CHAPTER 4

RESULT AND DISCUSSION

4.1 Result for fully-recessed LOCOS

4.1.1 Thickness measurement for pad oxide.

Table 4.0: Thickness of 1st pad oxide

Statistic	Layer 1 d	GOF
Mean	393.2 Å	0.99187
Median	390.9 Å	0.99238
Std. Dev.	4.8 Å	0.0031033
Min.	388.5 Å	0.98599
Max.	402.2 Å	0.99496
Meas. #	Layer 1 d	GOF
1	388.5 Å	0.99377
2	393.9 Å	0.99238
3	390.4 Å	0.99496
4	402.2 Å	0.98599
5	390.9 Å	0.99223

According to Table 4.0, shows the thickness of the 1st pad oxide for fully recessed LOCOS after oxidation process completed. The thickness of 1st pad oxide is measured in the 5 differences point on the wafer surface using spectrophotometer. The time process during the pad oxide grows took about 1 hour and the temperature is 900^0 C. Refer to the table shown above, the average thickness of pad oxide is about 393.2 Å which is less 1.7 % from the target thickness whereby, the target thickness for 1st pad oxide is 400 Å. But the percentage error still can be considered because the value of the target thickness compared with the experiment thickness not quit far.

Table 4.1: Thickness of 2nd pad oxide

Statistic	Layer 1 d	GOF
Mean	311.9 Å	0.99861
Median	311.3 Å	0.99884
Std. Dev.	3.8 Å	0.00052939
Min.	307.1 Å	0.99766
Max.	316.7 Å	0.99915
Meas. #	Layer 1 d	GOF
1	315.6 Å	0.99896
2	311.3 Å	0.99884
3	307.1 Å	0.99766
4	308.5 Å	0.99843
5	316.7 Å	0.99915

According to Table 4.1 above shows the thickness of the 2nd pad oxide for fully-recessed LOCOS after thermally grown using a furnace. The thickness of 2nd pad oxide is determined in the 5 differences point on the wafer surface same as the 1st pad oxide. Time process during the oxide grows took about 45 minute and temperature is 900^0 C. Referred to the Table 4.1, the average thickness of pad oxide is 311.9 Å which is greater 3.96 % from the target thickness whereby, the target thickness for 2nd pad oxide is 300 Å. But the percentage error still can be considered because the value of the target thickness compared with the experiment thickness not too far. The function of this layer called a pad or buffer oxide is to cushion the transition of stresses between the silicon substrate and the subsequently deposited nitride. In general, the thicker the pad oxide, the less edge force is transmitted to the silicon from the nitride. On the other case, a thick pad oxide layer will render the nitride layer ineffective as an oxidation mask by allowing lateral oxidation to take place. Therefore the minimum pad oxide thickness that will avoid the formation of dislocation should be used.

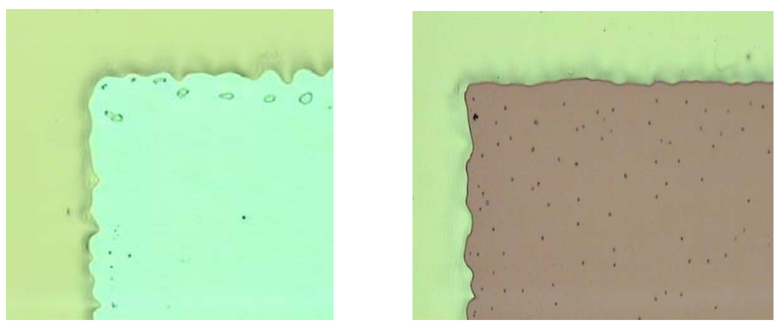
4.1.2 Nitride thickness measurement

Table 4.2: Thickness of nitride

Statistic	Layer 1 d	GOF
Mean	2272.9 Å	0.88301
Median	2331.9 Å	0.89107
Std. Dev.	85.4 Å	0.012942
Min.	2120.3 Å	0.85913
Max.	2339.1 Å	0.89363
Meas. #	Layer 1 d	GOF
1	2331.9 Å	0.89363
2	2120.3 Å	0.85913
3	2336.3 Å	0.89177
4	2339.1 Å	0.89107
5	2236.6 Å	0.87944

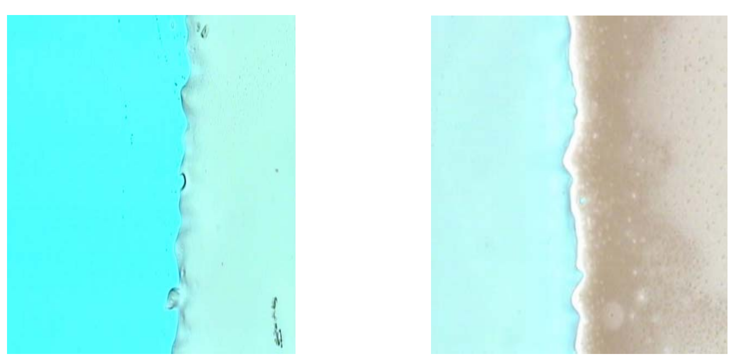
Based on the Table 4.2, shows the reading thickness for nitride layer after deposited using PECVD. Time to deposited nitride layer is took about 8 minute same as first nitride layer. The average thickness for the second nitride layer is 2272.9 Å which is this valued is much greater than the target thickness. In this case, the percentage error for the experiment thickness due to expected thickness is 13.6 % and the function of deposited nitride layer is to act as an oxidation mask. Nitride is effective in this role because oxygen and water vapor diffuse very slowly through it, and can preventing oxidizing species from reaching the silicon surface under the nitride. According to Table 4.0 to Table 4.2, GOF is stand for good of fitness which is means the differences thickness between the edit structures valued compared with the actual valued. So, the closer the good of fitness to valued one the better result will be obtained.

