6/19/2012

Technics-Improved PECVD SiNx Etch Uniformity Using SF6 and 8" Cover Plates

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The etch uniformity of PECVD SiNx with SF6 in the Technics has been investigated using a cover plate over the chuck. Since the pumping port of this tool is located at the center of the sample chuck, the gas flow around the center is much larger than that around periphery of the chuck. As a result, the etching speed around the center is much faster than that around the periphery. This report shows that etching uniformity can be improved by using an 8" disc covering the whole chuck and carefully controlling the SF6 flow.

A 4"x4" stainless steel plate was first tried. The gap between the plate and the chuck was 1.5 mm. However, SF6 plasma was not observed on the plate, but outside the plate. It is assumed that there was strong gas turbulence on the plate.

Next, an 8" Si wafer and an 8" stainless steel disc were tested, and plasma etching on the disc was confirmed. The difficulty using 8" cover was to control the stability of plasma. Figure 1 shows the total (base + SF6) pressure at which plasma blinking starts vs. the gap between 8" cover plate and the chuck.

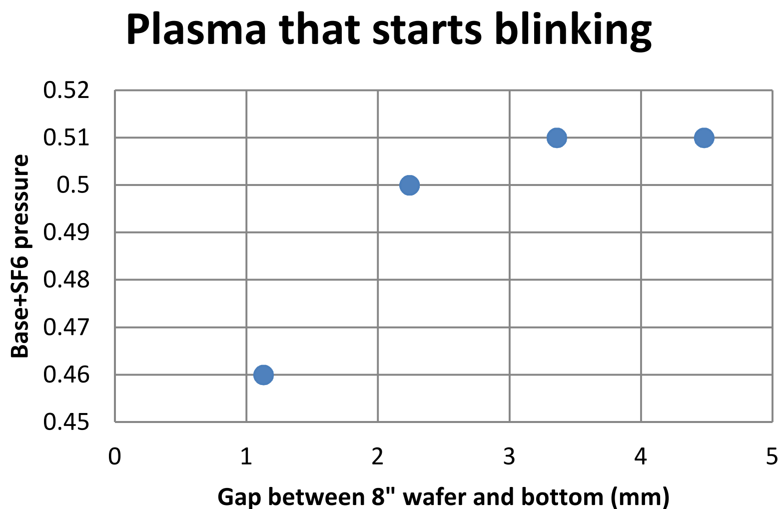


Figure 1. Total pressure at which plasma starts blinking vs. the gap space between 8" disc and the chuck. The base pressure was 0.43-0.44 Torr. The blinking was determined through visual observation.

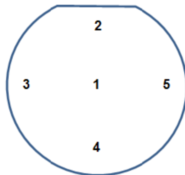
As can be seen in figure 1, the plasma becomes unstable when the pressure increases, and the stability limit of plasma saturated at 0.51 Torr, even if the gap was increased.

Table 1 indicates the results of SF6 etching of PECVD (Penn Nanofab standard recipe) silicon nitride on 4” silicon wafers. The wafers were centered with the 8” cover plate. Thicknesses were measured by ellipsometer before and after etching.

Table 1. Technics etching conditions and etching depths of PECVD silicon nitride on 4” silicon wafers placed on an 8” disc covering the tool chuck.

Base	Torr	0.427	0.438	0.452	0.443	0.445	0.445	0.441	0.454	0.445	0.443
SF6	mTorr	73	39	43	45	40	38	42	35	40	42
SF6 flow[1] (Top ball)		3.3	1.5	1.5	1	0.8	0.8	0.8	0.8	0.8	0.8
RF power	W	207	200	200	190-350	200	200	200	106	107	107
gap space[2]	mm	3.36	1.48	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Etch time	sec	240	60	60	30	15	30	45	30	45	60
Etch[3]	nm										
1		18.2	107.2	148.2	100.6	33.9	74.5	121.7	51.5	87.2	110.4
2		43.4	103.5	146.8	113.4	27.2	86.4	132.4	51.5	88.4	115.5
3		28.5	106.4	146	111.7	30	82.5	123.9	43.3	76.3	111.4
4		23.3	104	144.8	107.6	28.6	81.1	121.1	37.8	73.3	110.4
5		36.2	105	147.2	104.9	28.7	82.2	123.3	42.3	83.6	114.8
Avg		29.9	105.2	146.6	107.6	29.7	81.3	124.5	45.3	81.8	112.5
Stdev		10.1	1.6	1.3	5.2	2.6	4.3	4.6	6.0	6.7	2.5
Etch rate	nm/min	7.5	105.2	146.6	215.2	118.8	162.6	166.0	90.6	109.1	112.5
Uniformity	%	40.9	1.8	1.2	6	11	7.4	4.5	15.3	9.3	2.3
8" cover[4]		Si	Si	SS	SS	SS	SS	SS	SS	SS	SS

1) The gas flow was indicated by two balls in a flow meter. The values in the table are indications of top ball in the meter.
2) The distance between the 8” cover and the sample chuck.
3) The measuring points on 4” wafer are illustrated below.



