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A Novel Bottom-Gate Poly-Si Thin Film Transistors with High ON/OFF Current Ratio

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1. Introduction

Laser annealing technology has been extensively studied in the poly-Si thin film transistors (TFT) for its possible integration of drivers and pixel array on the glass substrate because of the low thermal budget[1]. Recently, much attention has been attracted on the excimer laser crystallized bottom-gate (BG) poly-Si TFT with PECVD a-Si:H and n+ a-Si:H film where the device structure and fabrication process are almost identical to those of commercial a-Si:H TFT[2]. Therefore, the BG poly-Si TFTs may eliminate effectively both the process change and addition process steps from the conventional TFT-LCD fabrication so that they can be applicable for the low cost and large size LCD panels. In the BG TFT, however, it may be rather difficult to realize the lightly doped drain (LDD) structure in order to suppress the anomalous leakage current because the doping is achieved by melting an n+ a-Si:H layer.

The purpose of our work is to report the new bottom-gate poly-Si TFT where the leakage current is decreased significantly while the ON current is scarcely decreased. In the new device, the mask number and the fabrication process are almost identical to those of a commercial a-Si:H TFT except the laser annealing.

2. Device Fabrication

The cross-section of the proposed etch-stopper BG poly-Si TFTs are shown in Fig. 1. The major difference of the proposed TFTs compared with the conventional etch-stopper BG poly-Si TFT is a local a-Si region near the drain inside the gate electrode. The local intrinsic a-Si layer may play a key role in suppressing the leakage current due to their large series resistance under the OFF state. However, under the ON state, the series resistance of intrinsic a-Si layer is decreased significantly due to the considerable inducement of electron carriers by the positive gate bias.

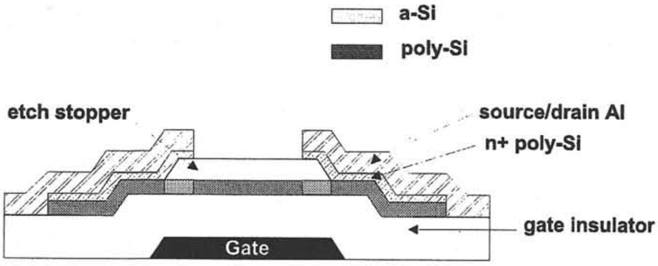

Fig. 1 The cross-section of the proposed bottom-gate poly-Si TFT.

The key process sequence of the new devices, as shown in Fig. 2, is the selective crystallization of a-Si by employing the blocking layer of the n+ a-Si layer overlapping the etch stopper SiN_x for XeCl-UV laser ($\lambda \sim 308$ nm) (Fig. 2b). After patterning of etch stopper layer, a 400 Å-thick n^+ a-Si:H is deposited. The n+ a-Si:H layer and intrinsic a-Si:H layer are etched by source/drain mask step. By XeCl laser irradiation, the a-Si channel region without n+ a-Si layer is recrystallized but the a-Si region with n+ a-Si layer is unchanged so that the selective crystallization is obtained without any additional process and mask. The total number of mask is five which is identical to those of conventional etch stopper TFT.

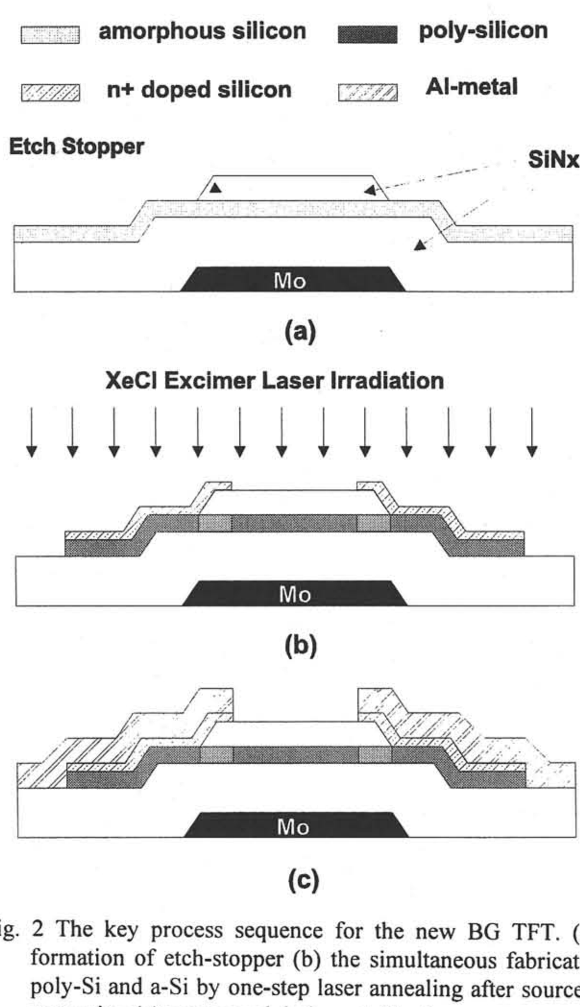

Fig. 2 The key process sequence for the new BG TFT. (a) the formation of etch-stopper (b) the simultaneous fabrication of poly-Si and a-Si by one-step laser annealing after source/drain patterning (c) source and drain metallization

