Characterization of instability in a-Si:H TFT LCD utilizing copper as electrodes

Yung-Chia Kuan[a], Shuo-Wei Liang[b,], Hsian-Kun Chiu[a], Kuo-Sheng Sun[a]*

[a]CPT, Chunghwa Picture Tubes, LTD

1127, Hopin RD., Padeh City, Taoyuan, Taiwan, 334, R.O.C.

[b]Research Alliance, Taiwan TFT LCD Association (TTLA)

Industrial Technology Research Institute Bldg. 15, 195 SEC. 4, Chung Hsing Rd, Hsinchu, Taiwan, R.O.C.

Phone: 886-3-5913237, Email: Kenneth_Liang@itri.org.tw

Abstract

The hydrogenated amorphous silicon thin film transistor (a-Si:H TFT) with copper as source and drain electrode has been fabricated to obtain its transfer characteristics and stressed with positive and negative bias to investigate the instability variation comparing to conventional MoW-Al based TFT device. The results show that there is no copper diffusion into active layer of a-Si:H TFT, even during the thermal process. In addition, a 15-inch XGA a-Si:H TFT LCD display utilizing Cu as gate electrodes has been developed.

1. Introduction

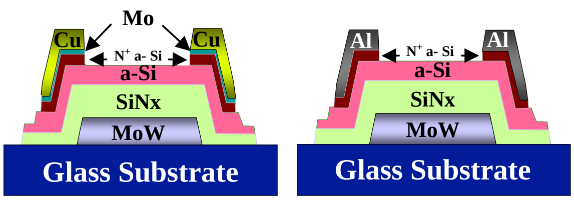
Thin-film transistor liquid crystal displays (TFT-LCDs) have been applied to make large-sized TV applications. As screen size gets larger, one of the common problems is the data and scan line signal delay due to the high resistance of metal. The metals for the data and scan lines typically used like molybdenum (Mo), chromium (Cr), or aluminum alloy, all show the problem of high resistivity for making large and high resolution displays[1]. The copper (Cu) metallization has been considered as the solution to reduce the RC delay to achieve good uniformity with its superior electromigration and lower resistivity. However, the use of copper might cause several concerns; diffusion into active layer, poor adhesion to glass substrates, and contamination issues. Thus, to integrate Cu into a-Si:H TFT fabrications, these concerns have to be answered.

In this paper, we report the a-Si TFTs utilizing copper as source and drain electrodes, and the instability of MoW-Cu ased a-Si:H TFTs were studied. A comparison of threshold voltage shift and subthreshold swing behavior between MoW-Cu based and traditional MoW-Al based TFTs after a prolonged performance of the gate voltage stress were performed. Also, the reliability of MoW-Cu based TFT stressed with gate and drain bias was studied. In addition, temperature dependence of the instability mechanisms stressed at the DC bias for a fixed stress time in MoW-Cu based and MoW-Al based TFTs were investigated.

2. Experiments

There are two types of thin film transistor structure used in this study, both were conventionally inverted staggered structures, as shown in Fig. 1 (a) and (b). In structure (a), after the MoW electrodes were patterned, the silicon nitride, a-Si:H, and n^+ a-Si:H films were deposited by plasma-enhanced chemical vaper deposition (PECVD). Then 36-nm-thick Mo and 300-nm-thick Cu films were sputtered on n^+ a-Si:H layer as source and drain electrode. It took two steps to form the S/D pattern. The Cu film was first etched by wet etchant, and then the barrier layer, Mo, was dry etched by SF_6/Cl_2 mixed gas. The n^+ a-Si layer in the channel region was removed with reactive ion etching (RIE). In structure (b), the same fabrication process was implemented, except the source and drain electrodes were constructed with aluminum.

The channel geometry (W/L) of TFTs was 80 μm/12 μm, and the gate-source and gate-drain overlaps were 4 μm. The transfer characteristics were measured and stressed with a computer-controlled HP4145B semiconductor parameter analyzer. The threshold voltage shift was defined as the difference in Vth before and after applying the stress voltage for 10s, 100s, 1000s, and 10000s. The stress gate voltage was between -80 and 80 V and the stress drain voltage ranged from 0V to 30V. Bias temperature stress (BTS) was also applied to verify the reliability of these two types of device. During the stress, the source and drain electrode of the TFTs were commonly grounded to avoid the electrical distortion. Before each measurement, MoW-Al based and MoW-Cu based a-Si TFTs were both annealed at 150℃ for 60 min and cooled to room temperature . All measurements were carried out in the dark.



(a) MoW-Cu based TFT (b) MoW-Al based TFT

Fig. 1. Two types of a-Si:H TFT structure.

