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# LOW RESISTANCE GATE LINE FOR HIGH-RESOLUTION TFT/LCD DISPLAY

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**Abstract**

12"-XGA and 16"-SXGA LCD panels are manufactured with low resistance Mo/Al gate line. Stable etching for thicker aluminum is achieved. Mo passivity current density is 0.06A/cm^2 and electromotive force of Mo-Al electric cell makes Mo passivity. The stability of Mo passivity depends on the amount of nitrous acid on the cathode electrode. As "Dip" etching makes nitrous acid drift away,Mo passivity easily degrade and taper shape of Al is created because of higher etching rate of top Mo.

## 1.Introduction

Recently, the demand of high resolution large-size TFT/LCD display is rapidly increasing. In order to make high resolution large-size display, aluminum is widely used to reduce the time constant of gate line. But aluminum has many weakpoints, such as, (1) Al is easily damaged by etchant. (2) Al causes many problems (hillock, blister) by heating. (3) Al has poor adhesion to glass or under coat. If the coverage of gate insulator is not enough, the etchant intrude into aluminum layer and aluminum gets damages. To avoid the lack of coverage of gate insulator, Kawamura et al[1] is reporting aluminum taper etching using photo resist/Al structure, but the adhesion between photo resist and Al easily changes due to various condition such as humidity or time after baking. Photo resist/Mo/Al structure is better from this viewpoint, but this structure sometimes causes overhang of Mo and causes lack of coverage of gate insulator. We successfully suppress the overhang of Mo to make taper shape of Al by reducing the Mo passivity with "Dip" etching method and resolved the mechanism of Mo overhang.

## 2.Structure

Fig.1 shows the cross section of our gate line structure. As Al makes hillocks or blisters at high temperature, we must make multi-layer structure using high-melting-point metal Mo and MT(Molybdenum-Tantalum alloy) on Al. Multi-layer structure also prevents from open line, if one metal gets to be open. Mo is also used to make taper of Al using the difference of etching rate between Mo and Al. As taper shape makes the coverage of gate insulator better, we can prevent from the intrusion of ITO etchant. Taper shape of Al also prevent from ESD (Electrostatic Discharge) from the top edge of Al gate line.

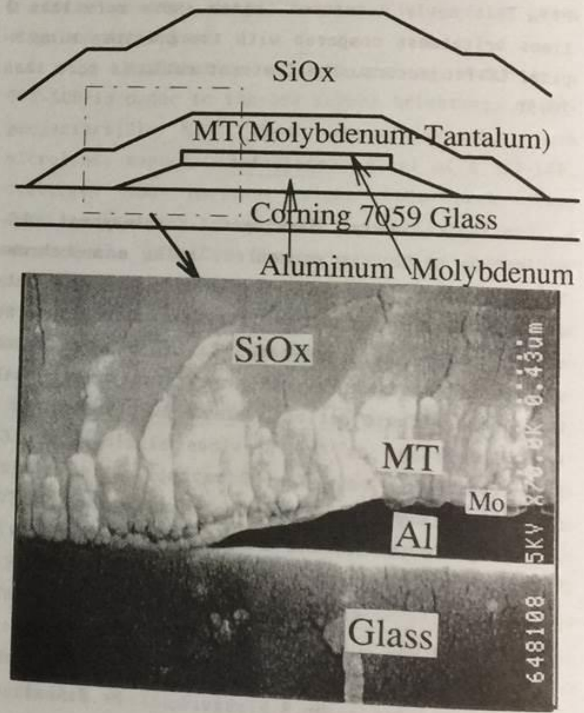



**Fig.1 Cross section of new Al clad gate structure**

## 3.Experiment

### 3.1 Taper Etching Control

In order to make taper shape of Al, we applied Mo/Al structure (500Å/2000Å). After making 0.5%HF (Hydrogen Fluoride) cleaning, washed the Corning 7059 glass substrate in distilled water, and then dried in IPA (Isopropyl Alcohol) vapor. After cleaning process, Al and Mo are deposited in Tokuda SYSTEM 512 Sputtering System in the atmosphere of Ar at 150C temperature. The sputtering Condition of Al and Mo are

Al:7kW, Ar150sccm(~0.5Pa)
Mo:1.5kW, Ar150sccm(~0.5Pa)

After sputtering process, photo resist was coated and was patterned by aligner and developer. After photo resist was developed, photo resist was baked in 130C for 150 sec.

After making photo resist pattern of gate line, we tried wet etching with two different methods, that is , dip etching and conventional spray etching.

Fig.2 shows the etching time dependence of side etching length (measured by SEM) of Mo and Al. We can see that we get taper shape (Fig.3 (i)) if the side etching length of Mo is larger than that of Al in Fig.2. If side etching length of Mo is smaller than that of Al, Al has overhang shape (Fig.3 (ii)) and we can not apply it as gate line etching.