3. Experimental Results

The measured I_D-V_G curves of the conventional BG TFT and proposed BG TFT are shown in Fig. 3. The leakage current of proposed BG TFTs with a-Si length of 1 μ m is decreased significantly compared with those of conventional BG TFT due to the considerable reduction of field emission in the drain depletion region by the highly resistive intrinsic a-Si region. However, the ON current of a new TFT with the a-Si length of 1 μ m is almost identical to that of conventional TFT due to the significant decrease of series resistance of the a-Si region by the overlapped gate field-induced electrons. The field-effect mobility of new BG TFTs is about 27 cm^2/Vs which is comparable with 31 cm^2/Vs of conventional TFTs. In order to verify the role of a-Si region on the device characteristics, the a-Si TFT with W/L = 10/10 μm has been fabricated. Although the subthreshold slope is worse than that of conventional a-Si:H TFT due to the dehydrogenation before laser annealing, the drain current of dehydrogenated a-Si TFT is increased with gate voltage increase by more than the magnitude of three orders, as shown in Fig. 3.

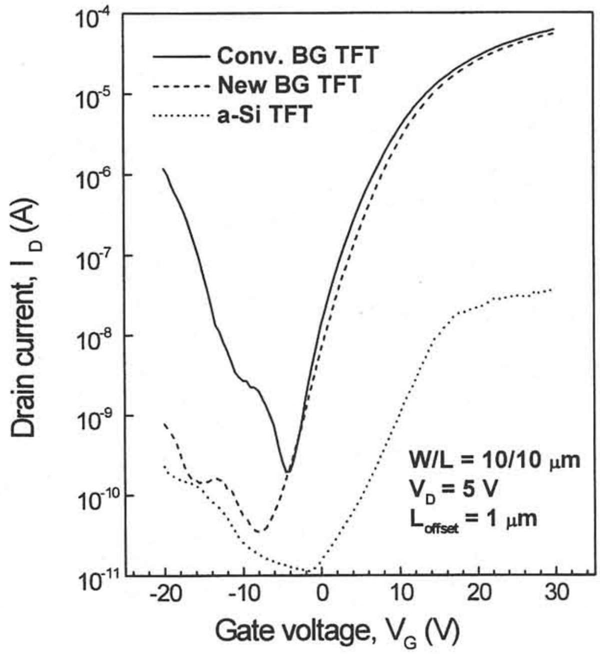

Fig. 3 The I_D-V_G curves of the conventional BG TFT and proposed BG TFT, the length of a-Si region is 1 μm. The dotted line is denoted to the a-Si TFT.

The hydrogenated BG TFT exhibits the improvement of subthreshold slope due to the reduction of trap-states in the a-Si region as shown in Fig. 4. However, the field-effect mobility (45.6 cm^2/Vs) of a hydrogenated new BG TFT is much lower than 64.6 cm^2/Vs of conventional BG TFT due to the more significant improvement of poly-Si quality than a-Si quality by hydrogenation.

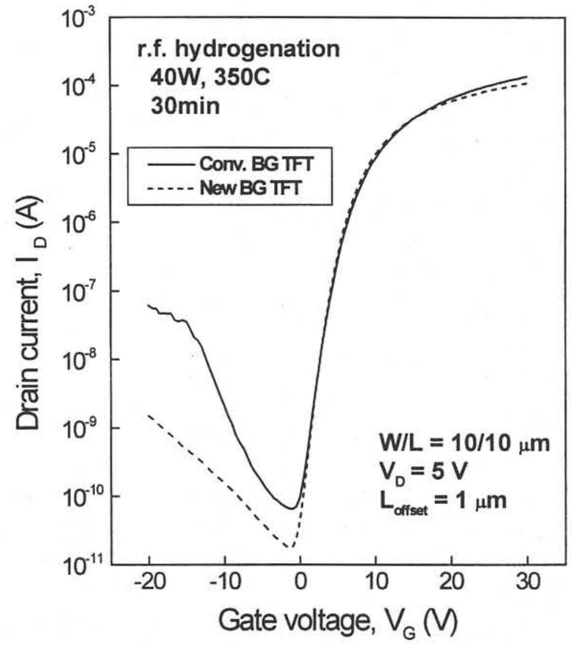

Fig. 4 The I_D-V_G characteristics for the conventional and new BG TFT after 30 min hydrogenation.

4. Conclusion

We have fabricated the new BG poly-Si TFT where the leakage current is decreased significantly while the ON current is not decreased. We have investigated that the ON/OFF current ratio is increased significantly by more than three orders in the new BG poly-Si TFT compared with conventional BG poly-Si TFT. Because the additional process and mask are not required, the present a-Si:H TFT-LCD technology can be utilized for the proposed BG Poly-Si TFTs so that they can be fabricated successfully on the low cost and large area glass substrate.

References

1) T. Sameshima, M. Hara and S. Usui : Jpn. J. Appl. Phys. **28** (1989) p. L309
2) C.D. Kim and M. Matsumura : IEEE Trans. Electron Devices **43** (1996) p. 576.