ETCHING PROCESS CHARACTERIZATION OF NITRIDE LAYER AND POLY SILICON LAYER USING TRION III ETCHER

SUDMUN HABIB

ADVISORS: DR JACKSON, DR PEARSON, DR EWBANK

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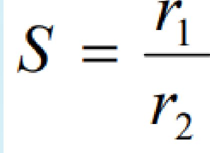
INTRODUCTION

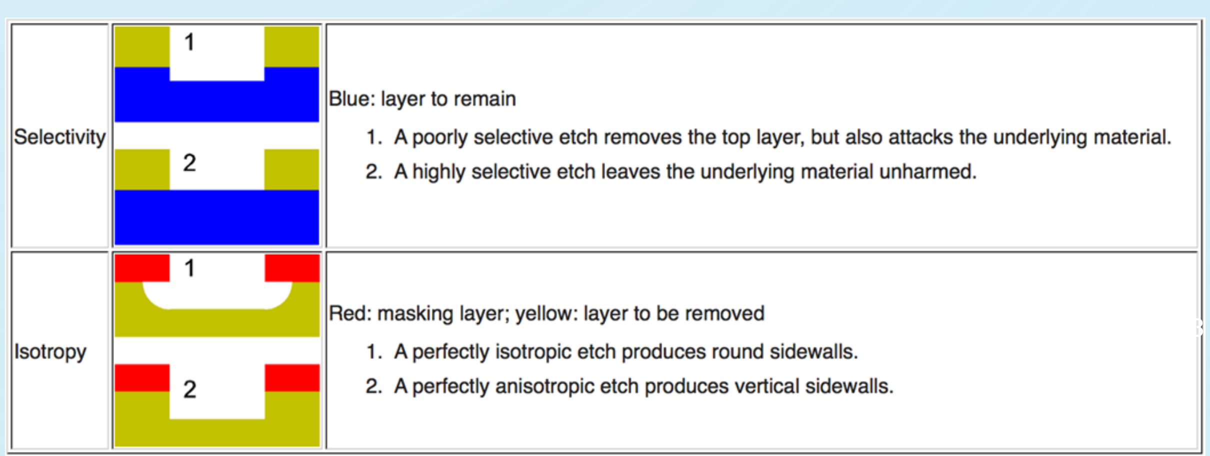
- Etching in Microelectronic fabrication is a process by which material is selectively removed from the silicon substrate or from thin films on the substrate surface.
- The two basic types of etch process used in semiconductor fabrication are
  - Wet-chemical etching
  - Dry-etching
- Factors used to characterize effectiveness of etch process:
  - Etch-rate
  - Etch-rate uniformity
  - Etch profile(Isotropic or Anisotropic)
  - Selectivity between films
  - Etch bias



$$S = \frac{r_1}{r_2}$$

Anisotropy:

$$A = 1 - \frac{\text{Lateral Etch Rate}}{\text{Vertical Etch Rate}}$$



Selectivity	1 2	Blue: layer to remain 1. A poorly selective etch removes the top layer, but also attacks the underlying material. 2. A highly selective etch leaves the underlying material unharmed.
Isotropy	1 2	Red: masking layer; yellow: layer to be removed 1. A perfectly isotropic etch produces round sidewalls. 2. A perfectly anisotropic etch produces vertical sidewalls.

DRY ETCHING

- In this research the Trion III plasma dry etch tool was characterized for Nitride and Polysilicon Layer etching.

- Dry Etching offers the capability of Anisotropic etching over Isotropic wet etch process.

- As technology is evolving and we are pushing the boundaries of Node Scaling, Etch profile and etch control of sub nm layers are becoming critical for device yield and performance.

- The basic concept of Plasma-etching is: An Rf glow discharge produces chemically reactive species (atoms, radicals and ions) from a relatively inert molecular-gas. The etching gas is selected to generate species which react chemically with the material to be etched, and whose reaction product is volatile.

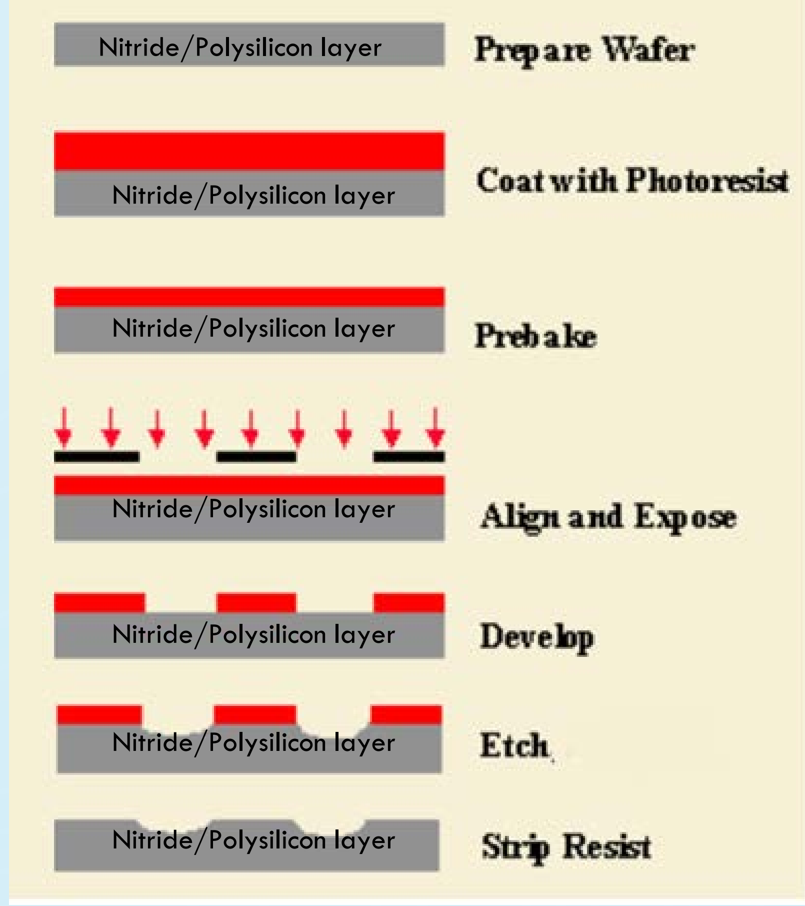
ETCH PROCESS

Silicon nitride and Polysilicon deposition

DOE for characterization of Trion III etcher

Analysis by SEM, Microscope, Spectromap and Nanospec

Process Flow



Test setup process

TEST SETUP: NITRIDE

- Gas used: CF_4, SF_6 and O_2
- RIE Power: 125 - 250 Watts
- Pressure: 75 mTorr - 150 mTorr
- Initial testing of nitride blank etch rate was carried out
- Followed by etch rate with photoresist on nitride
- Finally Etch selectivity and profile tests were carried out using line/space features exposed on Nitride
- Recipe was gathered from our previous used now decommissioned Drytek quad etcher, the DOE was designed around the base recipe.

Test Type	SF6(sccm)	CF4(sccm)	O2(sccm)	Pressure(mTorr)	Power (watts)
Etch Selectivity/ETM	0	40	5	75	125
Etch Selectivity/ETM	0	40	5	150	250
Etch Selectivity/ETM	0	40	5	150	125
Etch Selectivity/ETM	40	0	5	150	125

NITRIDE DEPOSITION

- The pre etch data shows good Non Uniformity numbers of around 1.2 % with Std deviation of 30 Angstorms on average
- Nitride Etch rate tests were done on blank Nitride deposited wafers.
- