs). Laser-based crystallization schemes for producing large-grained poly-Si films have been extensively studied for years. Sequential lateral solidification (SLS) is a highly promising crystallization technology, capable of providing high performance LTPS TFTs and integrated circuits for flat-panel display applications. Recently, a two-shot SLS (TS-SLS) process has been developed to manufacture the TFTs backplane. High quality poly-Si films of a large grain size can be produced by the specific mask design for a laser beam system and the optimum TS-SLS process. Superior TFT characteristics fabricated by TS-SLS technology have been demonstrated in many publications [1] [2].

However, several TS-SLS process-induced non-ideal phenomena were also observed, even though the uniform and periodic arranged poly-Si grains were obtained. For instance, non-uniform device characteristics still appeared for identical-sized TFTs with various locations on the backplane substrate, as shown in Fig. 1. Such characteristics can be attributed to the various numbers and positions of grain boundary in the channel region. Additional, varying the channel direction significantly influenced the TFTs performance [3]. This is because the current flow in the channel region might be parallel or perpendicular to the grain boundaries. The characteristics of TS-SLS TFTs whose channel direction is perpendicular to the lateral grain growth direction are markedly inferior to those of the parallel channel direction. Moreover, some CMOS-based circuits performed the wrong functions when switching from the conventionally adopted excimer laser crystallization (ELC) to TS-SLS process. This circuit error can be ascribed to the misjudgment of improved TFTs characteristics when applying the TS-SLS process to fabricate TFTs peripheral circuits.

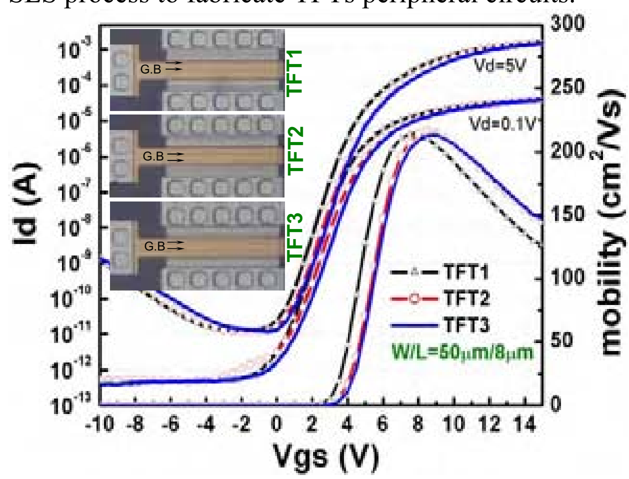

Figure 1. Variation of device characteristics due to the various numbers and positions of grain boundaries.

The inability to eliminate the above undesired effects leads to inaccurate circuit design and poor image quality in TFT panels when applying SLS process to high-performance display manufacturing. Although TS-SLS technology can produce poly-Si TFTs with large grains and high carrier mobility, the non-uniform device characteristics issue may constrain its applications in high performance poly-Si TFT analog circuits and AMOLED panels.

Therefore, this work presents a novel TFT device and process design to avert TS-SLS process-induced outcomes that produce undesired effects. Novel device gate engineering is used to solve the channel direction-dependent effect. Next, optimum design of critical device parameters of TS-SLS TFTs is enhanced to overcome the location-induced device characteristics variations. Moreover, different design considerations between conventional excimer laser crystallization and the SLS process are also proposed.

2. Experimental

The LTPS TFTs were fabricated on glass substrate by both conventional excimer laser crystallization (ELC) and TS-SLS process. The detail process flow was described as follows. TEOS buffer oxide and amorphous Si thin film with a 500Å thickness were deposited on the glass substrate by PECVD. After dehydrogenation annealing, the amorphous Si films were crystallized by conventional excimer laser and TS-SLS process, respectively. Next, the 1000Å TEOS oxide was deposited by PECVD after the active islands were patterned. Subsequently, the source/drain region was formed by the ion shower technology, followed the activation and gate electrode was patterned. After interlayer was deposited, contact opening and metallization were performed to complete the fabrication of the LTPS TFTs.