3. Results

Fig. 2 (a) and (b) show the plan-view SEM photographs of the MoW-Cu based and conventional MoW-Al based TFT structures, respectively. Fig. 2 (c) shows the XTEM image of the channel region using Cu as source and drain electrodes. From the XTEM image, there is an undercut observed between the interface of Cu and Mo films due to the two-step etching. However, good transfer characteristics were obtained from MoW-Cu based TFTs, and no clear difference is found between these two types of structure, as shown in Fig. 3. The average mobilities of MoW-Cu based and MoW-Al based TFT are 0.8 cm^2/Vsec and 0.5 cm^2/Vsec, and their threshold voltages are 2.05 V and 2.73 V, respectively.

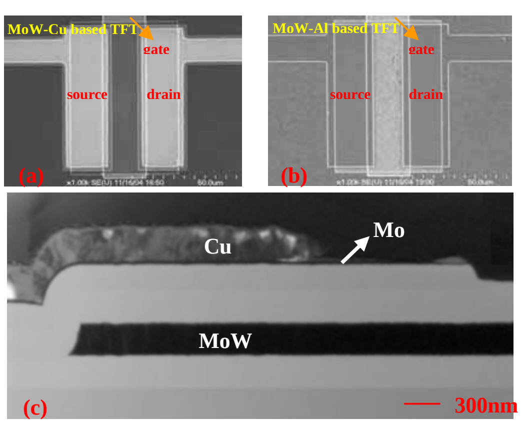


Fig.2. (a) Plan-view SEM photographs of MoW-Cu based and (b) plan-view SEM photographs of conventional MoW-Al based TFT structures. The gate electrode is 300-nm-thick MoW film for both structure (a) and (b), and the S/D electrode is 36nm Mo/300nm Cu and 300-nm-thick Al, respectively. (c) XTEM image view of the MoW-Cu TFT in the channel region.

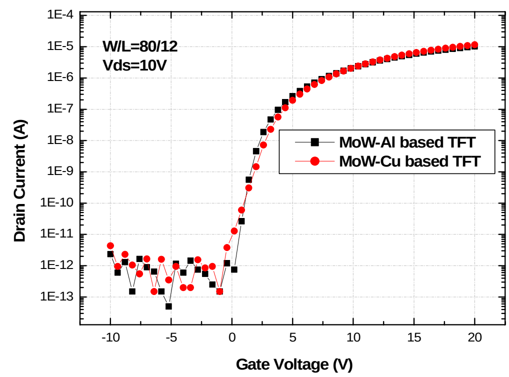
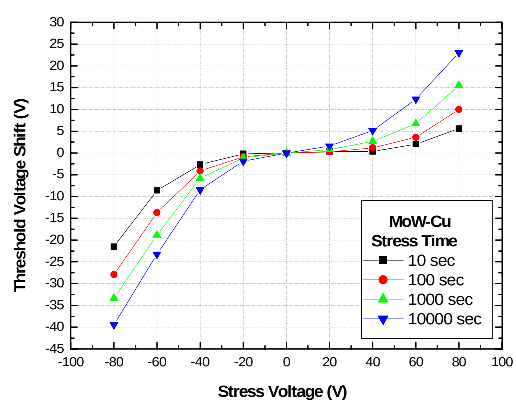
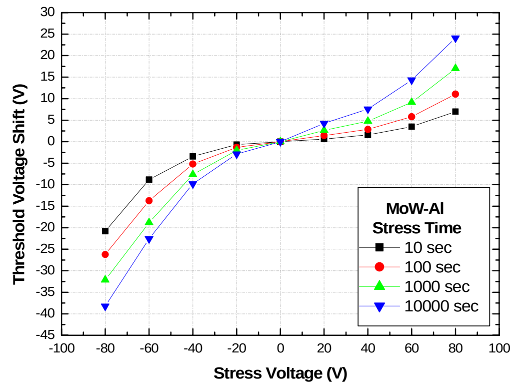


Fig. 3. Transfer characteristics of MoW-Cu based and MoW-Al based a-Si:H TFTs. No clear difference is found between these two types of structure.

Fig. 4 (a) and (b) show the stress voltage dependence of threshold voltage shift with stress time of 10, 100, 1000, and 10000 seconds of MoW-Cu and MoW-Al based TFT device. For these two structures, the threshold voltages are all positively increased with positive gate bias. For the stress of negative voltage below -40 V, the threshold voltages are negatively shifted, compared to positive gate bias. In terms of threshold voltage shift, we cannot find any differences between these two types of structure.



