Cu as an Electrode Material in TFT-LCD Products

C.W, Park,W.H. Cho, K.T. Kim H.C.Choi C.H. Oh*

MNT/TV Development Division, LG.Philips LCD
642-3, Jinpyung-dong, Gumi-city, Kyungbuk, 730-350, Korea

Abstract

In this paper, production of TFT-LCD adopting Cu electrode, in spite of low resistivity, which was not commercially applied to TFT LCD products because of processibility, reliability problems etc. was mentioned. Based on the test result of etch and strip process of Cu electrode, the TFT device using Cu material shows the same characteristics as the conventional TFT devices. we describe the realization of a 20.1" UXGA model which was firstly applied to Cu electrode.

Introduction

Recently the importance of display has been increased because display is a novel tool that information goes through in multi-media era. In contrast with conventional display (CRT), flat panel displays have been rapidly growing in the display market. Among them, TFT-LCD is distinguishable because of its great features like light weight thin thickness and low power consumption.[1]-[3] Therefore many R&D activities and investments of TFT-LCD are still going on.

As the size of LCD panel increases , it becomes more difficult for the LCD panel to have a good uniformity of display quality. A good uniformity of display quality is based on sufficient charging at the TFT array. This charging property has a lot to do with electrode material in the TFT process. As the LCD panel size and resolution increases, it faces the problem caused by gate or data line delay.

We have been looking for an electrode material that has lower resistivity. We applied copper as a new electrode material. In this paper, we review on copper as a new electrode material in TFT-LCD products.

Cu based TFT Process

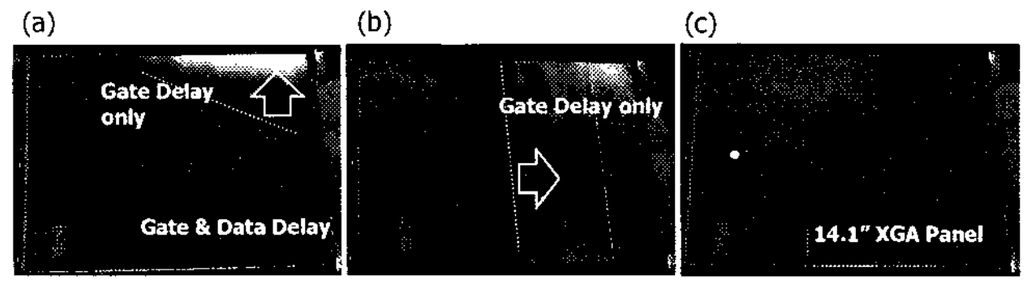

Fig. 1. Experimental results that show the effect of the signal delays on display quality

Figure 1 is an example to show the effect of signal delay in a TFT-LCD panel. We had made some 14.1 XGA panels with different bus metals. A bright area in the upper right corner in Fig. 1 (a) & (b) is shown. This is because of insufficient charging of TFT in this area. Figure 1 (c) is the result when we don't apply any signal delay for the panel. The panel shows a uniform black state. In case of 42-inch diagonal LCD panel, signal delay of gate bus line is so serious that it is not possible to drive the panel sufficiently with conventional driving methods. The gate material of the panel is Al though. Recently dual gate driving method was proposed for large panels, but it was not efficient and fundamental. We have been thinking a new electrode material that has low resistivity to solve the signal delay problem of large panels. Copper (Cu) would be the best candidate as a new electrode metal.[4]

Definitely Cu is promising as a electrode material. However there has been no report that Cu is used in TFT-LCD production line. This is because Cu has had many issues unsolved until now. Those are (1) inter-layer diffusion & adhesion, (2) efficient chemicals for etch & strip process and (3) no change of TFT device characteristics due to Cu contamination. The following is about how we had overcome those hurdles.

The first one is about inter-layer diffusion of Cu during the process. It is well known that Cu is

diffusive to Si layer during the process. To block diffusing Cu into a-Si layer, we applied a few tens nm thick barrier-metal under the Cu layer.

The second issue is about chemicals (etchant). Unlike other metals, it is very hard to etch Cu with conventional etchants. The main issues are (1) concurrent etch characteristic of Cu & barrier metal, (2) Critical Dimension (CD) bias & etch profile, and (3) etch rate reduction as the number of glass sheets increases. The conventional etchant is based on oxone as the main oxidant agent. The etching profile of conventional etchants is very poor. Moreover the rate of etching reduces according to the variation of oxone content as time goes. This fact is very important because mass production needs a steady etchant that keeps its etching ability for a long time. We have developed a new etchant. Figure 2 shows the etching characteristics of a newly developed etchant. Figure 2 (a) shows the etching profiles of Cu/Mo thin film. Our new etchant shows a good linear characteristic on CD as over-etch time goes. And we can see there is no edge-profile change. In Figure 2(b), we checked etch rate variation by changing the number of glass treated in the process. This experiment should be done for a stable control of the process. By the comparison, we realize how long those new etchant last on etching ability.