3. Results

To solve the channel direction-dependent effect, novel gate engineering of SLS TFTs is proposed and fabricated, as depicted in Figure 2. The proposed L-shaped gate TFTs include two channel regions whose channel direction is simultaneously parallel and perpendicular to the grain growth direction. Therefore, the channel current flows are both parallel and perpendicular to the grain boundary for TFTs with various channel direction. The variation in device performance for various channel direction is then minimized to increase the device uniformity.

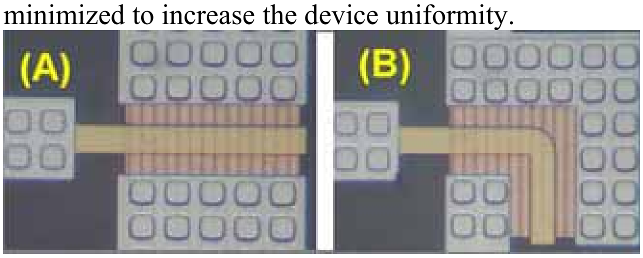

Figure 2. Device schematics of (A) conventional channel TFT and (B) proposed L-Gate channel TFT.

Large amounts of both conventional gate and proposed L-shaped gate TFTs with different channel direction were measured. The TFTs turn-on characteristics and statistic data of mobility distribution were shown in Figure 3 and Figure 4, respectively. These measured results demonstrate that the proposed L-shaped gate TFTs provide better device uniformity and are not sensitive to the channel direction for both n- and p-channel TFTs.

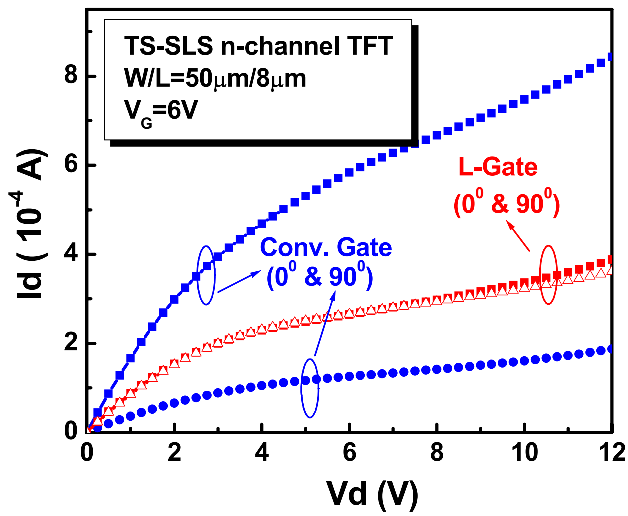

Figure 3. Turn-on characteristics of conventional and L-Gate TFTs with 0° and 90° channel direction.

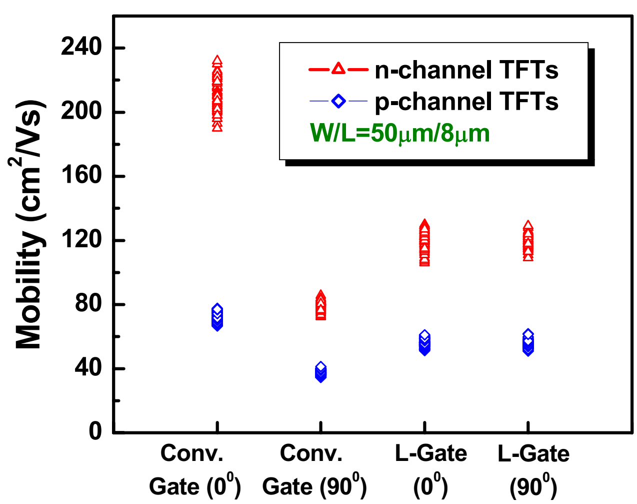

Figure 4. Mobility distributions of conventional and L-Gate TFTs with 0° and 90° channel direction.