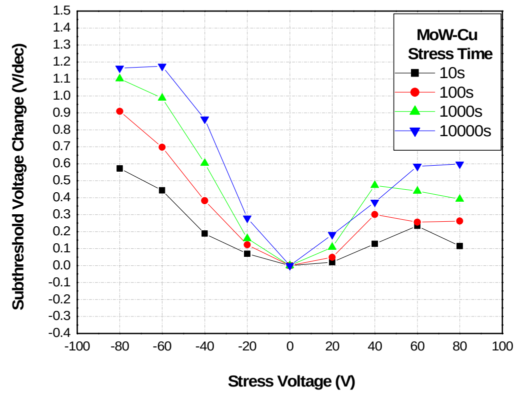
(a)



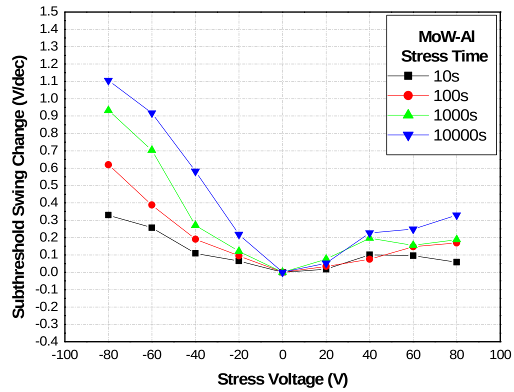
(b)

Fig. 4. Threshold voltage shift of stress voltages with different stress times for two types of a-Si:H TFT structure. (a) Vth shift for MoW-Cu based TFT device. (b) Vth shift for conventional MoW-Al based TFT device.

In Fig. 5, the subthreshold swing change from the pre-stressed TFTs as a function of the applied gate bias for various stress time is shown. For the positive stress bias of the MoW-Cu based TFT device, the subthreshold swing changes increase slightly. For the negative bias, the subthreshold swing changes are significantly raised below -40V with the stress time. Similar subthreshold swing behaviors are also observed in MoW-Al based TFT device. The instability mechanisms of conventional a-Si:H TFTs under DC bias stresses are resulted from the formation of state creation and charge trapping[2]. Since the resemble characteristics are performed and obtained in MoW-Cu based TFT device, it suggested that same mechanisms may be explained to its instability. Furthermore, it is proved that there is no Cu diffusion into active layer of a-Si:H TFTs during gate bias stress.



(a)

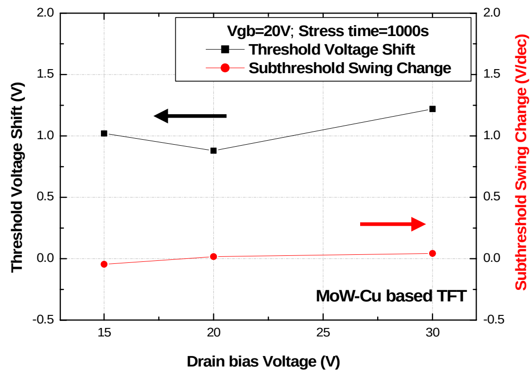


(b)

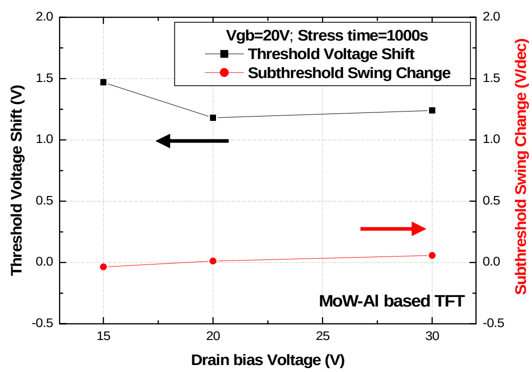
Fig. 5. Dependence of the subthreshold swing change on stress voltages with various time for two types of a-Si:H TFT structure. (a) S.S. change for MoW-Cu based TFT device. (b) S.S. change for conventional MoW-Al based TFT device.

In figure 6 (a) and (b), the threshold voltage shift and subthreshold swing change of the applied gate bias and drain bias were compared, while the gate bias voltage (Vgb) remained constant during the stress time for these two types of structure. For either threshold voltage shift or subthreshold swing change, no apparent variations with the drain bias voltage were observed. Comparing the results of Fig. 4 and Fig. 6, it suggested that for both MoW-Cu based and MoW-Al based TFT structures, the gate bias determines the threshold voltage shift, rather than the drain voltage. The same result is also found by M.J. Powell and N.