Figure 4.0 shows the etching process for nitride layer after done using reactive ion etch (RIE). This process took about 3 minute and after process completed the result is captured using high optical microscope taken at 500X magnification. The box as indicates in Figure 4.0 (a) shows the active area which is consist of the nitride layer and the out of box area is covered by photoresist after develop using developer. The color of the active area is changing from the blue (Figure 4.0 (a)) to brown color in Figure 4.0 (b). That means, the etching process is done successfully. Based on Figure 4.1 shows the result after oxide etch process completed observed using optical microscope which is taken at 400X magnification.



(a) Before nitride etched (b) After nitride etched

Figure 4.0: Etching process for nitride layer



(a) Before oxide etched (b) After oxide etched

Figure 4.1: Etching process for pad oxide layer

4.1.3 Grow local oxidation

The main purpose of this project is to study the effect of the bird's beak using two different pad oxides where as one of the pad oxide is about 300 Å and another is 400 Å. In Figure 4.2 shows, the graph after etched nitride layer, pad oxide layer and silicon substrate which is measured using ambios profiler. Based on the graph, shows the delta width after etched completed is about 401.3 Å. The delta width means that the point measured from the R cursor to M cursor respecting to x-axis and the valued of the delta height is 2648 Å which is the point is referred zero level to the point 2648 Å respecting to y-axis. The valued of the delta height shows that the sum of the nitride layer, pad oxide layer has been removed. This also means that the thickness of the nitride layer added with the oxide layer is range from 2498.4 Å to 2584.8 Å has been removed successfully and the remains valued of the delta height range 63.2 Å to 150 Å is the thickness for silicon substrate. Therefore, the thickness of the silicon also has been removed with respect to the remains valued of the delta height.

