Study on vertical wet etching of aluminum metal film for TFT application

***Sang-Hyuk Lee*[1]*, Bo-Hyun Seo*[1]*, In-Kyu Lee*[1]*, and Jong Hyun Seo*[1]†**
***Kang-Woong Lee*[2]*, Jae-Hong Jeon*[2]*, Heehwan Choe*[2]*, Jong-Hyeok Ryu*[3]**
***Byungwoo Park*[4]*, and Dae-Hyun Chang*[4]**
[1] **Dept. of Materials Engineering, Korea Aerospace University, 100, Hanggongdae gill, Hwajeon-dong, Deogyang-gu, Goyang-city, Gyeonggi-do 412-719, Korea**
Tel: +82-2-300-0161, E-mail: jhseo@kau.ac.kr
[2] **School. of Electronic Engineering, Korea Aerospace University, 100, Hanggongdae gill, Hwajeon-dong, Deogyang-gu, Goyang-city, Gyeonggi-do 412-719, Korea**
[3] **KW-Tech,Rm907, Byucksan Technopia, 434-6 Sangdaewon, Jungwon, Seongnam, Gyeonggi, 462-716, Korea**
[4] **FNS Tech, 11-1block 4Local Industry Complex Mosi-Ri, Jiksan-Eup, Cheonan-City, Chung-Nam, Korea**

Keywords: Wet etching, Vertical transfer, TFT, Aluminum

Abstract

Compared with tilt transfer wet station, vertical etching system has a variety of advantages that are 50% space savings, higher throughput, fairly good etch uniformity over an entire glass for thin film transistor application. The aim of the present work is to study on a vertical etching system to improve the process factors. The computational fluid dynamics analysis is used to demonstrate the change of the etch uniformity as a function of tilt angle of the glass substrate.

1. Introduction

As the size of the mother glass for TFT industry becomes lager and lager, most of the TFT companies encountered the ‘puddling effect’ that the etch rate in the puddle area of the glass substrate is much slower than the other areas. The puddling phenomena of the glass substrate result from both the heavy weight of wet chemicals on the glass and the weight of the mother glass itself. To avoid the puddling effect in the wet station, most of companies have adopted a method of the tillt transfer system with a timed sprays or pressure profiles across spray bars.

However, the tilt transfer system still has problems of large footprint and slow etch rate especially on the bottom of the glass where psuedo-puddling effects occurs due to glass’s heavy weight. To overcome such issues, the vertical transfer wet etching system for TFT application is proposed and developed by FNS Tech. The smaller footprint of vertical equipment has always been recognized as an advantage. The vertical transport of a huge mother glass of the height over 2 m is a significant problem for many fabricators to solve.

Since the gravity affects liquid etchant flow, liquid accumulation on the substrate during wet etching, the etch rate and etch uniformity on a huge glass substrate can be affected by tilt angle from nearly zero to vertical. The purpose of this study is to reveal the relationship between etch uniformity and tilt angle in wet station.

2. Experimental

Aluminum/molybdenum thin films were deposited on glass substrate using by DC magnetron sputtering at the temperature of 50℃. All the samples were patterned with gate lines of 10 mico-meter widths using by photolithography process. The etching tests of the Al/Mo samples were conducted in vertical wet station equipped with spray bar. After the etching tests, the etching rates were measured by KLA-Tencor surface profiler. For wet etching simulation, computational fluid dynamics (CFD-ACE+) were used .

3. Results and discussion

Even though an exact mechanism of the wet etching of the aluminum/molybdenum thin film is not known, it is well-known that the dissolution of the aluminum thin film in highly concentrated phosphoric acid solution is determined by a diffusion process. A viscous thin liquid film formed on the aluminum surface immediately after an immersion of the aluminum specimen in wet etching solution is a strong evidence for the diffusion controlled system. The main reaction equation is described in Eq. (1).

$$Al_2O_3 + 2H_3PO_4 \rightarrow 2AlPO_4 + 3H_2O \qquad (1)$$

The wet etching phenomenon controlled by diffusion process can be expressed by following equation [1].

