The Improvement of the Off-Current Characteristics in the Short Channel a-Si:H TFTs

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Keywords : *a-Si:H TFT, Channel, Plasma Treatment*

Abstract

We have investigated the effects of hydrogen plasma treatment by PECVD (Plasma Enhanced Chemical Vapor Deposition) in the back channel region, the method for reducing the off state leakage current which increases with the short channel length of a-Si:H TFTs. To improve the off current characteristics, we analyzed the hydrogen plasma treatment with various RF power and plasma treatment times of PECVD. As the result of hydrogen plasma treatment in the back channel region it was remarkably reduced the off current level of 2um channel length TFT.

1. Introduction

a-Si:H TFTs are widely used as the switching device of active matrix liquid crystal displays (AMLCD)[1], and there have been extensive studies to improve their performances. Recently, many companies are trying to develop large size panels with high resolution. However, to realize higher quality of AMLCD panels successfully, it is necessary to improve the electrical characteristics of TFT, and there are many relevant studies[2]. One of them, shortening the channel length of TFT is the most effective solution to improve the on current characteristics. When the channel length of TFT was shortened, the operating characteristics are improved due to the reduction the charging times resulted from the increase of the on current level. However, the off current level also increases. As a result of increasing off current level, AMLCD panels have a poor holding performance and non-uniform distortion of picture due to vertical cross-talk and poor reliability[3,4]. Accordingly, it is necessary to fabricate the short channel TFT which has high on and low off current characteristics for high-performance TFT.

In this work, we have studied the on and off current characteristics of TFT with various channel lengths and analyzed the hydrogen plasma treatment to reduce the off current level in the short channel TFT.

2. Experimental

Inverted staggered bottom gate type thin film transistors with different channel lengths of 2-5um were fabricated (W = 30um). Figure 1 shows the cross-sectional view and process flow for the 4 masks a-Si:H TFT structure. The Mo/AlNd double layer was deposited on substrate by DC magnetron sputtering for the gate layer. After gate photo and etching process, silicon nitride (SiNx), a-Si:H and phosphorous doped a-Si:H (n+ a-Si:H) were continuously deposited by plasma enhanced chemical vapor deposition system (PECVD). This TFT is a back-channel-etched type with a n+ a-Si:H (phosphorous (P) doped) layer that is used to form an ohmic contact to source/drain electrodes. In our 4 masks process, the Mo (source/drain electrode) was deposited before the active layer patterning and then, Mo and active-n+ a-Si:H layers were simultaneously patterned with only one mask. After the Mo and active area were patterned, photo resist (PR) ash, metal etch and n+ a-Si:H layer etch were carried out continuously in same dry etch chamber to define a channel region. An over-etch process of n+ a-Si:H layer was used to assure complete removal of the n+ a-Si:H in the back channel region.

And then, To reduce the off current level when the channel length was shorten, the hydrogen plasma treatment was applied in the back channel region before passivation layer (SiNx) deposition. The hydrogen plasma treatment conditions were varied of RF power and plasma treatment time. These devices were measured for their electrical characteristics at room temperature (~25 degree C), by HP4156 analyzer.

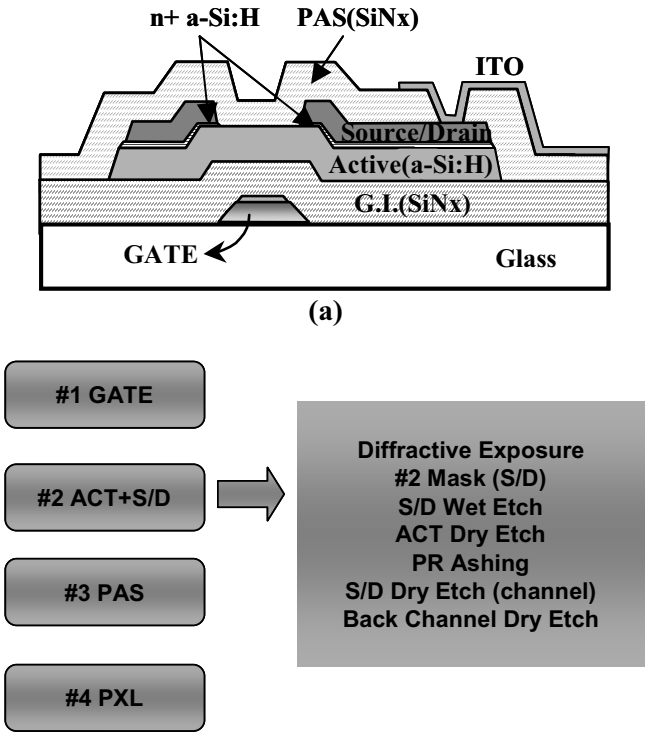

Figure 1 (a) Cross sectional view of bottom gate a-Si TFT device, (b) Process flow for the 4 masks TFT structure.

3. Results and discussion

We have investigated the on and off current characteristics of inverted staggered hydrogenated amorphous silicon thin film transistors with various channel lengths and the effect of hydrogen plasma treatments to reduce the off current level for the short channel TFT.

Fig. 2 shows the difference of the on and off current characteristics with various channel length of a-Si:H TFT when the gate voltage is applied. As the channel length of the TFT was shortened, the on current level increased but the off current level negatively increased also. In general, the off current characteristic is related to the front and back channel interfaces (ex. defect sites, process damage, etc.). We focused on the back channel region interface, which is damaged during PR ash and n+ a-Si:H layer dry etch process in our 4 masks process. And the TFT would be more sensitive to the defect sites, physical damage, and so on, with reducing the channel length.