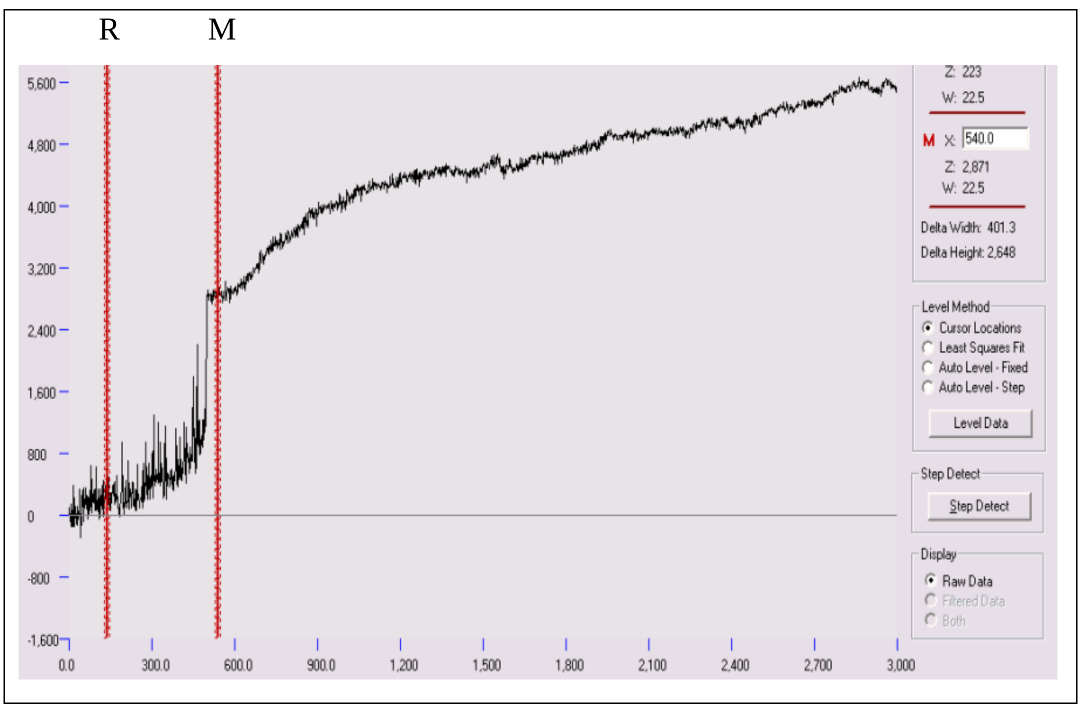


Figure 4.2: Graph after etching process

Table 4.4 indicates the thickness of LOCOS after growth using wet oxidation at temperature around 1000^0C for 1 hour and 30 minutes process. The measurement is done in 5 differences point on the wafer. The average thickness for LOCOS is 4588.8 Å which is greater than expected thickness whereby the expected thickness is 4500 Å. But, it still can be considering because it not associate the problem. The thicker the local oxidation the better result will be obtained. During this process, the wet oxidation is chosen because it much faster compared with the dry oxidation. The molecules oxygen move faster in wet oxidation process compared with the dry oxidation. In this case, the thicker pad oxide will be obtained in the short time if wet oxidation is selected. According to Table 4.4, the value of good of fitness is nearly to value one. That means, the valued of the edit structure compared with the experiment valued is very close. The oxide grows where there is no masking nitride, but at the edges of the nitride, some oxidants also diffuse laterally, because the molecules oxygen is anisotropic and it will cause the oxide to grow under and lift the nitride edges. Because the shape of the oxide at the nitride edges is that of the slowly tapering oxide wedge that merges into the pad oxide, it has been names bird's beak.

Table 4.4: Thickness for grow LOCOS

Statistic	Layer 1 d	GOF
Mean	4588.8 Å	0.99861
Median	4558.5 Å	0.99848
Std. Dev.	71.5 Å	0.00022292
Min.	4473.9 Å	0.99830
Max.	4675.8 Å	0.99897
Meas. #	Layer 1 d	GOF
1	4558.5 Å	0.99897
2	4675.8 Å	0.99867
3	4473.9 Å	0.99830
4	4543.4 Å	0.99848
5	4668.2 Å	0.99845
6	4612.9 Å	0.99876

4.1.4 Composition of oxide under nitride layer

The composition of the oxide under the nitride layer is observed using Energy Dispersive X-ray (EDX) as illustrated in Figure 4.3 and 4.4. This is approach to obtain the amount of oxide which is diffuse under the nitride layer or it's called bird's beak. The amount of the oxide has been measured with the length chosen is 20 micron starting from the boundary of an active area. The mass of the oxide for the 300 Å pad oxide is about 6.90 % has been obtained as shown in Table 4.5. If compared with the 400 Å pad oxide the mass amount is 10.02 % that means, the amount of oxide that diffused under nitride layer for 400 Å is much greater compared with another pad oxide. In this case, the result shows that the thicker the pad oxide the greater the amount of oxide diffused under nitride layer. The valued of the nitride and silicon is not taken to the account because this project just varies on the thickness of pad oxide. So, the valued of the nitride and silicon are not influence the result and can be neglected.

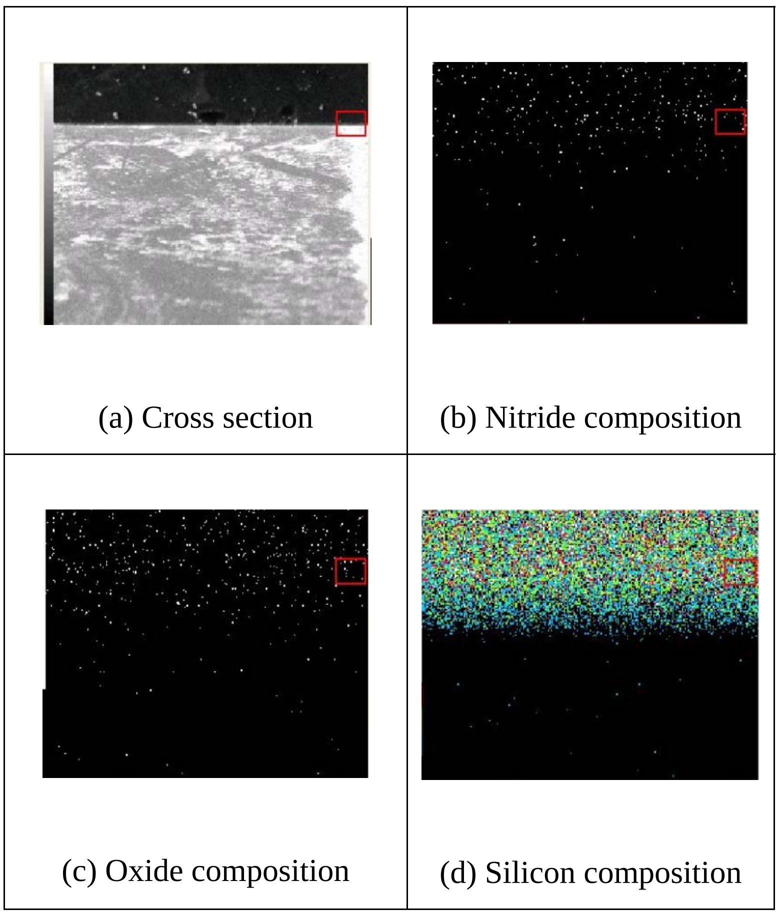
Table 4.5: Composition of oxide under nitride layer for 300 Å pad oxide.

Element	Mass (%)
Oxide	6.90
Nitride	4.12
Silicon	88.98

Table 4.6: Composition of oxide under nitride layer for 400 Å pad oxide.