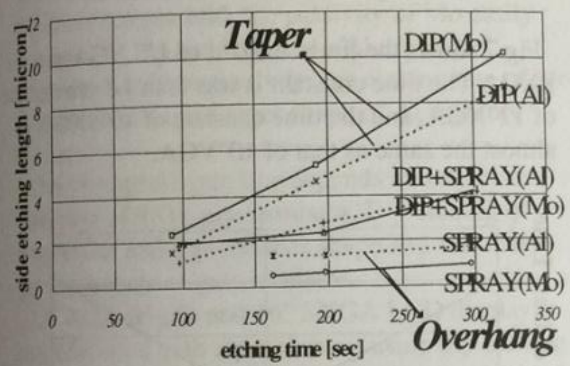
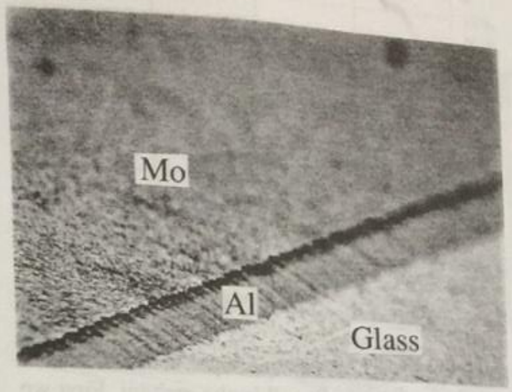



**Fig.2 Etching time dependence of side etching length (Measured by SEM)**

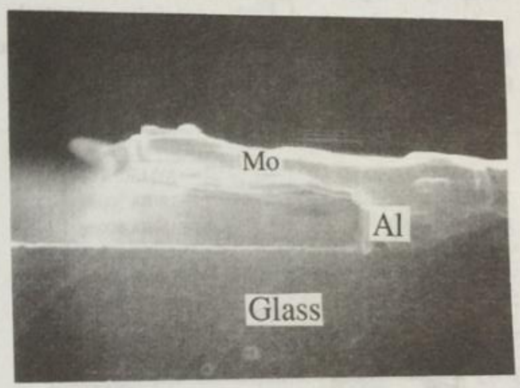
We can see that the etching rate of dip etching is larger than that of spray etching. And in case of spray etching, the etching rate of Mo is smaller than that of Al, and in case of dip etching, the etching rate of Mo is larger than that of Al. In the case of etching technique using both dip and spray, the etching rate is middle of dip etching and spray etching, and the etching rate of Mo is almost the same as Al.

By SEM measurement, we can see that passivity of Mo is created by spray etching. By this measurement we can see that dip etching is suitable to make taper shape of Al constantly.

By defect analysis, the sample with non-taper-shape Al had many stripping points of SiOx or ESD defect, but the sample with taper-shape Al had no such defects occurred.




**(i) TAPER shape made by DIP etching**




**(ii) OVERHANG shape made by SPRAY etching**
**Fig.3 Etching method dependence of aluminum shape**

3.2 Taper Etching Mechanism

To know how "Dip" etching suppresses the passivity of Mo, we measured the electric potential dependence of Mo.

As Mo and Al is adhered in the etchant, electromotive force exist between Mo and Al. To see if the electromotive force makes passivity of Mo, we measured polarization diagram of Mo. Polarization diagram of Mo shows that the passivity current density of Mo is 0.06 A/cm^2. (Fig.4) In the etchant with 3% nitric acid, Mo dissolves faster than Al, and Mo becomes anode. As the electomotive force between Mo and Al makes current more than 0.06 A/cm^2, the passivity of Mo is made in the etchant.

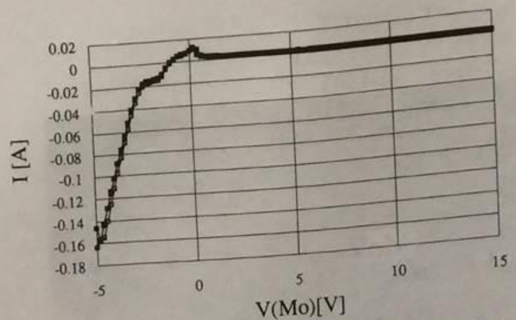



**Fig.4 Electric potential dependence of Mo dissolution current**

Then we tried nitrous acid dependence of Mo passivity using Mo-Pt cell in the etchant. First we applied 15V to Mo and stopped applying voltage to see the degradation of Mo.(Fig.5) The electric potential of Mo passivity goes down just after stopping voltage, and the electric potential reaches to the passivity potential. The passivity potential goes on for 60 sec and then passivity degraded and the electric potential goes to the potential of Mo.

