Study on the n+ etching process in TFT-LCD Fabrication for Mo/Al/Mo Data Line

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Abstract

n+ etching process is investigated in the fabrication of TFT-LCD using low resistance data line of Mo/Al/Mo. Problems of consumption of upper Mo layer and contamination of channel area are resolved. Either of HCl or Cl_2 can be selected as a main etchant gas, and either of SF_6 or CF_4 can be selected as an additive. Plasma treatment after n+ etching process can reduce the off-current high problem.

1. Introduction

In recent years, the substrate size and resolution of active-matrix liquid crystal displays (AMLCDs) have been increasing rapidly. To meet the need for large area or high resolution LCDs, developments of processes are actively investigated[1,2]. In a viewpoint of the design of TFT-LCD interconnects, materials with lower resistivity is required[3,4]. Among the low-resistivity materials such as silver(Ag), copper(Cu), aluminium(Al), and their alloys, Ag and Cu have low resistivity. However, Ag shows poor adhesion and Cu has problems in patterning process[5,6]. Al is a good candidate in a view point of adhesion and patternability. Although stress-migration phenomena such as hillock may occur, we can get away with the problem by applying capped structure-such as Mo/Al/Mo or Ti/Al/Ti.

Usually, the data line metal might be used as a mask for n+ etching process. However, in the application of Mo/Al/Mo data lines, some amount of Mo might be consumed during n+etch process. In the usual n+ etch process, combinations of fluorine and chlorine gases are used. If Mo is exposed in the n+ etch process, Mo is easily consumed. This Mo-consumption suggests that we cannot use data line as a mask in n+ etch process.

In the current work, bottom gate AMLCDs using Mo/Al/Mo data lines were fabricated, and n+ dry etching was carried out by using a capacitively coupled plasma. At first, three types of masks are tested. Further, completion of combinations of gases were examined for n+ dry etching process, along with effects of plasma treatments after a n+ etching process.

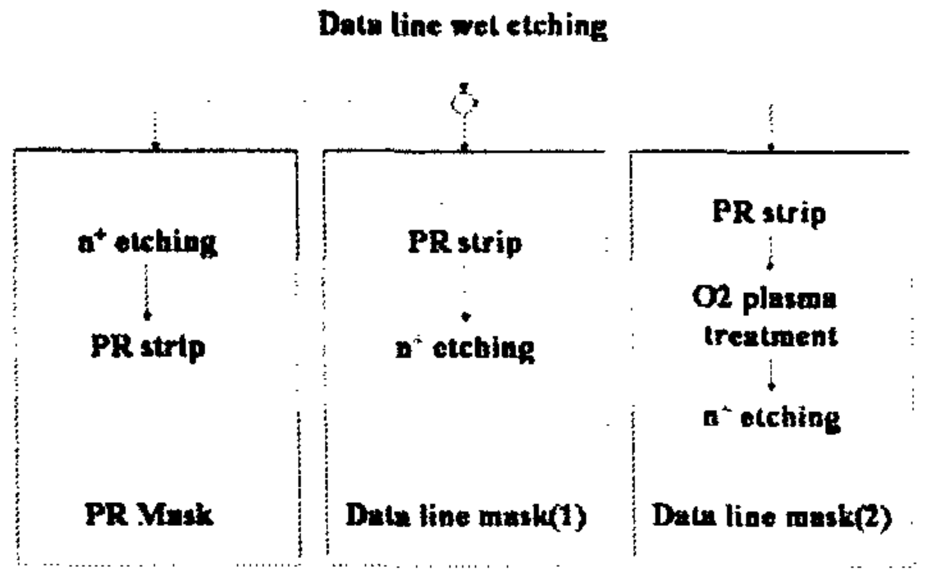

Figure 1. Process flow of n+ etching using three types of mask.

2. Mask of n+ etch process

The usual bottom gate TFTs were fabricated using Mo/Al/Mo data lines to test n+ etching process. At first, gate line was patterned. After that, triple layers(n+a-Si/a-Si/SiNx) were deposited and dry etch process is performed to remove n+a-Si/a-Si except island active area. Sputtering was used to deposit Mo/Al/Mo, and wet etching was used to make data line pattern. In the n+ etching process, three types of masks were tested for n+ etching process. One is photoresist(PR). Another mask was Mo/Al/Mo data line. The third was oxygen plasma treated Mo/Al/Mo data line after PR strip. Figure 1 describes process flows for different kinds of masks. In the n+ etching process, capacitively coupled plasma(CCP) source was used. For a gas selection, one of chlorine gases (HCl or Cl_2) and one of fluorine gases (CF_4 or SF_6) were selected. After n+ etching, the panels