Element	Mass (%)
Oxide	10.02
Nitride	2.08
Silicon	87.90

The red box as shown in Figure 4.3 is referred to the point measured of oxide for 300 Å pad oxide where as, the length of the red box is 20 micron from the boundary of an active area. Figure 4.3 (a) shows the cross section for the 300 Å pad oxide and Figure 4.3 (b) shows the composition of nitride that existed in the red box. According to Figure 4.3 (c) and (d) shows the composition of oxide and silicon that existed in red box. Based on the composition illustrated above, the valued of the silicon is much greater compared with the value of nitride and oxide. It's because, the thickness of the silicon substrate is very large compared with nitride and oxide.



(a) Cross section

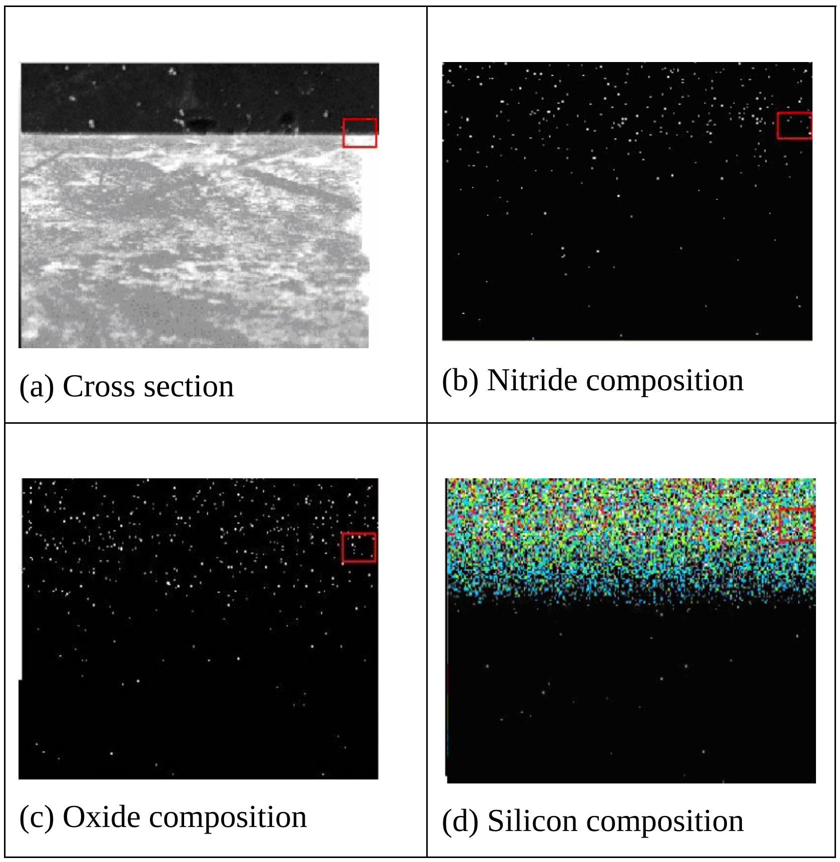
(b) Nitride composition

(c) Oxide composition

(d) Silicon composition

Figure 4.3: Composition for 300 Å pad oxide

The red box as shown in Figure 4.4 is referred to the point measured of oxide for 400 Å pad oxide where as, the length of the red box is 20 micron from the boundary of an active area same as 300 Å pad oxide. The main purpose is to measured the amount of the oxide that beneath under nitride layer. The white dot as illustrated in Figure 4.4 (b) and (c) shows the amount of the nitride and oxide. So, the greater the white dot exist, the large amount of nitride and oxide is obtained.



(a) Cross section

(b) Nitride composition

(c) Oxide composition

(d) Silicon composition

Figure 4.4: Composition for 400 Å pad oxide

The amount of three elements is representative by the graph as shown in Figure 4.5. The highest peak as shown in the graph above is represent by the silicon substrate. This graph is conjunction to the composition of oxide, nitride and silicon that measured using Energy Dispersive X-ray (EDX).The white dot as shown in Figure 4.4 is representing by the graph below. In this project, discussion of the result is just referred to the amount of the oxide.