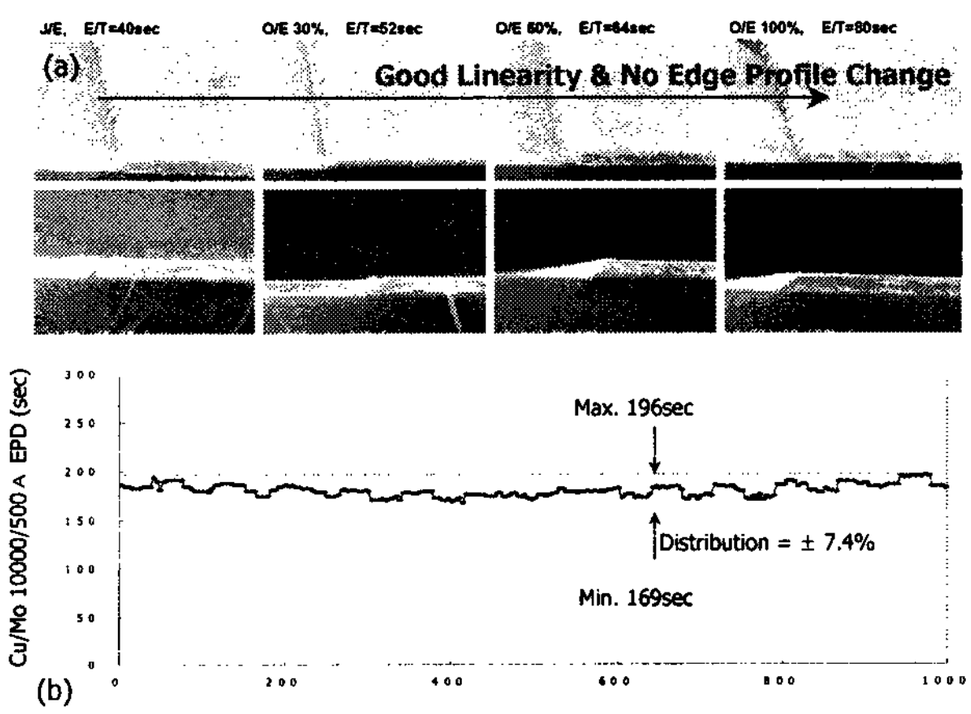

Fig. 2. Etching profile and etch rate variation of our new etchant

The last issue of Cu is about the effect of contamination of Cu ion into TFT device characteristics. It is already known that some semiconductors have an instability problem with copper ion contamination. To quantify the concentration of Cu ion that makes TFT malfunction,