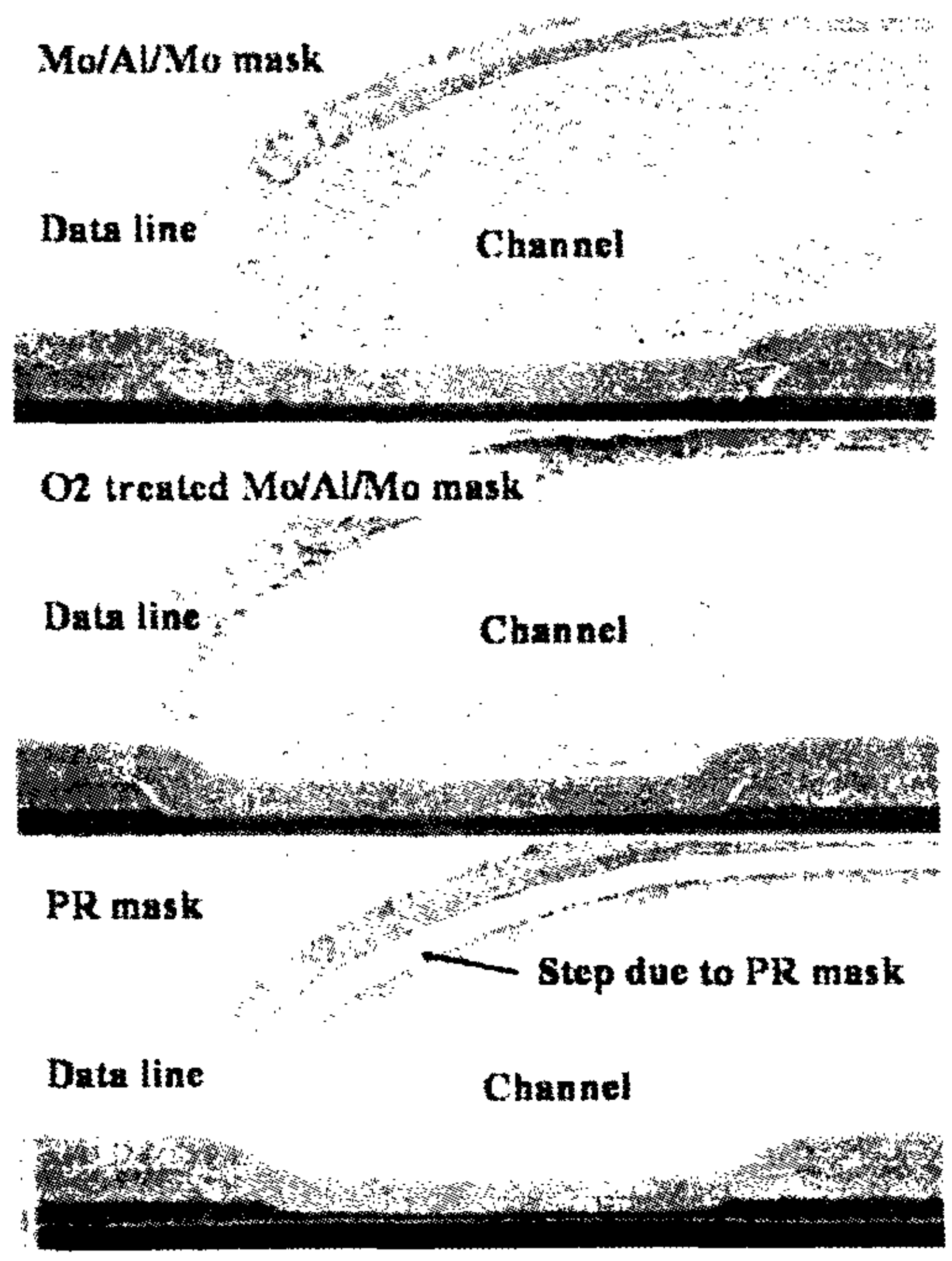

Figure 2. SEM picture of channel area for three kinds of mask for n+ etching.