4) Si, silicon wafer; SS, stainless steel disc

When comparing the two experiments using 8” Si wafer as the cover plate (3rd column and 4th column), it is seen that the average etch rate of 7.5 nm/min at the SF6 pressure of 73 mTorr is much smaller than 105.2 nm/min at the SF6 pressure of 39 mTorr. Furthermore, the 40.9 % uniformity at 73 mTorr is much worse than that of 1.8 % at 39 mTorr. According to this result, the optimal SF6 pressure for etching was determined to be ~40 mTorr.

The dependence of the etching on SF6 flow was investigated. The RF power was not stable at SF6 flow of 1.0 (6th column), although the etch rate (215 nm/min) doubled when comparing with that of 105 nm/min in the 4th column. When the SF6 flow was reduced to 0.8 (as shown in the 7th to 12th columns), the RF power was stable.

Two stable RF power settings were investigated: 107 and 200 W. Figure 2 shows etching depth of silicon nitride vs. etching time under these conditions.

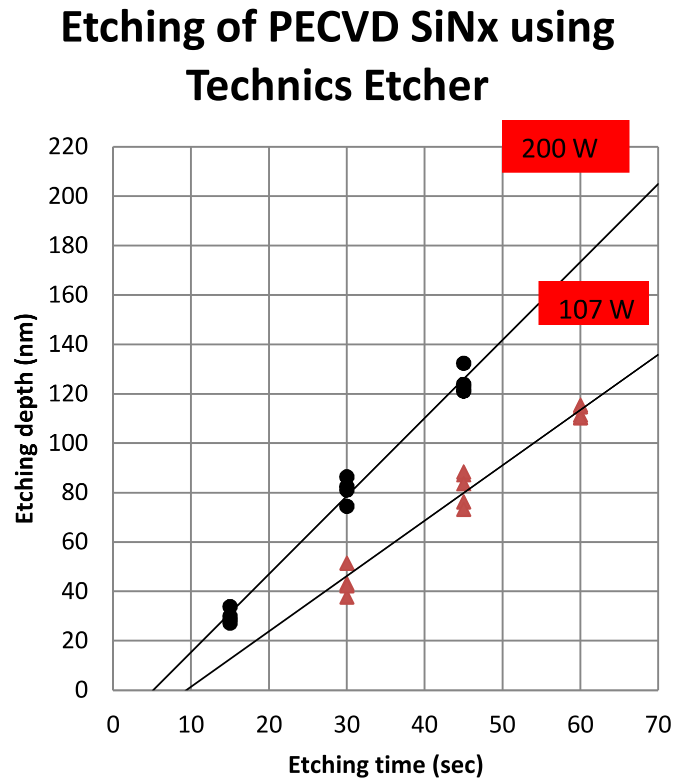


Figure 2. Etching depth of silicon nitride vs. etching time. Base pressure is 0.44-0.45 Torr; SF6 pressure is 38-42 mTorr; SF6 flow of top ball in the flow meter is 0.8. The linear regression lines are also added onto the plots.

The average etching rates at 107 and 200 W are 104.0 ± 11.8 and 149.1 ± 26.4 nm/min, respectively. The etch uniformity at 107 W are 15.3 % (15 second etch), 9.3 % (30 second etch), and 2.3 % (45 second etch), respectively. The etch uniformity at 200 W are 11.0 % (30 second etch), 7.4 % (45 second etch), and 4.5 % (60 second etch), respectively. This suggests that the etching uniformity improves with increased etch time, which might be related to the plasma stability.

Conclusions

This report shows that the uniformity of PECVD SiNx etching using SF6 can be improved by using an 8" cover plate over the whole chuck and carefully adjusting the gas flow and the separation between the plate and the chuck.

A SF6 pressure of ~40 mTorr was determined to give an acceptable etching rate and uniformity. A 150 nm/min etch rate can be attained at 40 mTorr SF6 pressure (1.5 mm separation and 0.8 flow) and 200 W.

The etching uniformity becomes less than 5 % when the etching depth is more than 100 nm, which might be related to the plasma stability.