Reactive Ion Etching of a-Si for high yield and low process cost

Chang-Wu, Hur

Abstract— In this paper, amorphous semiconductor and insulator thin film are etched using reactive ion etcher. At that time, we experiment in various RIE conditions (chamber pressure, gas flow rate, rf power, temperature) that have effects on quality of thin film. The using gases are CF_4, CF_4+O_2, CCl_2F_2, CHF_3 gases. The etching of a-Si:H thin film use CF_4, CF_4+O_2 gases and the etching of a-SiO_2 ,a-SiN_x thin film use CCl_2F_2, CHF_3 gases. The CCl_2F_2 gas is particularly excellent because the selectivity of between a-Si:H thin film and a-SiN_x thin film is 6:1. We made precise condition on dry etching with uniformity of 5%. If this dry etching condition is used, that process can acquire high yield and can cut down process cost.

I. INTRODUCTION

Dry etching is widely used in semiconductor fabrication. It is also a critical process for the fabrication of large-area a-Si:H devices because it can solve some wet etching problems. Conventionally, wet etching is first considered for microelectronics fabrication process. The initial cost, e.g., equipment price, is low and the operation procedure, e.g., no involvement of vacuum technology, is simple. In the early stage of a-Si:H device manufacturing, wet methods were used exclusively. However, there are many practical problems in the wet process. For example, side reactions were observed in the wet etching of the n^+layer, i.e., a conductive residue between the source and drain was left after the etching. In another case, involving the tri-layer structure, when the a-Si:H island is wet etched, the undercut of silicon pattern is large, which may cause a step coverage problem for the subsequent metal deposition.

In addition, a sloped gate metal pattern is difficult to obtain with a wet etch method without modifying the metal layer structure. Reactive ion etching (RIE) can solve the above problems and many other advantages.

Etch characteristics of a-Si materials can be very different from their counterparts in VLSI, e.g., the former's etch rate is either much higher or lower than that of the latter. The optimum plasma chemistry for the etch selectivity strongly depends on the film's composition an℃d structure.

Manuscript received Sep, 2007.

Chang Wu Hur is with the Mokwon University, Department of Electronics Engineering (phone: 82-42-829-7655).

Each etch process can affect the production cost or the yield. For example, the high etch rate favors the production throughput. A highly selective n+ to intrinsic a-Si:H etch step makes it possible to manufacture the TFT using the bi-layer structure, which requires one mask fewer than that of the tri-layer structure. In this paper, amorphous semiconductor and insulator thin films are etched using reactive ion etcher. At that time, we experiment in various RIE conditions (chamber pressure, gas flow rate, rf power, temperature) that have effects on quality of thin film. If this dry etching condition is used, that process can acquire high yield and can cut down process cost.

II. THEORY

Each The etch chemistry of a-Si:H is the same as that of single crystal or polycrystalline silicon. It can be etched with fluorine- or chlorine- containing plasma, such as CF_4, SF_6, CCl_4, CCl_2F_2, CHF_3, HCl, NF_4, Cl_2, CF_3Cl, CF_2Cl_2 and $SiCl_4$, in combination with various other gases, O_2, H_2 and Ar. When there is no surface hindrance layer formed during the etching, the etch rate is affected by both the concentration of the effective etchant, such as F or Cl, and the ion bombardment energy. For the TFT application, the intrinsic PECVD a-Si:H film usually contains a large amount of hydrogen atoms, which are bounded in the SiH or SiH_2 form. Some hydrogen atoms are loosely attached to the Si network to rate is higher than that of single crystal silicon because fewer Si-Si bonds have to be broken. During the etch, most hydrogen is probably released in the Si-H form.The heavily phosphorous-doped a-Si:H layer, i.e., n+, can also be etched with the same fluorine- or chlorine-containing plasma process as that of the intrinsic a-Si:H. Process influences of these two materials are also the same. The etch chemistry of SiN_x is the same as that of LPCVD Si_3N_4. Both are etchable with the fluorine- or chlorine-containing gases, such as CF_4, SF_6, CF_3Cl, CF_2Cl_2 and various combination with O_2,

The etch selectivity between a-Si:H and SiN_x needs to be controlled in preparing various TFT structure. The high a-Si:H-to-SiN_x etch selectivity can be achieved by two methods: 1) selectivity forming a residue on the a-Si:H surface or 2) using the Cl-containing plasma chemistry. The first method is usually obtained by including hydrogen in the fluorocarbon feed stream. The second method is effective in achieving a high selectivity, as shown in Figure 1.

