

Dry Etch Process Development for TFT-LCD Fabrication Using an Atmospheric Dielectric Barrier Discharge

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Abstract

We present the development of dry etch process for the liquid crystal display (LCD) fabrication using a dielectric barrier discharge (DBD) system at atmospheric pressure. In this experimental work, the dry etch characteristics and the electrical properties of thin film transistor are evaluated by using the scanning electron microscopy and electric probe, and TFT-LCD panel (300 mm X 400 mm) is manufactured with the application of the amorphous silicon etch step in the 4 mask and 5 mask processes.

1. Introduction

Thin film transistor liquid crystal display (TFT-LCD) is regarded as a popular display panel for various applications such as a mobile phone, a PC monitor, and a television because of its advanced display properties [1,2,3]. In its recent industrial manufacturing, it is increasingly required to significantly decrease the cost of LCD panel manufacturing, especially for large sized display.

Dry etch process using low pressure plasmas plays a key role in manufacturing TFT-LCD device. The advantages of the low pressure plasma are well known. They generate high concentrations of reactive species that can etch at rates up to 1 $\mu\text{m}/\text{min}$. The temperature of the gas is usually below 150 $^{\circ}\text{C}$, so that thermally sensitive substrates are not damaged. The ions produced in the plasma can be accelerated toward a substrate to cause directional etching of submicron features [4,5].

In addition, a uniform glow discharge can be generated, so that materials processing proceeds at the same rate over large substrate areas. On the other hand, operating the plasma at reduced pressure has several drawbacks. Vacuum systems are expensive and require maintenance. Load locks and robotic assemblies must be used to shuttle materials in and

out of vacuum. Also, the size of the object that can be treated is limited by the size of the vacuum chamber.

Atmospheric pressure plasmas overcome the disadvantage of vacuum operation [6, 7]. However, the difficulty of sustaining a glow discharge under these conditions leads to a new set of challenges. Higher voltages are required for gas breakdown at 760 Torr, and often arcing occurs between the electrodes. To prevent arcing and lower the gas temperature, dielectric barrier discharge scheme has been devised., and this source can etch at low temperature.

The etch process at atmospheric pressure has the potential to enable roll-to-roll etch proceeding. The roll-to-roll fabrication of LCD devices has attracted a great attention because it offers the possibility to significantly decrease the cost of flexible display manufacturing [3].

In this experiment work, the dry etch characteristics by the atmospheric plasma technology are evaluated using the optical microscope and the scanning electron (SEM) in 4-mask and 5-mask process. Also, the electrical transfer curves are measured for TFT fabricated by the process.

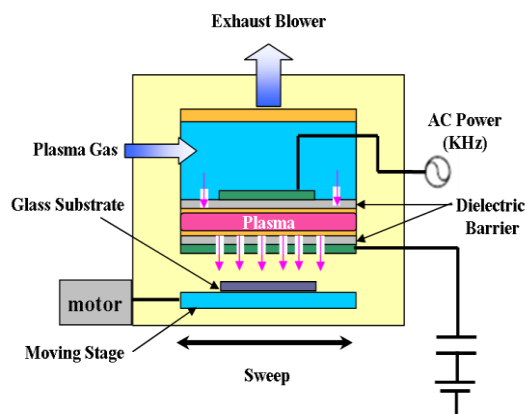


Fig. 1. Schematic of a dry etching process system

using an atmospheric dielectric barrier discharge

2. Experimental

The experimental system for the atmospheric dry etch process consists of a plasma generator using a dielectric barrier discharge, injectors of plasma and etching gases, a substrate stage, and a gas exhaust. A schematic diagram of the system is shown in Fig. 1.

The atmospheric plasma is generated by the plate type dielectric barrier discharge. A mixture of nitrogen and helium is used as a plasma gas. And, SF_6 gas is used as an etching gas. The plasma flows for etching blow into a substrate through many small size gas holes. The gases and etching products are exhausted by a blower. As a result, pressure of the etching system is sustained at about 720 Torr. A substrate stage is repetitively swept under the plasma flow and amorphous silicon etching process is conducted by the plasma flow, which has numerous radicals for silicon etching.