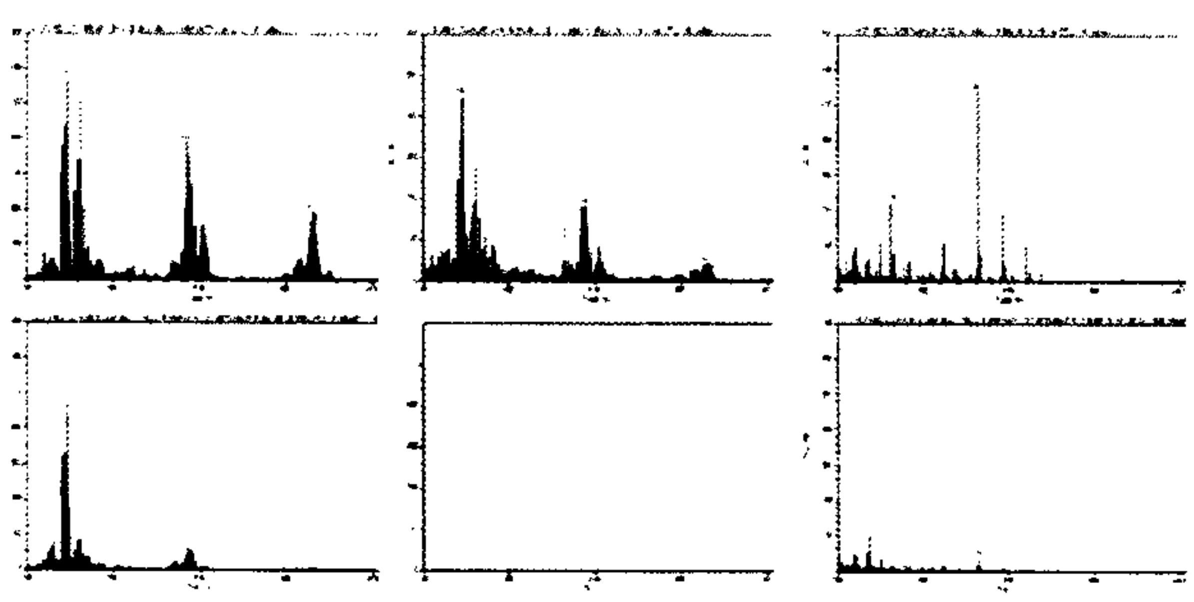

Figure 3. TOF-SIMS analysis of channel area (MoAlMo mask, O_2 plasma treated MoAlMo mask, and PR mask from left): Upper figure is obtained after n+ etching to observe the surface contamination and lower figure is obtained after Ga DC-sputtering(50 sec) is applied to the upper sample.

were further processed with normal passivation and pixel processes to obtain transfer characteristics of TFTs.

Surface of channel area is given in figure 2. To reduce data line consumptions, HCl and CF_4 were used for data line and O_2 plasma treated data line masks. Mo/Al/Mo data line mask for n+ etching shows heavy channel contamination. O_2 plasma treated data lines mask also shows channel area contamination, but less than Mo/Al/Mo data line mask case. However, no channel area contamination existed when PR mask is used. PR mask n+ etching gives a step near data lines when PR is removed after n+ etching, because normal wet etching of data line gives an undercut under PR due to isotropy of wet chemical. The width of this step depends on wet etching undercut.

To identify channel area contamination, the channel area was analyzed using Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS). The TOF-SIMS results are shown in figure 3. As were expected, there are many etch-byproducts in channel for Mo/Al/Mo data line mask.

For O_2 plasma treated data line mask, there were less etch byproducts in channel compared to Mo/Al/Mo data line case. The etch-byproducts contain Mo, and this asserts that there was Mo consumption during n+ etching process. Contrary to these two cases, there was little contamination in PR mask case. The channel area does not contain Mo etch byproducts.

Transfer characteristics of TFTs for three cases are given in figure 4. For Mo/Al/Mo data line mask, the off-current is higher than other cases. O_2 plasma treated Mo/Al/Mo data line mask gives a good characteristic, although there was some channel area contamination. But this cannot guarantee the stable characteristics of TFTs, because the etch byproducts may increase the off-current. PR mask shows typical I-V characteristic as expected. As a mask for n+ etching, there are two problems in using Mo/Al/Mo data line, with or without O_2 plasma treatment. One is Mo consumption which may reduce margin in passivation etch process, and the other is channel area contamination by Mo etch byproducts which may affect characteristics of TFTs.