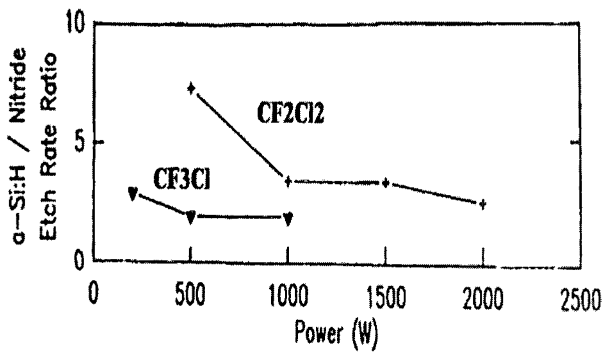


Fig. 1 a-Si:H-to-SiN_x etch ratio in CF_3Cl and CF_2Cl_2 plasma

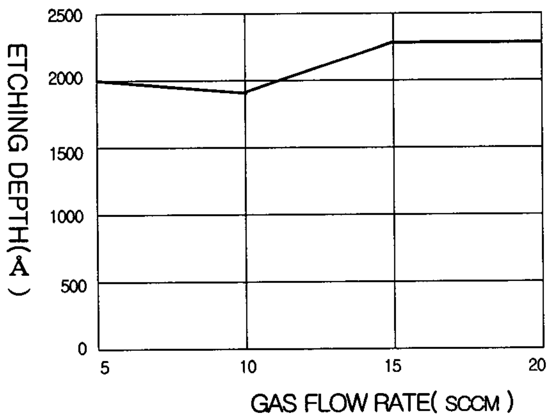
For the bi-layer TFT structure, a high etch selectivity between the n+ layer and the intrinsic a-Si:H channel, I.e., n+/a-Si:H etch rate ratio greater than 1, is critical to the product yield and device performance. For the inverted, staggered tri-layer TFT, a high n+-to-gate SiN_x etch selectivity is required to define the ohmic contact region. In general, the n+ etch chemistry is similar to that a-Si:H, e.g., F- and Cl-containing gases are effective etchants.

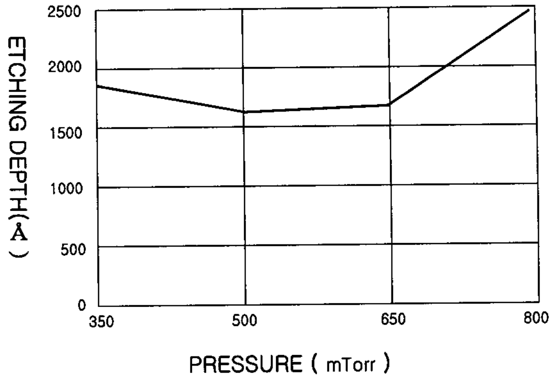
III. THE ETCHING OF A-SI:H THIN FILM

a. The etching (Plasmatec RIE 80μP) by CF_4+O_2,(8%) gas has regular 5% uniformity in power of 50watts, gas flow rate of 10 sccm and chamber pressure of 50mTorr.(Fig.2)

This condition can be used for comparative precise etching because of low etch rate. The etching of power of 50watts, gas flow rate of 25 sccm and chamber pressure of 50mTorr has unstable quality over 5% uniformity and cannot be used for very low etch rate.