In addition, some critical device parameters of TS-SLS TFTs were well-designed to alleviate the location-induced device characteristics variation by referring to the SLS laser system mask layout and related process engineering. As sketched in Figure 5, the same numbers and positions of grain boundaries could be appropriately controlled in the channel region for the identical sized TFTs, even though these TFTs are on different locations of the backplane substrate. Thus, uniform TFTs device characteristics can be expected by adopting the proposed design approach due to the grain boundaries control engineering.

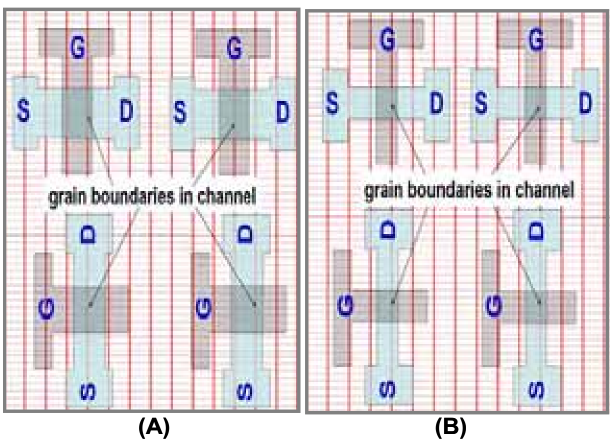

Figure 5. Device diagrams of (A) conventional design and (B) proposed design showing the numbers and positions of grain boundary in TFTs channel.

Furthermore, different levels of device performance enhancement between n-channel and p-channel TFTs are estimated when switching process from the conventionally adopted excimer laser crystallization (ELC) to TS-SLS. As shown in Figure 6, the TS-SLS n-channel TFTs exhibited more significant performance improvement than p-channel TFTs, including mobility, threshold voltage, and subthreshold swing characteristics, when comparing with excimer laser crystallized TFTs. Therefore, when switching process from ELC to TS-SLS, some critical CMOS circuits should be redesigned. Designers should take these different levels enhancement into consideration to avoid the device mismatch leading to circuit error.

We have successfully demonstrated 4.1-inch VGA low-temperature poly-Si AMLCD by TS-SLS technology in DTC/ITRI as displayed in Figure 7.

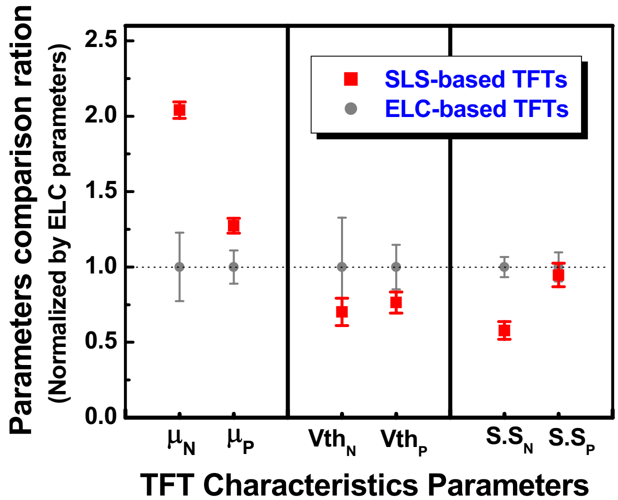

Figure 6. Different levels of device performance enhancement between n-channel and p-channel TFTs when switching process from ELC to TS-SLS.

Figure 7. SLS technology has been successfully implemented for 4.1-inch VGA LTPS AMLCD in DTC/ITRI.

4. Conclusion

The proposed TS-SLS TFTs with novel L-gate structure can provide better device uniformity and be insensitive to the channel direction for both n- and p-channel TFTs. Moreover, the proposed TS-SLS device and process design can enhance the critical design-related performance and increase the uniformity of SLS-based devices and circuits. The design considerations proposed herein can enable integration of various circuit components directly on the TFT substrates not only to reduce manufacturing costs, but also to increase the functionality of large-area microelectronics. Furthermore, the proposed design can increase the accuracy of panel circuitry functions and optimize the TS-SLS technology for AMLCDs and AMOLEDs applications.

5. Acknowledgements

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6. References

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