

## Stability of a-Si:H TFT After High Temperature Annealing

**Sung Jin Park, Yong Tae Sul, and Byung Seong Bae\***

School of Display Engineering, Hoseo University, Asan City, Chungnam, 336-795, Korea  
\*bsbae3@office.hoseo.ac.kr

**Young Seoung Kim, Jae Won Choi, and Jin Jang**

Department of Information Display, Kyunghee University, Seoul City, 130-701, Korea

**Joon-Hoo Choi, Joon Chul Goh, and Kyuha Chung**

LCD R&D Center, Samsung Electronics Co. Ltd., Kyunggi-do, 449-711, Korea

**Abstract:** We made bottom gate amorphous silicon thin film transistor (TFT). We investigated a stability of a-Si:H TFT after annealing at temperatures higher than deposition temperature of a-Si:H. For various annealing temperatures, we measured the threshold voltage shift induced by gate bias stress. Improvement of TFT stability after high temperature annealing is attributed to dehydrogenation by high temperature annealing.

**Keywords:** amorphous silicon; thin film transistor; hydrogenation; stability.

### 1. Introduction

Hydrogenated amorphous silicon TFTs (thin film transistors) are widely used as a switching element of AMLCD (active matrix liquid crystal display) and they are also used in pixel circuits of organic light emitting display [1, 2], because a-Si:H TFT can be processed easily on glass and plastic substrates.

However, it brings on a threshold voltage shift by the gate bias voltage stress. The gate bias voltage stress cause the increase of dangling bond density around the interface between the a-Si:H layer and gate insulator [3]. It is known that charge trapping at a weak bond results in the broken bond and it is stabilized by the diffusion of hydrogen [4].

Threshold voltage shift is serious for the organic light emitting display which is the current driven display [5]. The uneven pixel to pixel voltage shift results in the non-uniform brightness over the screen of organic light emitting display [1].

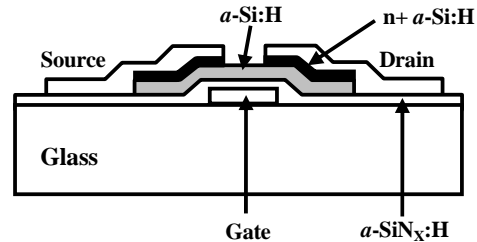
The hydrogen in a-Si:H layer has a important role in the creation of dangling bond. And also, hydrogen itself reduces the dangling bond during the deposition of a-Si:H. During the annealing over deposition temperature, content and bond state of hydrogen are changed. The change of hydrogen content can affect the behavior of threshold voltage shift of a-Si:H TFT [6].

To investigate the effect of hydrogen content on the stability of a-Si:H TFT, we evaluated stability of a-Si:H TFTs with gate bias stress as increasing the annealing temperatures. Increasing the annealing temperature, we evaluated stability of a-Si:H TFTs with gate bias voltage stress.