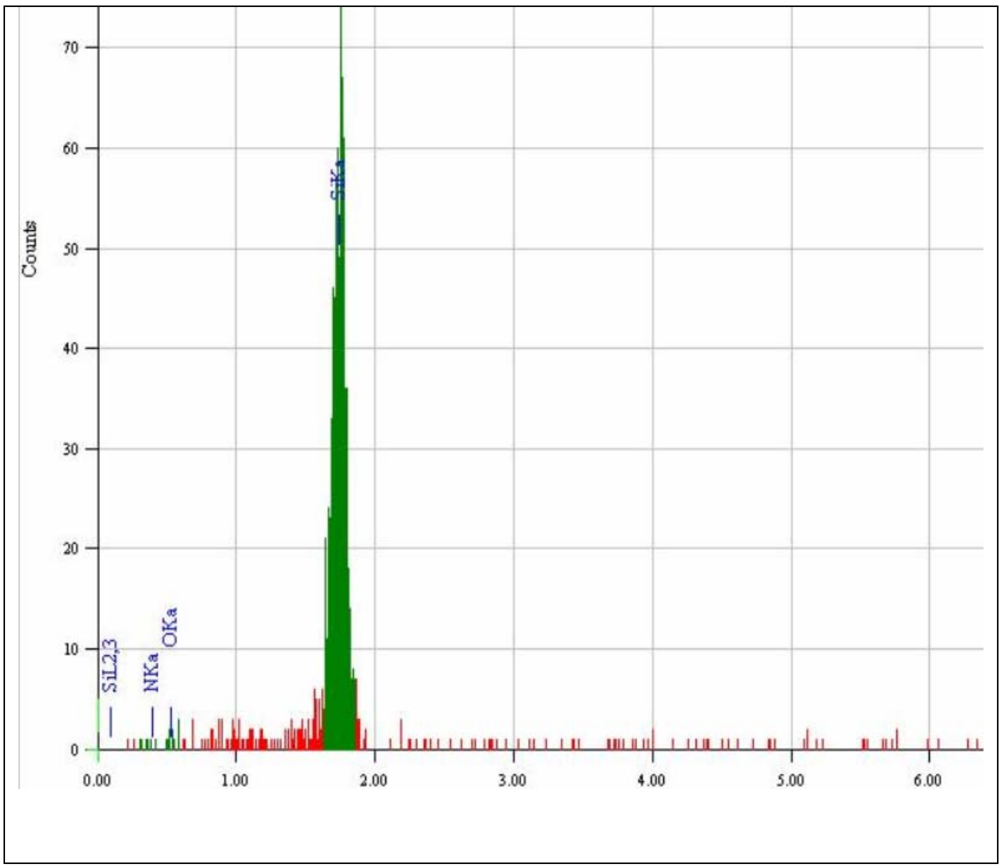


Figure 4.5: Graph for three elements

4.2 Result for poly-buffered LOCOS

4.2.1 Pad oxide, nitride and amorphous thickness measurement

Table 4.7: Thickness for 1st pad oxide

Statistic	Layer 1 d	GOF
Mean	380.6 Å	0.86057
Median	378.9 Å	0.89488
Std. Dev.	13.3 Å	0.10759
Min.	358.7 Å	0.67122
Max.	394.7 Å	0.99108
Meas. #	Layer 1 d	GOF
1	358.7 Å	0.67122
2	376.5 Å	0.91471
3	394.7 Å	0.99108
4	393.9 Å	0.83094
5	378.9 Å	0.89488

Table 4.7 indicates the thickness of pad oxide after grow using dry oxidation process. The thickness of the pad oxide is measured in 5 different points using spectrophotometer. The target thickness of oxide is 400 Å. The average thickness of 5 points is 380.6 Å which is the value of the pad oxide is less from the expected value. So, the percentage error of the experiment thickness compared with the expected thickness is 4.85 %.

Table 4.8: Thickness for 2nd pad oxide

Statistic	Layer 1 d	GOF
Mean	506.2 Å	0.96333
Median	500.5 Å	0.97495
Std. Dev.	25.4 Å	0.021830
Min.	478.9 Å	0.92669
Max.	542.6 Å	0.98597
Meas. #	Layer 1 d	GOF
1	500.5 Å	0.97848
2	481.1 Å	0.92669
3	478.9 Å	0.95055
4	528.1 Å	0.97495
5	542.6 Å	0.98597

According to Table 4.8 above shows the thickness of the 2nd pad oxide for poly-buffered LOCOS after thermally grown using a dry oxidation. The thickness of 2nd pad oxide is determined in the 5 differences point on the wafer surface same as the 1st pad oxide. Time process during the oxide grows took about 1 hour and temperature is 900 C. Referred to the Table 4.8, the average thickness of pad oxide is 506.2 Å which is greater 1.24 % from the target thickness whereby, the target thickness for 2nd pad oxide is 500 Å. But the percentage error still can be considered because the value of the target thickness compared with the experiment thickness not too far. The function of this layer called a pad or buffer oxide same as fully-recessed LOCOS.

Table 4.9: Thickness for amorphous silicon

Statistic	Layer 1 d	GOF
Mean	563.1 Å	0.96400
Median	544.4 Å	0.96892
Std. Dev.	37.1 Å	0.012344
Min.	520.7 Å	0.94270
Max.	625.6 Å	0.97814
Meas. #	Layer 1 d	GOF
1	542.0 Å	0.96892
2	582.8 Å	0.95873
3	520.7 Å	0.97150
4	625.6 Å	0.94270
5	544.4 Å	0.97814

Table 4.9 shows the thickness measurement for amorphous silicon after deposited using PECVD. The time process took about 3 minute and the average thickness for amorphous is about 563.1 Å which is greater 63.1 Å than 500 Å the expected value. The percentage error for the amorphous silicon is greater 12.62 % compared to expected value.

The deposition of amorphous silicon followed by the annealing process is to convert the amorphous to polysilicon. The polysilicon layer will act as a buffer layer which is can prevent penetration from the nitride layer and also can control the diffusion of oxide during field oxidation. After the annealing process completed there are some problem occurred to the surface of polysilicon. There are some defect occurred on the sample which is can influences the performance of the next process. Then the polysilicon layer is etched using RIE and the process took about 6 minutes using the same recipe of fully recessed LOCOS.