3. Effects of Etching Gases and Plasma Treatments

Samples were prepared to test n+ etching process following same procedures as described in section 2. In this section, only PR mask is used in the n+ etching process. Both fluorine and chlorine gases in n+ etch process were used, either of Cl_2 and HCl as a chlorine source and either of CF_4 and SF_6 as a fluorine source. There are four possible combinations in selecting gases. For the reasons of selectivity to the SiNx layer, chlorine gas was used as main gas and fluorine gas was used as additive. After n+ etching, three kinds of treatments were carried out; He, O_2, and He/O_2 plasma. In addition to the plasma treatment, a retardation of samples after n+ etching and plasma treatment is performed.

Figure 5 shows that there is no difference between four combinations. The figure indicates that selection of n+ etching gases is not a significant parameter but the plasma treatment is an important one. The use of PR mask enhanced the margin in selecting gases in n+ etching process. Although PR mask is used for n+ etching process, there might be off-current high problem, if a plasma treatment is not accompanied after n+ etching process.

The effects of plasma treatment are shown in figure 6. Skip of the plasma treatment results in the off-current higher than 100 pA. Anyone of three kinds of treatment lowers the off-current less than 1 pA. It is reasonable to say that He or He/O_2 plasma treatments clean the substrates, change the structure of a-Si:H[6], and enhance