### 2. Fabrication and experiment

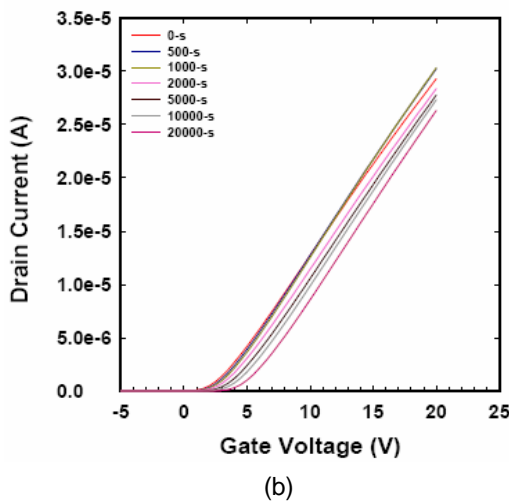
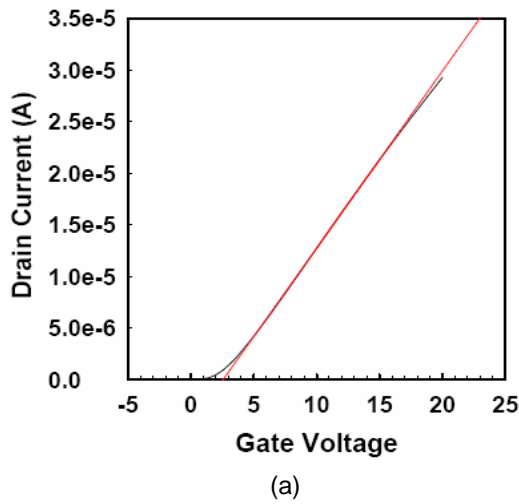
We made a-Si:H TFTs by conventional a-Si:H TFT process and the cross-sectional structure of a-Si:H is shown in figure 1. After the bottom gate pattern, silicon nitride which is a gate insulator, a-Si:H as a semiconductor layer and n+ a-Si:H layer were deposited by PECVD (plasma enhanced chemical vapor deposition). Heavily phosphorous doped n+ layer was used as an ohmic contact layer between a-Si:H and a source/drain metal. N+ layer between source and drain electrode was etched out by dry etching and a channel dimension was  $W/L = 3000/5$ .

In order to reduce a parasitic characteristic, we made a vacuum chamber that could prevent a light illumination and moisture.



**Figure 1.** Cross-sectional structure of a-Si:H TFT.

A fabricated a-Si:H TFT was annealed for 2 hours at 250 . After annealing, temperature was set to the 60 which was a measurement temperature. At the measurement temperature, transfer characteristics were measured, and then we applied gate bias stress,  $V_g = 25$  V. During the gate bias stress, we measured the transfer characteristics with small source/drain voltage of 1 V. After 20,000 s bias stress, we elevated temperature to higher annealing temperatures such as 275 , 325 , etc. After annealing, the bias stress experiment was done at the measurement temperature of 60 . This step was repeated as increasing annealing temperatures. We compare the stability and mobility between different annealing temperatures.



**Figure 2.** The transfer characteristics measured at 60°C after annealing at deposition temperature; (a) initial transfer characteristics, (b) transfer characteristics after gate bias stress.

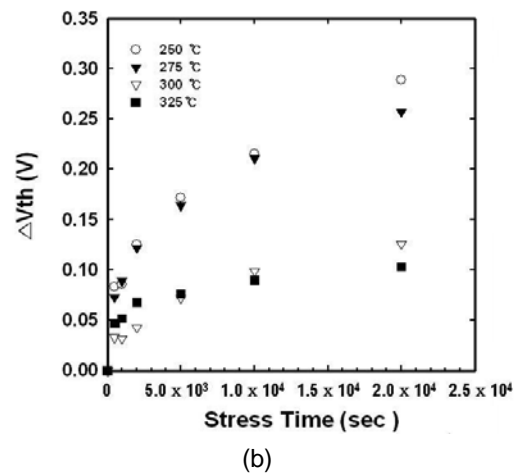
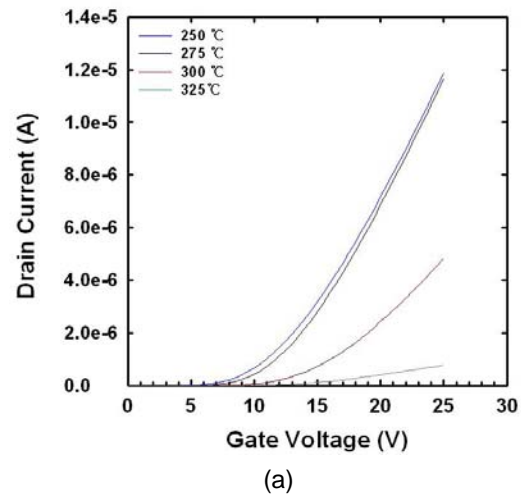
### 3. Results and Discussions

Figure 2 (a) presents initial characteristics measured at 60 after annealing at 250°C and Figure 2 (b) shows the threshold voltage shift with gate bias stressing of  $V_g=25$  V. Threshold voltage increased with gate bias stress time.