$$\frac{\partial \rho\phi}{\partial t} + \nabla \bullet (\rho\vec{\mathbf{V}}\phi) = \nabla \bullet (\Gamma\nabla\phi) + S_\phi \qquad (2)$$

Where $\frac{\partial \rho\phi}{\partial t}$ is the rate of change of the relevant property per unit volume, $\nabla \bullet (\rho\vec{\mathbf{V}}\phi)$ is the convection flux of the species, $\nabla \bullet (\Gamma\nabla\phi)$ is the diffusion term, and S_ϕ is the source term. The other parameters in the Eq. [2] are summarized in the Table 1.

Table 1. Aluminum wet etching model parameters.

PParameter	Name	VValue/Units
ϕ	Concentration	mol/cm^3
ρ	Pressure	0.1 MPa
$\vec{\mathbf{V}}$	Velocity	cm/s
Γ $AlPO_4$	Diffusion coefficient of $AlPO_4$	1E^{-8}cm^2/sec
Γ H_3PO_4	Diffusion coefficient of H_3PO_4	1E^{-6}cm^2/sec

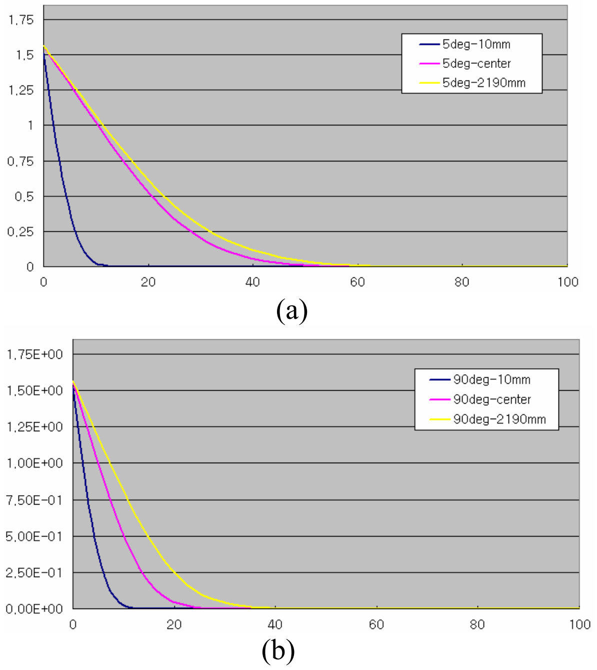

Fig. 1. $AlPO_4$ concentration profiles of (a) 5^o tilt transfer system and (b) 90^o vertical transfer system. Indicated (mm) is measured distance from the top of the glass substrate.

$AlPO_4$ concentration profiles are shown in Figure 1. In the case of 5^o tilt system, there is a sudden change in the concentration profiles between top and middle/bottom area of the glass substrate. The concentration of $AlPO_4$ in the top region of the glass substrate steeply dropped compared with middle and bottom region of the glass. It implies that the etch rates in the middle/bottom area is much slower than that in top area. It is attributed to the 'pseudo-puddling effect' in the tilt-transfer system. This resulted in the non-uniformity of etch rate and taper angle of the metal lines over the glass. However, in the case of vertical transfer system, the shapes of the surface concentration profiles are almost the same independent of the position in the glass. It means that the etch rate gradually decreased along distance from the top of the glass substrate. It is concluded that the 'pseudo-puddling effect' shown in the tilt transfer system did not appear in the vertical transfer system.

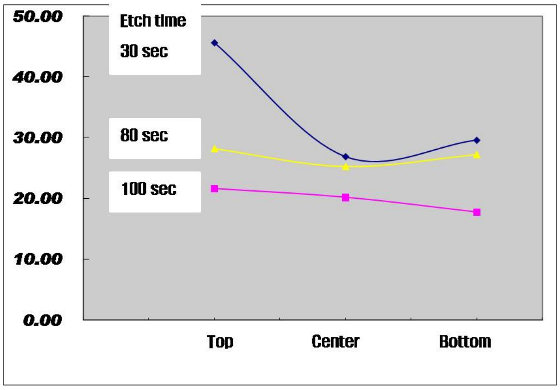

Fig. 2. Distribution of etch rates in the vertical etching system as a function of etching time. The etch rate scale is Å /sec.