For this etching evaluation and panel device fabrication, conventional 4-mask and 5-mask process is utilized. Fig. 2(a) and (b) show the schematic cross sections of the TFT structure fabricated by the 4-mask and 5-mask process, respectively. The Al/Mo layers are deposited and patterned for the gate electrodes. SiN_x , a-Si:H and n^+ a-Si:H layer are deposited successively. In 5-mask process, the active region of

mask

a-Si:H is etched by the atmospheric plasma process. In 4-mask process, meanwhile, Al/Mo/Al layer are deposited on the n^+ a-Si:H, and data lines are formed by a wet etch process. The active region of a-Si:H, which is revealed after data line patterning, is etched by the atmospheric process. As a reference, dry etching of the active region is carried out by the conventional low pressure process. The etching aspects are evaluated by optical microscope and SEM.

n^+ a-Si:H layer is etched with conventional low pressure plasma process. SiN_x layer for passivation is deposited, and the contact holes on the electrodes are produced by a conventional low pressure dry etching. The IZO pixel electrodes are patterned and TFT transfer characteristics are measured using the HP 4156.

3. Results and discussion

Fig. 3 shows optical microscope images of hydrogenated amorphous silicon pattern etched by the atmospheric plasma using the dielectric barrier discharge and the conventional low pressure one for 5-mask and 4-mask process, respectively. After

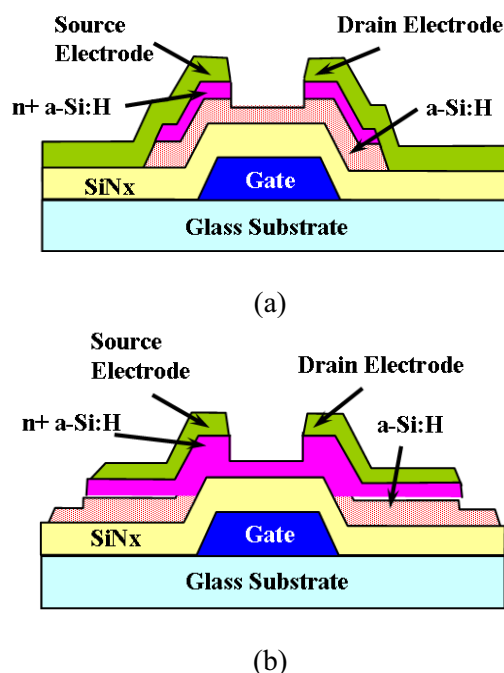


Fig. 2. Schematic cross sections of TFT structure by fabricated by conventional process: (a) 5-maks, (b) 4-

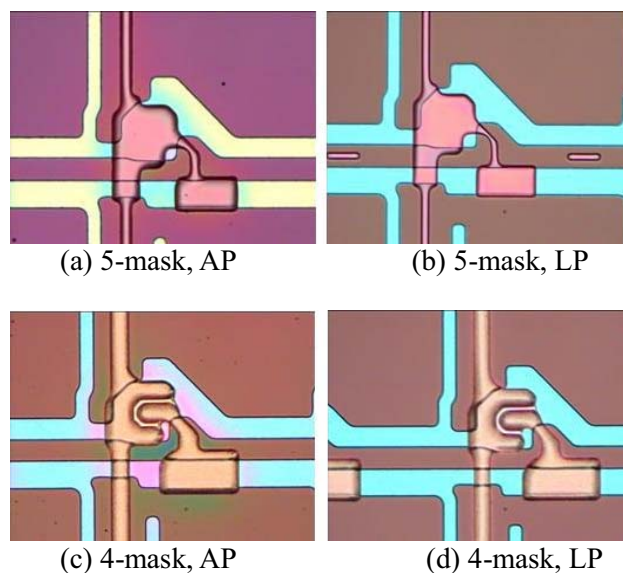


Fig. 3. Optical microscope images of TFT after s-Si:H etching step: (a) atmospheric pressure (AP) etching in 5-mask process, (b) low pressure (LP) etching in 5-mask process, (c) atmospheric pressure (AP) etching in 4-mask process, and (d) low pressure (LP) etching in 4-mask process