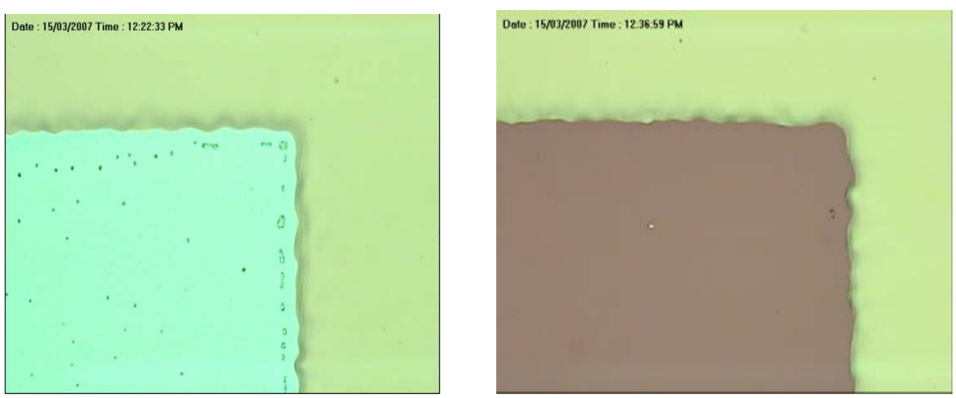
Table 4.10: Thickness for nitride layer

Statistic	Layer 1 d	GOF
Mean	2105.2 Å	0.82743
Median	2198.4 Å	0.81838
Std. Dev.	131.7 Å	0.026621
Min.	1896.6 Å	0.80050
Max.	2227.2 Å	0.87843
Meas. #	Layer 1 d	GOF
1	2198.4 Å	0.81659
2	2201.2 Å	0.80050
3	2227.2 Å	0.81838
4	1896.6 Å	0.87843
5	2002.8 Å	0.82324

Based on the Table 4.10, shows that the reading thickness for nitride layer after deposited using PECVD. Time to deposited nitride layer is taken about 8 minutes same as fully recessed LOCOS. The average thickness for the second nitride layer is 2105.2 Å which is this valued is much greater than the 2000 Å target thickness. In this case, the percentage error for the experiment thickness due to expected thickness is 5.26 % and the function of deposited nitride layer is to act as an oxidation mask.

4.2.2 Result for etching process

The image for an active area before nitride etched is shown in Figure 4.6. The green box shows the active area which is consists of nitride layer and the area out of the box is covered by the resist after develop using a developer. The result after etching process completed using reactive ion etches (RIE) is illustrated in figure 4.5 whereby, the color on the box is changing from the blue to the brown color. So, it’s show the etching process has been done successfully whereby, the thickness of the nitride then measured using spectrophotometer and show there is a small valued of the nitride still existed which is can be neglected. Based on Figure 4.7 shows the polysilicon image after 6 minutes etching process completed. The image is captured using high optical microscope taken at 500X magnification.



(a) Before nitride etched (b) After nitride etched

Figure 4.6: Etching process for nitride layer

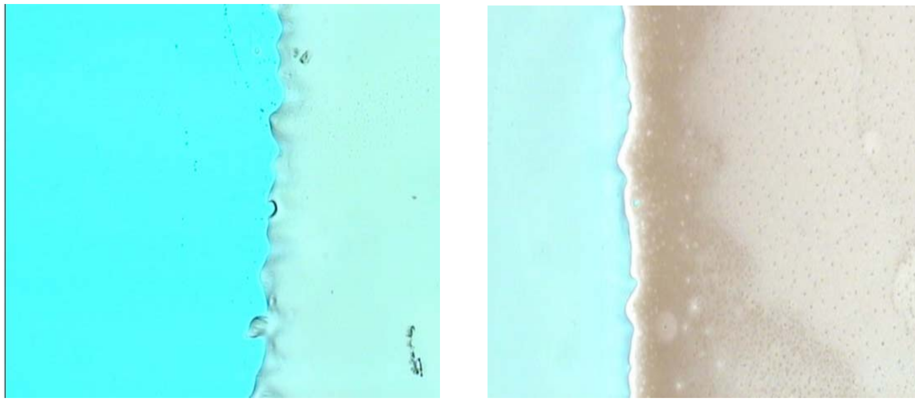


Figure 4.7: Etching process for polysilicon

4.2.3 Grow local oxidation

Table 4.11 indicates the thickness of LOCOS after growth using wet oxidation at temperature around 1000^0 C for 1 hour and 30 minutes process. The measurement is done in 5 differences point on the wafer. The average thickness for LOCOS is 4669.2 Å which is greater than expected thickness but, it still can be considering because it not associate the problem. The oxide grows where there is no masking nitride, but at the edges of the nitride, some oxidants also diffuse laterally, because the molecules oxygen is anisotropic and it will cause the oxide to grow under and lift under the polysilicon layer. In this case, the polysilicon layer will buffered the reaction of the oxygen under the poly layer. So, it will reduce the reaction of the oxide between substrate and polysilicon.