Figure 2 shows the distribution of measured etch rates in vertical etching system. In the initial stage of the vertical wet etching, there is a fluctuation in etch rates along the height of the glass substrate. The lowest etch rate appears in the middle center of the glass. It is a transient phenomenon and is attributed to the overlapping of up and down spray injection. Moreover, such non-uniformity of etch rates disappears as the etch times passed.

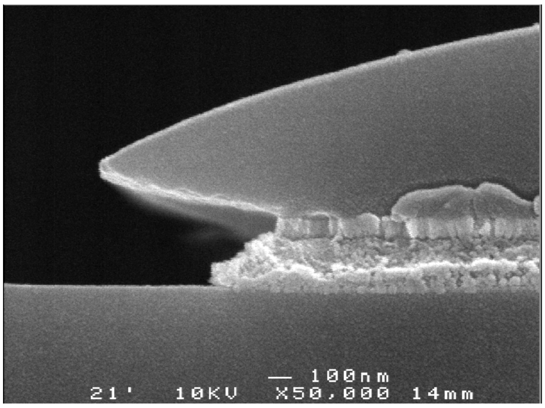

Fig.3. Cross-sectional scanning electron microscopy images of aluminum/molybdenum double layer etched by vertical transfer wet station.

Figure 3 shows the SEM images of Al/Mo sample etched by vertical transfer system. The thicknesses of aluminum and molybdenum are 2500Å and 500 Å, respectively. The taper angle of this gate line is approximately 50^{o} which is suitable for the thin film transistor application.

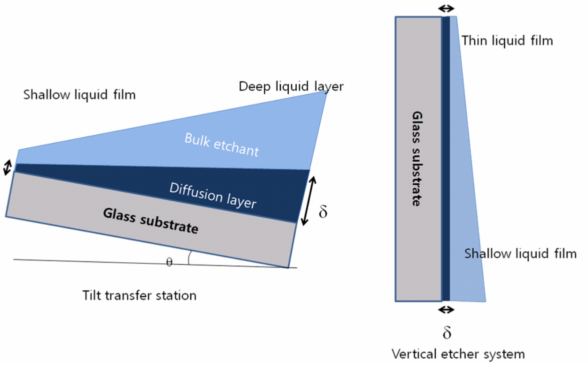

Fig.4 Tilt transfer station and vertical etcher system showing the different thickness of liquid layer

Fig. 4 shows the schematic diagrams for the tilt transfer station and vertical etcher system. As it shows, in tilt transfer system, liquid film gradually increased with increasing distance from the top of the glass substrate. On the other hand, vertical etcher system has almost a constant thickness of thin liquid film over the entire glass substrate. Since the etch rate is reversely proportional to the thickness of the diffusion layer on the thin film, it is expected that the etch rate of the tilt transfer system decreased with increasing the distance from the top region but the etch rate of the vertical etching system is nearly independent of the position on the glass substrate. The dissimilarity in the thicknesses of the diffusion layers between the two different transfer systems significantly influences the etch rate and etch uniformity over the glass substrate during the wet etching.

4. Summary

To overcome 'pseudo-puddling effect' which occurs in tilt transfer wet station, a new vertical transfer wet station was suggested. In this work, aluminum/molybdenum multi-layers on glass substrates for gate line were tested using by prototype vertical wet station. The etch rate uniformity were greatly enhanced compared with conventional tilt transfer wet station and taper angle of the etched sample was suitable for the thin film transistor application. Such phenomena were explained by both CFD simulation and a simple physical model.

Acknowledgement

This work was supported by a Grant-in-Aid for

Strategy Technology Development Programs from the Korea Ministry of Knowledge Economy (No.10031169).

5. References

1. Suhas V. Patankar, "Numerical Heat Transfer and Fluid Flow" pp.15-17, McGraw-Hill Book Company, 1980