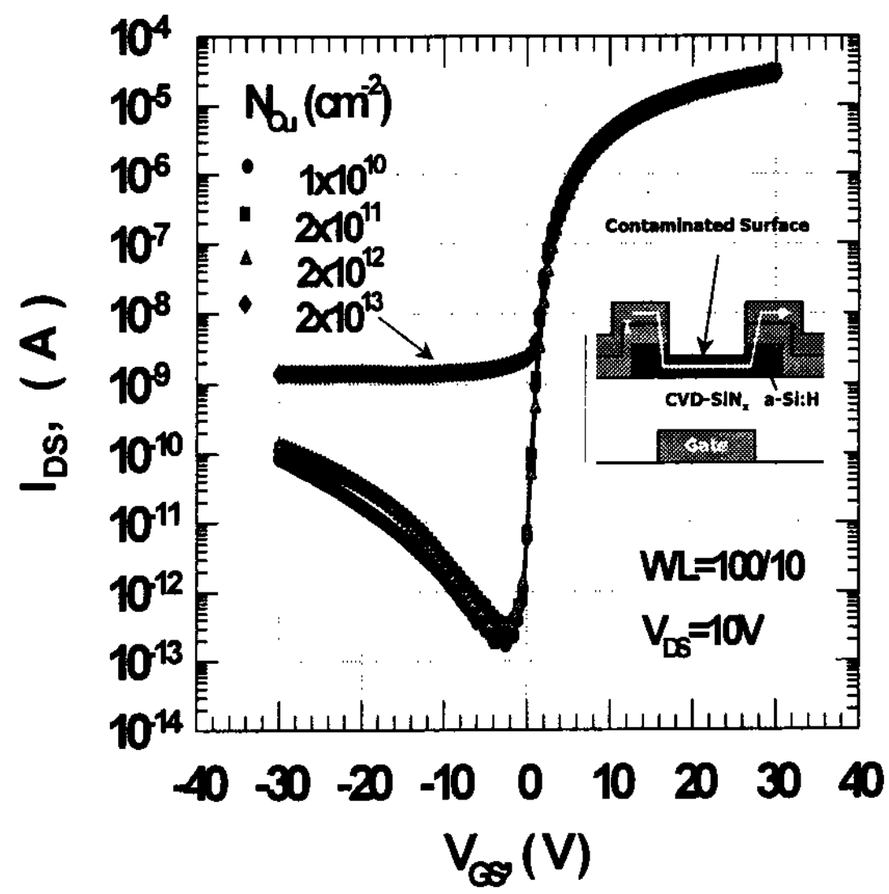

Fig. 3 TFT characteristics with different Cu ion concentrations

we made several samples with a different copper ion contamination by sputtering the devices with Cu. The concentration of Cu ion was determined by the sputtering time. The TFT characteristics of those samples were checked in Figure 3. TFT with less than 2 x 10^{12} N_{Cu}/cm^2 of Cu ion has no problems in the TFT characteristics. TFT with 2 x 10^{13} N_{Cu}/cm^2 shows abnormal TFT characteristics. These abnormal TFT characteristics can be explained by the leakage current in the TFT channel.

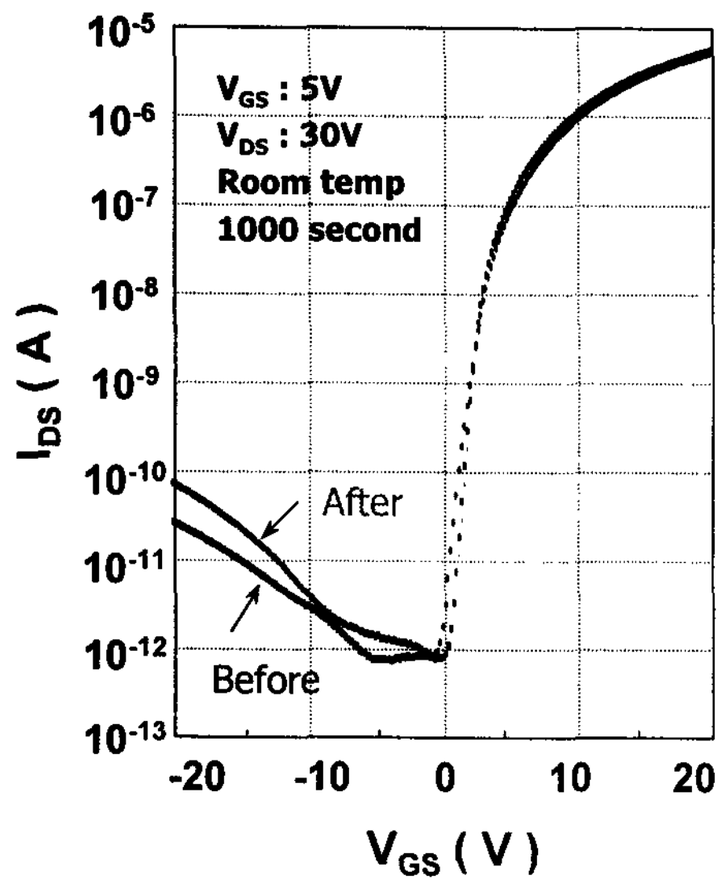

Fig. 4 Reliability test of our Cu-based TFT

Figure 4 shows the characteristics of the TFT device, where gate and S/D electrode are Cu/Ti layer. Its mobility is 0.5 cm^2/Vsec on average, its threshold voltage is 3.5 Volt, and on-off current ratio is over 10^6. This Cu-based TFT has almost the same characteristics as the TFT with conventional electrode materials. And in terms of reliability, we can't find any differences from conventional TFTs

We have developed a 20.1-inch diagonal UXGA TFT-LCD with Cu electrode. The specifications are shown in table 1. The LCD has good performances in terms of display uniformity.

Conclusion

In this paper, we deal with production of a TFT-LCD adopting Cu electrode, inspite of low resistivity, which was not commercially applied to TFT-LCD because of processibility, reliability problem etc.

In the future, As the trend of market for larger size and higher resolution, it is estimated that the demand for low resistivity material continues and mass production technology of TFT LCD using Cu material will be in accordance with such market trend.

Table 1 : Display specification of a developed 20.1-inch UXGA.

Item	Specification
Display size (diagonal)	510.54mm
Display pixel (Hor.×Ver.)	1600×1200
Pixel pitch	0.255mm×0.255mm
Number of colors	16.7M (8bit/color)
Color Gamut	72% NTSC
Color coordinate (White)	0.313, 0.329
Contrast ratio	> 400
Brightness	250cd/m²
Response time	16ms
Viewing angle (CR ≥ 10″)	Ver. ≥ 176′ Hor. ≥ 176′

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