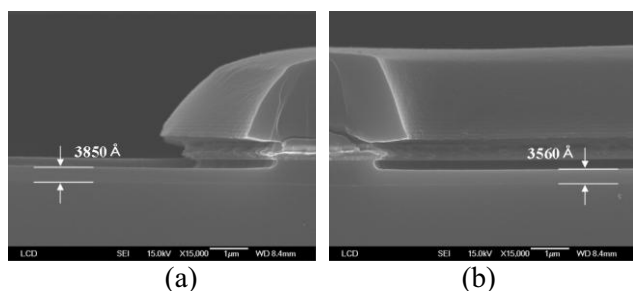


Fig. 4. High magnification SEM images after s-Si:H etching using the atmospheric pressure plasma in 4-mask process: (a) around data line and (b) around TFT (stain area)

a-Si:H dry etching with the atmospheric plasma, some stain, which is not seen in the conventional process, is found around TFT pattern as seen in Fig. 3(a) and 3(b). It appears because the etching depth in the stain area is different from the other one.

Fig. 4 shows SEM images of the a-Si:H pattern around the stain area in the 4-mask process. It is seen in Fig. 4 that the remained SiNx thickness is different between the stain areas and the other area. Accordingly, these SEM images prove that the reason of the optical microscopic stain is residual SiNx thickness difference.

Atmospheric plasma flow has viscous flow characteristics because sufficient collisions between the particles happen, contrary to low pressure plasma flow. So, the etching aspect is affected by the plasma flow characteristics. In the atmospheric dry etching process, vortex flow is produced around the silicon pattern by down-stream of the plasma with some radicals. As a result, etching rate of a-Si around the TFT pattern area happens to be higher than around no pattern area.

Fig. 5 shows the a-Si:H etching profiles by the atmospheric in 4-mask and 5-mask process, respectively. In the case of 4-mask process, a-Si:H is etched toward the line of data metal instead of photo resistor. It seems that the atmospheric process has isotropic etching characteristics because mean free path of the plasma radicals is extremely short at atmospheric pressure in comparison with the conventional low pressure plasma process. This process seems to be similar to wet etch characteristic even though a dry etch process.

In the 5 mask process, a-Si:H is etched toward the line of photo resistor masking as seen in Fig. 5(c). However, under-cut layer is generated under the photo resistor as the wet etch process. This results show that characteristics of atmospheric plasma etch process are

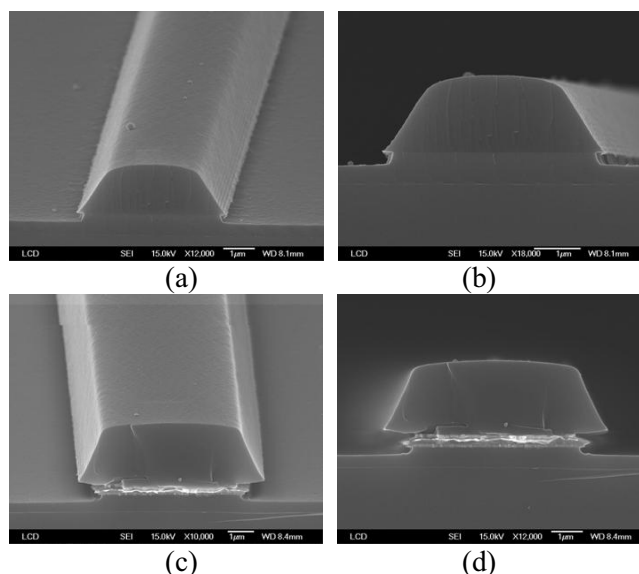


Fig. 5. Low magnification SEM images after a-Si:H etching using the atmospheric pressure plasma: (a) tilted view in 5-mask process, (b) cross sectional view in 5-mask process, (c) tilted view in 4-mask process, and (d) cross sectional view in 4-mask process