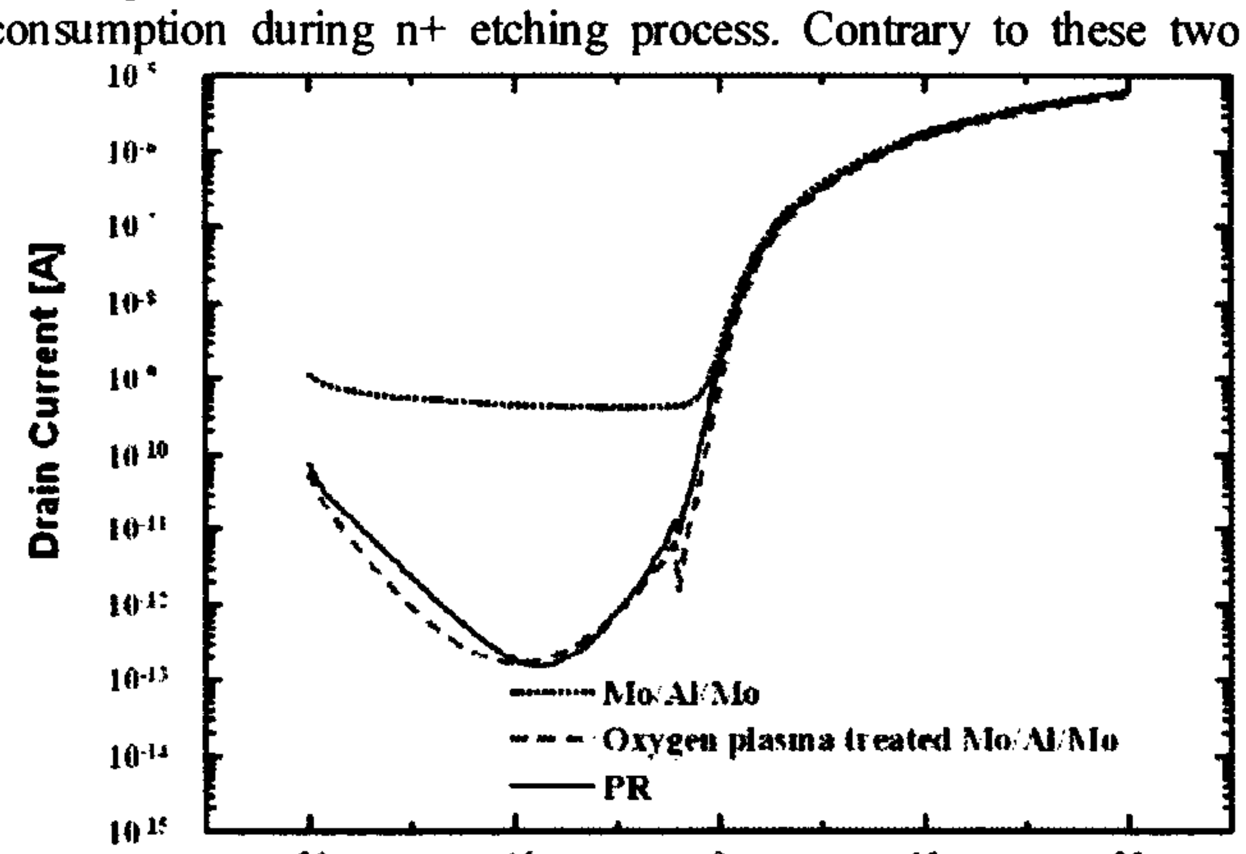

Figure 4. Transfer characteristics of TFTs for three kinds of mask

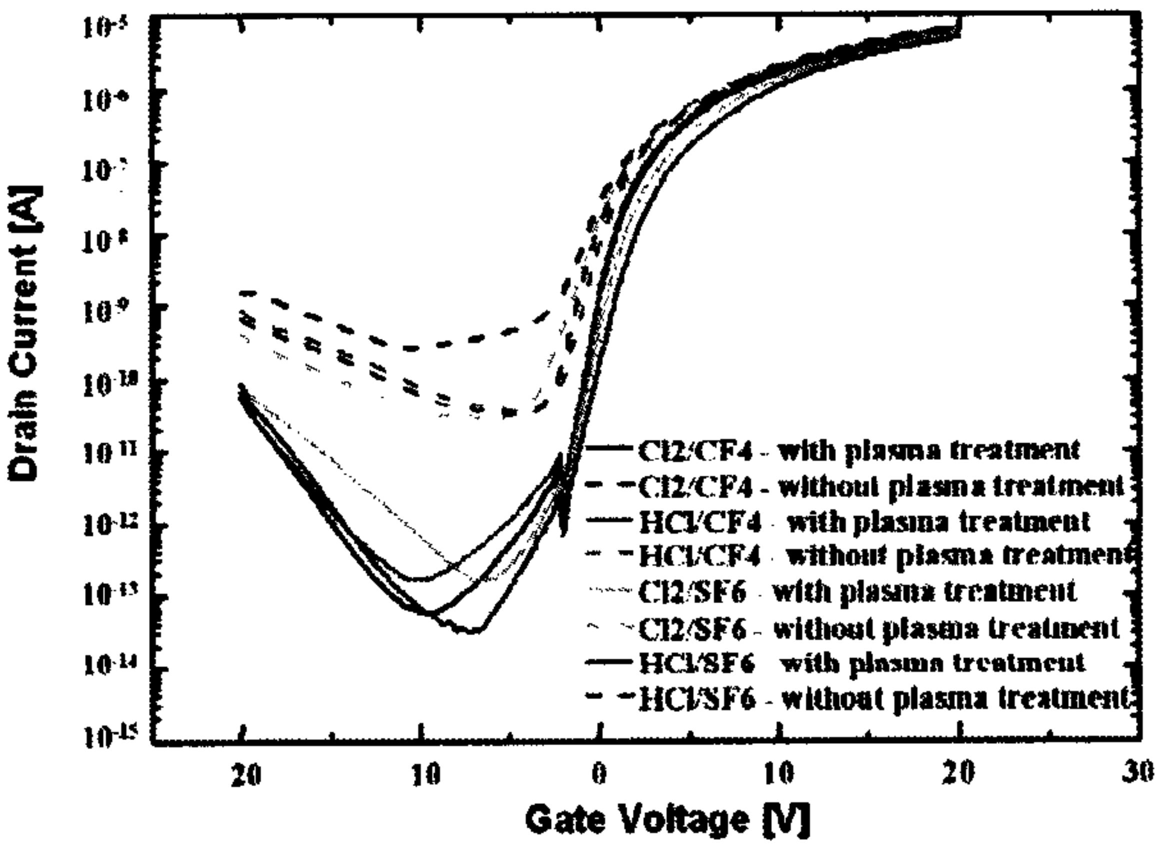

Figure 5. Transfer characteristics of TFTs for four kinds of gas selections. Plasma treatment is applied after n+ etching.