Table 4.11: Thickness of oxide after field oxidation

Statistic	Layer 1 d	GOF
Mean	4669.2 Å	0.89636
Median	4765.8 Å	0.91342
Std. Dev.	158.1 Å	0.087188
Min.	4367.7 Å	0.72806
Max.	4786.0 Å	0.96934
Meas. #	Layer 1 d	GOF
1	4367.7 Å	0.72806
2	4765.8 Å	0.96934
3	4786.0 Å	0.91342
4	4653.3 Å	0.95789
5	4773.4 Å	0.91311

4.2.4 Composition of oxide under polysilicon layer

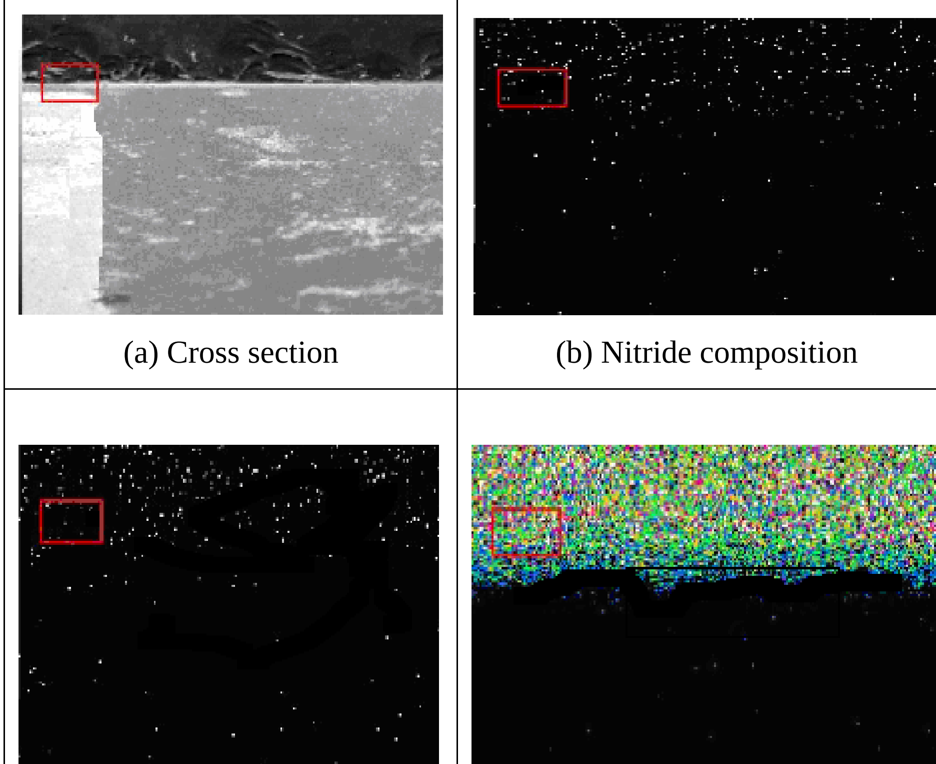
Composition of the oxide under the polysilicon layer is shown in Table 4.12 and 4.13 above. The composition of oxide under the polysilicon layer for 400 Å pad oxide is 5.02 % which is measured 20 micron from boundary of an active area. Compared with the 500 Å pad oxide the amount of the oxide under polysilicon layer is much greater which is the reading is 8.95 %. This means, the thicker the pad oxide the greater the reaction of the oxide through the poly layer. The measurement of the amount of oxide is done in same length for both pad oxide. The area measurement is representing by the red box as shown in Figure 4.8. The Figure 4.10 shows the graph for amount of oxide, nitride and silicon layer. The highest peak is referred to the silicon layer and the second highest is referred to the oxide layer and the less peak is represent by the nitride layer. In this project the measurement is considering only on the oxide layer.

Table 4.12: Composition of the oxide under polysilicon layer for 400 Å pad oxide

Element	Mass (%)
Oxide	5.02
Nitride	5.00
Silicon	88.77

Table 4.13: Composition of the oxide under polysilicon layer for 500 Å pad oxide

Element	Mass (%)
Oxide	8.95
Nitride	4.15
Silicon	86.90



(a) Cross section

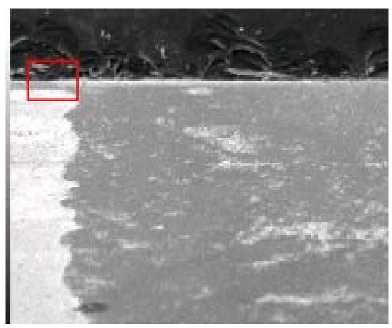
(b) Nitride composition

(c) Oxide composition

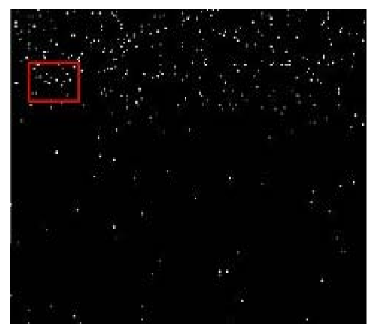
(d) Silicon composition

Figure 4.8: Composition of three elements for 400 Å pad oxide

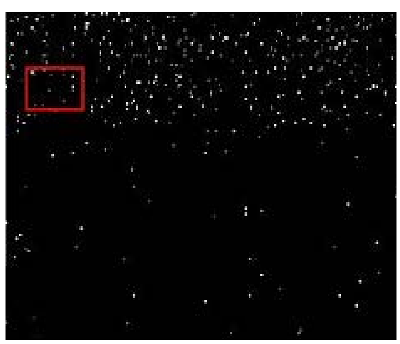
Based on Figure 4.9, shows the composition of oxide using 500 Å pad oxide. The length of the red box is 20 micron starting from the boundary of an active area. The measurement amount of oxide is done using EDX same as 400 Å pad oxide. The purpose of this measurement is to obtain the amount of the oxide that existed in the red box. If compared with 400 Å pad oxide its shows that the amount of oxide on the 500 Å pad oxide is much greater. This occurred because the reaction of the oxygen for 500 Å pad oxide during growth field oxidation is moving faster under polysilicon layer compared with 400 Å pad oxide. That means the thicker the pad oxide the greater the molecules oxygen beneath under polysilicon layer.