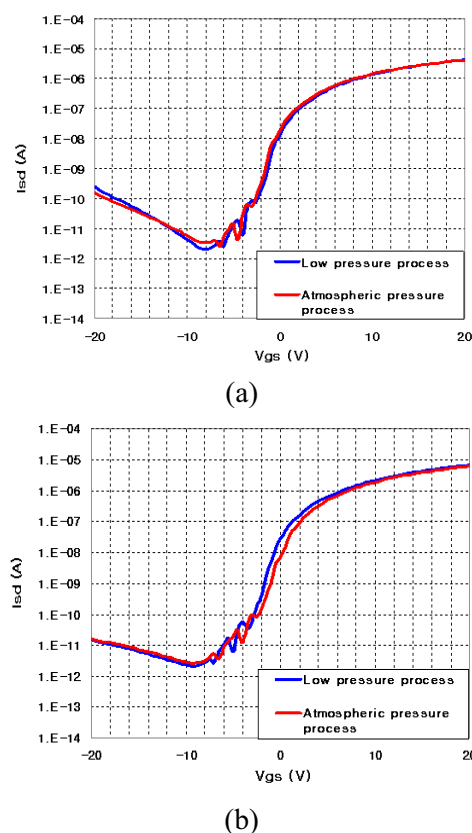


Fig. 6. Comparison of Transfer curves of TFT fabricated by the atmospheric pressure etching process and the conventional low pressure etch process: (a) 5-mask process and (b) 4-mask process

in the middle range between the wet and the conventional dry etch with low pressure.

Fig. 6 shows the compared transfer characteristics of the a-Si:H TFTs fabricated by the a-Si:H etching between with the atmospheric plasma process and the conventional low pressure that. In the 5-mask process, the threshold voltages of the TFTs by the atmospheric plasma etching and low pressure etching are 2.36 V and 2.46 V, respectively. The off current is below 2.48 pA and 2.91 pA, respectively. The Ion/Ioff current ratio are larger than 10^6 , which suggests these a-Si:H TFTs have good switching capability.

In the 4-mask process, the threshold voltages of the TFTs by the atmospheric plasma etching and low pressure etching are 2.94 V and 2.43 V, respectively. The off current is below 3.52 pA and 3.75 pA, respectively. The Ion/Ioff current ratio are also larger than 10^6 .

Transfer curve of TFT produced by the atmospheric pressure process is not different from those by the low pressure process. These TFTs are comparable to the TFTs fabricated by the conventional dry etching method. There is no significant degradation in the TFT characteristics.

Finally, 15-inch color TFT-LCD panel is successfully demonstrated. Fig. 7 shows the top view of this panel. Compared to the conventional panels with the low pressure dry etching, there is no significantly defect in the display image.



Fig. 7. 15-in color TFT-LCD panel fabricated by the atmospheric plasma dry etch process of active region of a-Si:H in 5-mask process.

4. Summary

For the application of an atmospheric plasma technology to dry etch process, in the experimental work, we have evaluated the etching characteristics by image analyses of optical and scanning electron microscopes. It has been found that a-Si is successfully etched by the atmospheric plasma process. It were also shown in the etch profile that characteristics of atmospheric plasma etch process were in the middle range between the wet and the conventional dry etch with low pressure.

TFT transfer characteristics by the atmospheric dry etching process were comparable to the TFTs fabricated by the conventional dry etching method and there was no significant degradation in the TFT characteristics. TFT-LCD panel manufactured by our process was successfully driven and don't have any display degradation.

5. References

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