The etching of rf power of 100watts, gas flow rate of 10 sccm and chamber pressure of 50mTorr has very excellent property under 2% uniformity and very fast etch rate. At the above condition, if chamber pressure and gas flow rate is changed to 50mTorr and 25 sccm respectively, etch rate ratio is increased and this status is very effective in achieving slope etching. (Table.1)





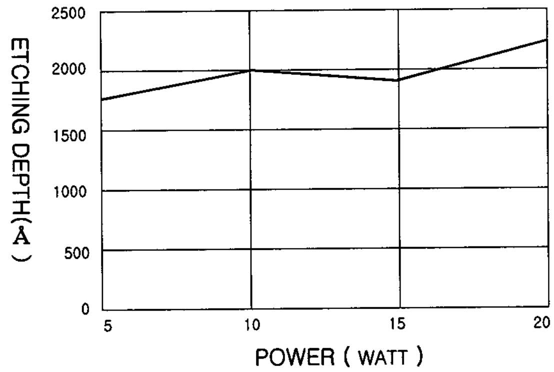


Fig. 2 Variation of etch rate as each process condition

Table 1 Etch rate of a-Si:H as deposition condition

a). Etch rate of a-Si:H as gas flow rate

SiH4 flow rate(sccm)	30	30	30	30
Pressure (mTorr)	500	500	500	500
Temperature(℃)	270	270	270	270
rf power (watt)	7	7	7	7
Etching rate (Å /min)	660	630	770	770

b). Etch rate of a-Si:H as rf power

SiH4 flow rate(sccm)	10	10	10	10
Pressure (mTorr)	800	800	800	800
Temperature(℃)	270	270	270	270
rf power (watt)	5	10	15	20
Etching rate (Å /min)	570	670	630	770

c). Etch rate of a-Si:H as chamber pressure

SiH4 flow rate(sccm)	10	10	10	10
Pressure (mTorr)	350	500	650	800
Temperature(℃)	270	270	270	270
rf power (watt)	7	7	7	7
Etching rate (Å /min)	600	530	630	830

b. The etching (Plasmatec RIE 800μP) by CF_2Cl_2 gas has etch rate of 800Å/min in power of 600watts, gas flow rate of 15 sccm, DC bias 60Volts and chamber pressure of 180mTorr. The etching by CF_2Cl_2 gas is effective in achieving a high selectivity and has small ion damage on lower film for low DC bias.

c. The etching by CHF_3 gas has etch rate of 40 Å /min in power of 600watts, gas flow rate of 40 sccm, DC bias

400Volts and chamber pressure of 50mTorr. The etching by this gas is also effective in achieving a high selectivity(6:1).

IV. THE ETCHING OF SIN_X THIN FILM

a. The etching (Plasmatec RIE 80µP) by CF_4+O_2,(8%) gas has regular 5% uniformity and etch rate of 800 Å /min in power of 100watts, gas flow rate of 10 sccm and chamber pressure of 50mTorr.

b. The etching by CHF_3 (Plasmatec RIE 800µP) gas has very excellent property in power of 600watts, gas flow rate of 40 sccm and chamber pressure of 50mTorr. Table 2 shows etch rate of SiN_x as deposition condition

Table 2 Etch rate of SiN_x as deposition condition

SiH4 flow rate(sccm)	30	30	30	30
NH4 flow rate(sccm)	120	120	120	120
Temperature(℃)	200	250	300	250
Pressure (Torr)	0.3	0.3	0.3	0.4
rf power (watt)	100	100	100	100
Etching rate (Å /min)	320	240	240	220

c. The etching (Plasmatec RIE 800µP) by CF_2Cl_2 gas has etch rate of 150 Å /min in power of 600watts, gas flow rate of 15 sccm, DC bias 60Volts and chamber pressure of 180mTorr. The etching by CF_2Cl_2 gas is effective in achieving a high selectivity.

V. THE ETCHING OF N^+A-SI:H THIN FILM

a. The etching (Plasmatec RIE 80µP) by CF_4+O_2,(8%) gas has regular good uniformity in power of 50watts, gas flow rate of 10 sccm and chamber pressure of 50mTorr.