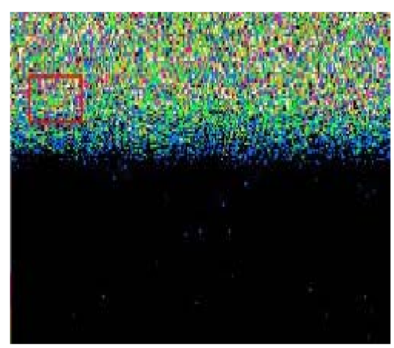
(a) Cross section



(b) Nitride composition



(c) Oxide composition



(d) Silicon composition

Figure 4.9: Composition of three elements for 500 Å pad oxide

According to the graph shown in Figure 4.10, there are three elements representing by nitride layer, oxide layer and silicon. The highest peak as shown below is represent by the silicon substrate and the second highest peak is represent by oxide and the lowest peak represent by nitride. This amount of three materials has been measured using EDX and the amount of the material is count based on the red box.

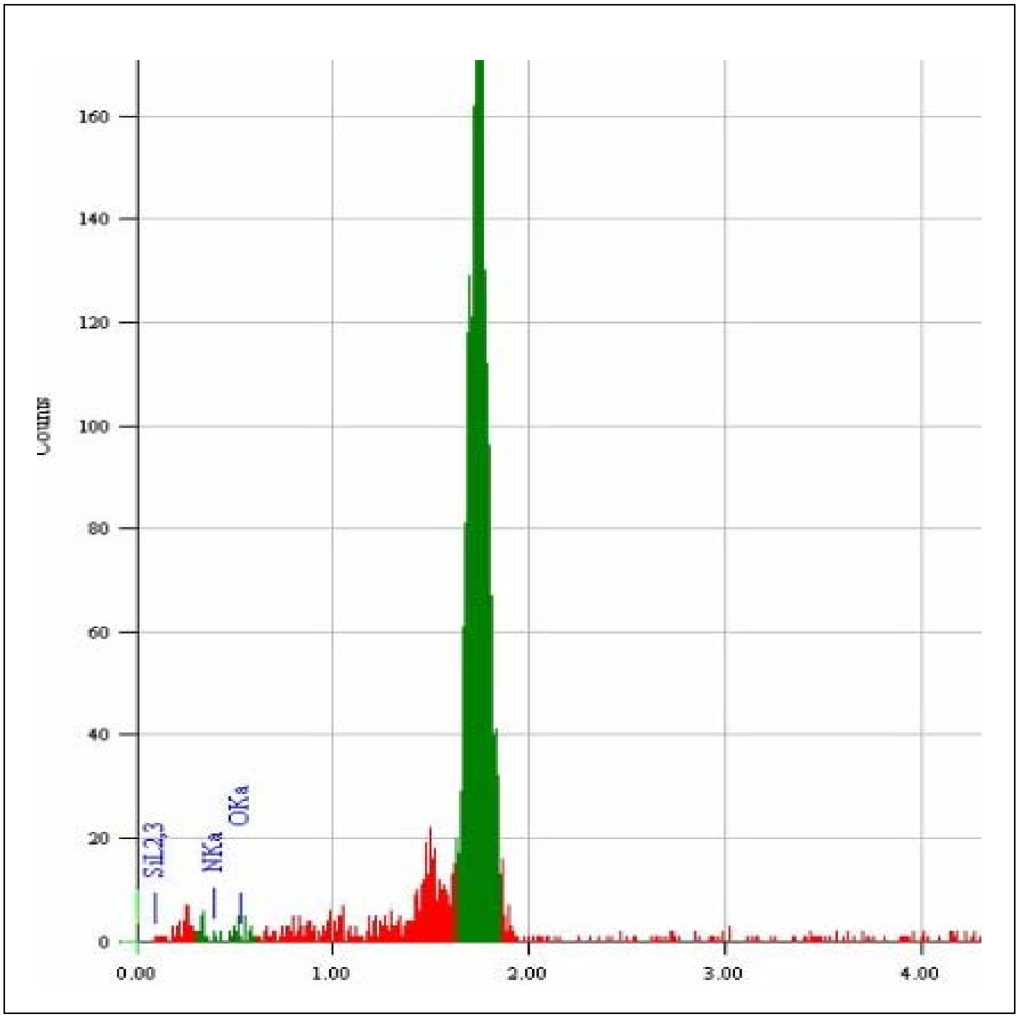


Figure 4.10: Graph for three elements