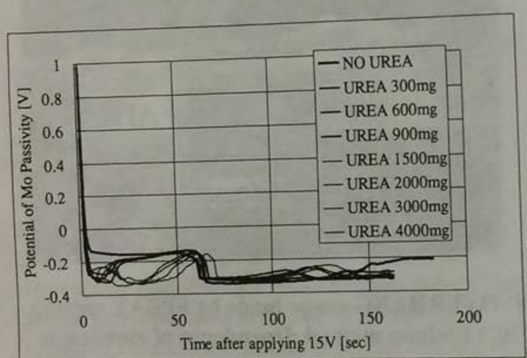



**Fig.5 Urea dependence of Mo passivity**

Next we tried adding urea to the etchant to reduce the amount of nitrous acid. The nitrous acid is reduced with this formula.

$$(NH_2)_2CO + 2HNO_2 \rightarrow 2N_2 + CO_2 + 3H_2O$$

We measured passivity degradation using this etchant with urea. As the amount of urea increase in the etchant, the passivity of Mo degrades much faster, and when the amount of urea come to 0.05 mol/l(1500mg in Fig.5) the passivity potential region disappeared. By this measurement, we can conclude that the Mo passivity easily degrade if the etchant is lack of nitrous acid because of Dip etching and the taper shape is made with Dip etching.

## 4.Gate Line Performance

Fig.6 shows the gate line resistance.The value of 12" XGA and 16" SXGA is the value in case of MT/Mo/Al structure. The value of 10"VGA is in case of conventional MT gate line. We can see that gate line of 12" XGA and 16" SXGA has very low resistance even if compared with VGA.

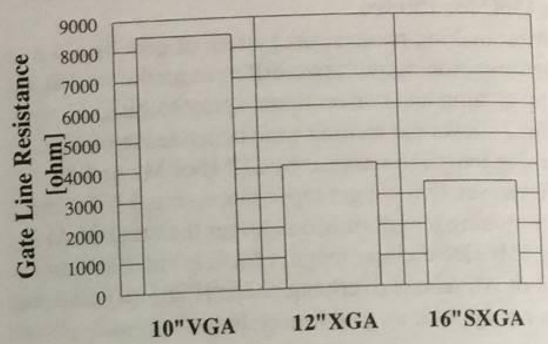



**Fig.6 Gate Line Resistance**

Fig.7 shows the time constant of 12" XGA and 16" SXGA.The time constant is less than 1.5 sec in case of 12"XGA, and the time constant of 16"SXGA is almost the same as that of 10"VGA.

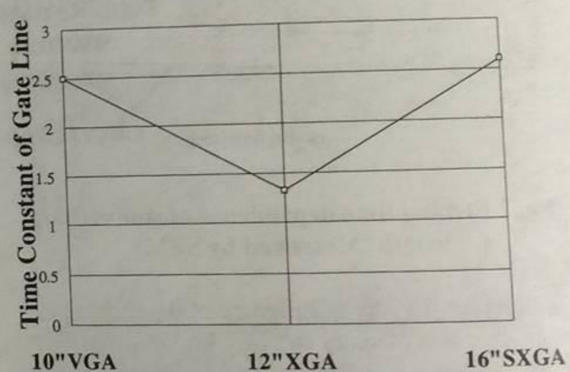



**Fig.7 Time Constant of Gate Line**

## 5.Yield of gate line test pattern

We made different kind of gate line structure by 10" VGA test pattern to see the yield of our gate line structure.

Fig.8 shows the gate line structure dependence of Signal Open defects.

The number of Signal open defects was 1/10 of the sample without taper etching. The yield of the sample of taper etching was better even if compared with the thinner 1000Å Al panel without taper etching.

| Al thickness [Å] | Mo [Å] | MT [Å] | Sig.Open/ Sig.line |
|---|---|---|---|
| 1000(w/o taper) | 500 | 2000 | 9.8E-4 |
| 2000(taper etch) | 500 | 2000 | 1.3E-4 |
| 2000(taper etch.) | 500 | 3000 | 1.9E-4 |
| 2000(w/o taper.) | 500 | 2000 | 1.5E-3 |

**Fig.8 Gate line structure dependence of Signal Open defects**

## 6.Conclusions

As polarization diagram of Mo shows that the passivity current density of Mo is 0.06A/cm^2, Mo makes passivity because of the electromotive force of Mo-Al electric cell.

Dip etching makes nitrous acid on cathode electrode drift away.Because of the shortage of polarizer nitrous acid, the passivity of Mo easily degrade. As dip etching of Mo/Al urges the degradation of Mo passivity, the etching rate of Mo is faster than Al and taper shape of Al is stably made.

The yield of Al gate line depends mainly on the coverage of SiOx gate insulator. Dip etching of Mo/Al can make good taper shape and can make good coverage of gate insulator.

12" XGA (Fig.9) and 16" SXGA LCD display is manufactured with taper etching using dip etching technique, and low resistance gate line is obtained, and the time constant of gate line is low enough to drive TFT effectively.

**Fig.9 12.3" XGA TFT/LCD Product (IBM Green PC)**


## 7.Acknowledgements

The author wish to thank to Mr.S.Tsuji for TEM photograph.


## 8.References


[1] Kawamura et al., "An a-Si TFT Array for 15-in. Full-Color High Resolution LCD",Japan Display92 (1992) 344