At this time, etch rate is 400 Å /min and n+a-Si:H thin film of TFT is usually 500 Å, so etching time takes 70sec. But, we have to think about over etch, so if we etch n+a-Si:H thin film for 1.5 minutes the status of etch film is very good and process control is very easy.

b. The etching (Plasmatec RIE 800µP) by CF_2Cl_2 gas has etch rate of 800 Å /min in power of 600watts, gas flow rate of 15 sccm, DC bias 60Volts and chamber pressure of 180mTorr. The etching by CF_2Cl_2 gas is effective in achieving a high selectivity and has regular good uniformity.

VI. CONCLUSIONS

Dry etching get be accomplished in vacuum chamber, so can protect contamination of sample and is also possible automation of equipment. This process can cut down cost because of high yield. In this paper, we experiment in various RIE conditions (chamber pressure, gas flow rate, rf power, temperature) that have effects on quality of thin film. The using gases are CF_4, CF_4+O_2, CCl_2F_2, CHF_3 gases. The etching of a-Si:H thin film use CF_4, CF_4+O_2 gases and the etching of a-SiO_2 ,a-SiN_x thin film use CCl_2F_2, CHF_3 gases. The CCl_2F_2 gas is particularly excellent because the selectivity of between a-Si:H thin film and a-SiN_x thin film is 6:1. We made precise condition on dry etching with uniformity of 5%. If this dry etching condition is used, that process can acquire high yield and can cut down process cost.

The etching of a-Si:H by CF_4+O_2,(8%) gas in rf power of 100watts, gas flow rate of 10 sccm and chamber pressure of 50mTorr has very excellent property under 2% uniformity and very fast etch rate. The etching of SiN_x by CHF_3(Plasmatec RIE 800µP) gas has very excellent property in power of 600watts, gas flow rate of 40 sccm and chamber pressure of 50mTorr.

The etching (Plasmatec RIE 80µP) of n+a-Si:H by CF_4+O_2,(8%) gas has regular good uniformity in power of 50watts, gas flow rate of 10 sccm and chamber pressure of 50mTorr.

If this dry etching condition is used, that process can acquire high yield and can cut down process cost. So we can recommend highly this dry etching method to TFT process.

REFERENCES

[1] Chang W. Hur, "Method of Making Thin Film Transistors", United States Patent, Patent No.5,306,653, Apr. 1994.

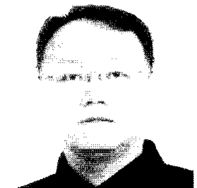
[2] B. Park, Process integration of a-Si:H Schottky diode and thin film transistor for low energy x-ray imaging applications, Mat. Res. Soc. Symp. A, April 13-17, 1998.

[3] K. Aflatooni, a-Si:H Schottky diode direct detection pixel for large area x-ray imaging, IEEE IEDM, December 7-10, Washington, D.C., 1997.

[4] B.W.Park, J.L.Choi, and C.W.Hur, "Micro-crystal silicon in image sensor," MIRS, vol.283, p.609, 1992.

[5] K. Aflatooni, R. Hornsey, A. Nathan, "Reverse current instabilities in amorphous silicon Schottky diodes: modeling and experiments," IEEE Trans. Electron Devices, vol.46, pp.1417-1422, 1999.

[6] Q. Ma, "ITO/a-Si:H Schottky photodiode with low leakage current and high stability ,"Mat. Res. Soc. Symposium B, Sanfrancisco, April, 5-9, 1999.



Change-Wu Hur
received his M.S. and Ph.D. degrees in Electrical and Electronic Engineering from the Yonsei University in 1984 and 1991, respectively. From 1986 to 1994, he joined at LG Research Center, where he worked as Senior Member of Technical Staff. In 1994, he joined the department of

Electronic and Information security Engineering, Mokwon University, Korea, where he is presently a professor. His research interest is in the area of VLSI and Display that includes ASIC design, Display technology and Wireless Communication design.