Figure 3 (a) shows transfer characteristics measured at 60 for the various annealing temperatures. Field effect mobility decreases with increasing annealing temperatures due to the evolution out of hydrogen from a-Si:H film.

Figure 3 (b) shows the threshold voltage increase during the gate bias voltage stress measured at 60 after annealing at the various temperatures.

As increasing the annealing temperatures, threshold voltage change decreases. This decrease of threshold voltage change with increasing annealing temperature

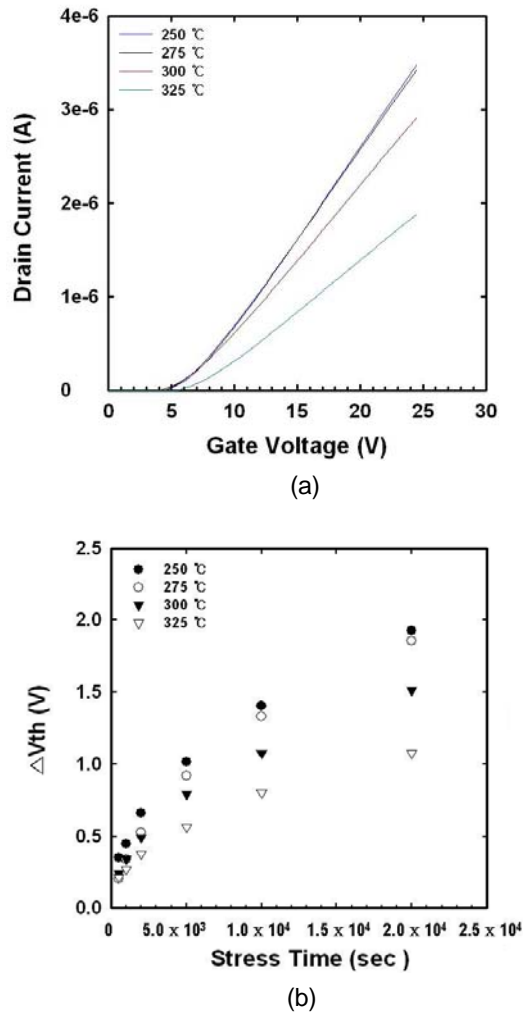


**Figure 3.** Transfer characteristics of TFT after annealing; (a) transfer characteristics measured at 60°C for various annealing temperatures, (b) threshold voltage shift with gate bias stress measured at 60°C for various anneal temperatures.

is attributed to the decrease of hydrogen content in the a-Si:H layer because the amount of evolution-out hydrogen increases with increasing of annealing temperatures. Since the hydrogen has a role of stabilizing of broken bond, reduced hydrogen content results in small change of threshold voltage.

Figure 4 (a) shows the transfer characteristics of W/L=500/5 measured at 60°C, as increasing annealing temperatures. Threshold voltage increased because defect density increases due to the reduction of hydrogen in the a-Si:H. Figure 4 (b) shows the threshold voltage change by the gate bias stress.

Threshold voltage change is smaller for the higher annealing temperatures, which is attributed to the reduction of hydrogen by high temperature annealing. As the hydrogen play a decisive role for the increase of dangling bond the reduction of hydrogen result in good stability of TFT.



**Figure 4.** The characteristics of W/L=500/5 TFT; (a) transfer characteristics measured at 60 °C after annealing at the various temperatures, (b) threshold voltage change by the gate bias stress measured at 60 °C for various annealing temperatures.

However, the mobility decreased after high temperature annealing due to the increased defect states after hydrogen evolution out.

#### 4. Conclusion

In this paper, we investigate the stability of a-Si:H after high temperature annealing. Threshold voltage change by gate bias stress decreased as increasing annealing temperatures.

However, the electric field mobility is reduced. This reduction of mobility and improvement of stability were attributed to the evolution out of hydrogen from a-Si:H layer, because the role of hydrogen is to stabilize the broken bond to increase the dangling bond. However, the mobility was decreased. Mobility decrease was attributed to the increase of defect state due to hydrogen evolution out.

#### 5. References

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