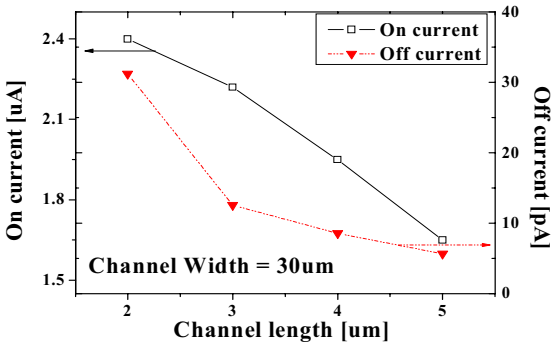

Fig.2 The On and off current characteristics of a-Si:H TFTs with various channel lengths.

To suppress the off current characteristics when the channel length was shorten, the hydrogen plasma treatment was applied in the back channel region and that plasma treatment conditions were varied of RF power and plasma treatment time before passivation layer deposition.

Fig. 3 shows different off current level with various RF power for the hydrogen plasma treatments. In the case of the conventional TFT (channel length = 5um), the off current level was slightly reduced with increasing the RF power of the hydrogen plasma treatment, but the off current level of the short channel TFT (channel length = 2um), was remarkably reduced at RF power 200W and saturated over 200W. The off current is related to the back channel state, and the hydrogen plasma treatment changes the surface state of back channel of TFT[5].

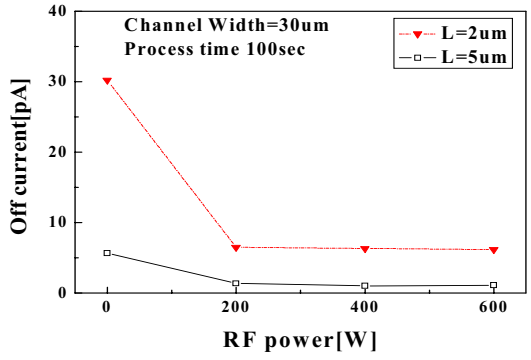

Fig.3 The off current characteristics of different channel length with various RF powers.

The reduction of the off current level with the hydrogen plasma treatment has two main

mechanisms; one is surface etching effect of active region that helps to remove phosphorous residue at the surface, and the other is compensation effect, such as hydrogenation of surface defect sites. In general, the hydrogen radicals in plasma status combine with silicon dangling bonds which have exposed after back channel process. The combination of Si-H compensates the leak site, so the increase of Si-H bonds corresponds with the decrease of off-state leakage current.

Fig. 4 shows the changes of the off current characteristics with various plasma treatment times, at fixed RF power (200W).In the case of 5um of channel length, the off current level was reduced slightly as the increment of the hydrogen plasma treatment times, but 2um of channel length, the off current level was reduced remarkably until about 100 seconds, and saturated at ~7pA. This result shows that the hydrogen plasma treatment needs sufficient energy of hydrogen radicals and time to make combination of Si-H bonds.

In conclusion, we could suggest the solution to reduce the off current level of the TFT with short channel lengths by using the hydrogen plasma treatment in the back channel region before passivation. The hydrogen plasma treatment plays an important role of the combination of Si-H bonds which helps to remove Si dangling bonds at the surface in the back channel. Finally we could fabricate the high performance short channel TFT with high on current and low off current as shown in Fig. 5

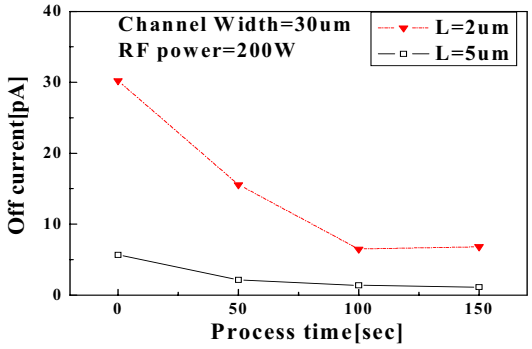

Fig. 4 The off current characteristics of different channel length with various plasma treatment times.

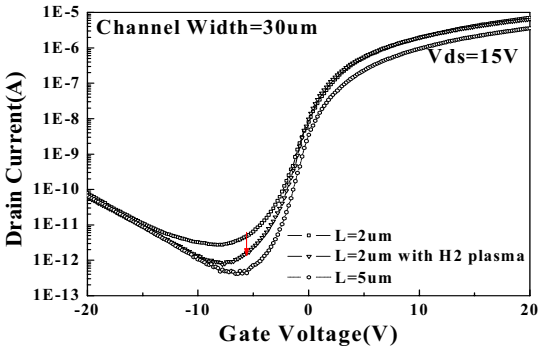

Fig. 5 Transfer curve of different channel length with hydrogen plasma treatment.

4. Summary

We introduced the characteristics of the short channel TFT. The shorter the TFT channel length is, the higher the off current level. We investigated the solution to improve the TFT characteristics and suggested solution to reduce off-current level by hydrogen treatment.

Consequently, In order to improve the picture quality of the AMLCD panels, it is necessary to minimize the channel length of TFT. But as the channel lengths shorten, the off current level, which is directly related to pictorial quality of the AMLCD panels, increases. The hydrogen plasma treatment in the back channel region could be a solution to fabricate high performance short channel TFT for the suppression of the off current characteristics.

5. References

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