T. Golo et al.[3,4].



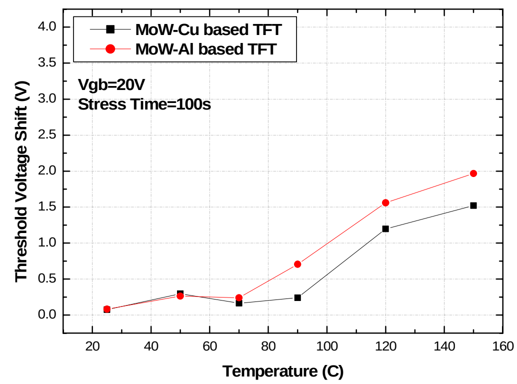
(a)



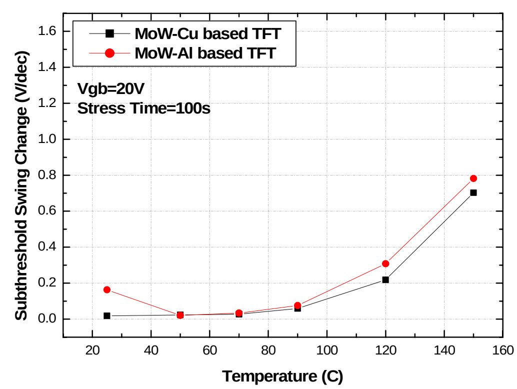
(b)

Fig. 6. Dependence of the threshold voltage shift and subthreshold swing change on drain voltages, while the gate bias voltage (Vgb) remained 20V during the stress time for two different types of structure. The drain bias is not an essential factor for Vth shift and S.S. change. (a) Vth shift and S.S. change for MoW-Cu based TFT device. (b) Vth shift and S.S. change for conventional MoW-Al based TFT device.

In addition, the bias temperature stresses were also applied to the reliability testing of these devices. Fig.7 (a) and (b) show the temperature dependence of threshold voltage shift and subthreshold swing change after the stress time of 100 seconds in two types of structure under a constant gate bias (Vgb) at 20V. It is found that thermal process accelerates the threshold voltage shifts and the subthreshold swing changes due to the activation of the state creation and charge trapping[5,6,7]. A similar variation is obtained for both MoW-Cu based and MoW-Al based TFT devices. It also proves that there is no Cu diffusion into active region during thermal bias stress process.



(a)



(b)

Fig. 7. Temperature dependence of (a) threshold voltage shift and (b) subthreshold swing change after the stress time of 100s. The gate bias stress voltage (Vgb) is 20V.

Due to the similar characteristics comparing with MoW-Al based TFT devices, a 15-inch XGA a-Si:H TFT LCD panel utilizing Cu as gate electrodes has been successfully developed. Transfer characteristics were obtained from Cu gate TFTs in Fig. 8 and the display specifications are shown in Table 1. Fig. 9 shows a picture of the panel displaying a full-color image.

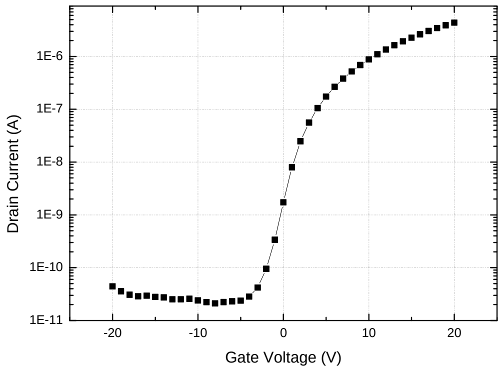


Fig. 8. Transfer characteristics of Cu gate TFTs

Table 1 15-inch Cu gate TFT LCD Specification

Items	Specification
Display Area (mm)	304.128 (H)*228.096 (V)
Number of Pixels	1024 (H)*RGB*768 (V)
Pixel Pitch (μm)	99 (H)*297 (V)
Color Pixel Arrangement	RGB Vertical Strip
Display Mode	Normally White
Brightness (cd/m^2)	250 (Typ.)
Viewing Angle (CR>10)	-70~70 (H), -60~60 (V)
Contrast Ratio	500:1 (Typ.)
Response Time (ms)	16 ms (Typ.)
Backlight Unit	CCFL

Fig. 9. Full-color image on 15-inch Cu based panel

4. Summary

The MoW-Cu based a-Si:H TFT that has similar transfer characteristics comparable with the conventional MoW-Al based TFT was fabricated. The reliability and instability of the MoW-Cu based TFT have also been investigated, and showed similar properties in contrast with MoW-Al based TFT device. All results are shown that there is no copper diffusion into active layer of a-Si:H TFT, even during the thermal process. Furthermore, we succeeded in developing the 15- inch XGA Cu gate TFT display panel.

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