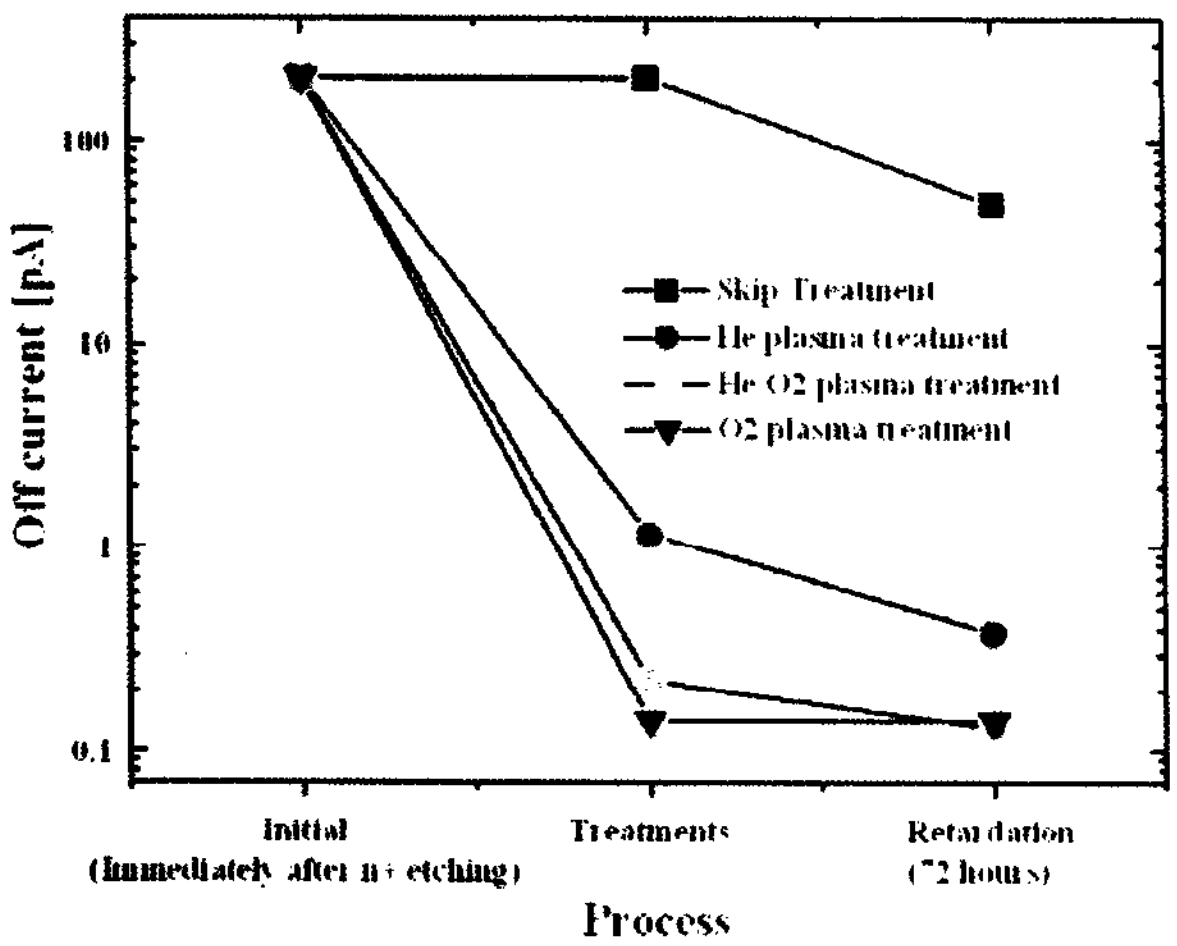

Figure 6. Off-current of TFTs for various treatment after n+etching.

the formation of Si- SiO_2 interface which may fill the role of passivation oxide[7,8]. To make native oxide layer on the a-Si:H, the samples were left in the clean room for 72 hours after n+ etching and plasma treatments. This retardation of process also shows a drop in off-current except for O_2 plasma treatment case.

For the sample without treatment, off-current decreased due to the retardation. This suggests that oxide film on Si surface play an important role in off-current drop, because retardation of samples forms native oxide film on Si surface. For the He plasma treatment case, there was off-current drop just after the treatment, and additional drop happened because of the retardation. The role of He plasma is supposed to detach terminated hydrogen from the Si surface. With this aid of He plasma treatment, the passivation oxide is rapidly formed after the He plasma treatment. It is supposed that the retardation forms additional oxide films on Si surface. There was a little off-current drop for He/O_2 plasma treatment and no off-current drop for O_2 plasma treatment. In these cases, oxide films are sufficiently formed on Si surface, because O_2 plasma is used in the treatment. Therefore the retardation gave little effect on the off-current.

Summarizing, in-situ plasma treatments after n+ etching decrease off-current, and it is supposed that the formation of passivation film play an important role in the off-current drop.

4. Conclusions

In this article, n+ etching process for TFTs using Mo/Al/Mo data line is discussed. PR mask n+ etching is a good solution for the problems of Mo consumption and channel contamination. The PR mask process widens the process margin in selecting n+ etching gases. And plasma treatment is required to lower the off-current.

5. Acknowledgement

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6. References

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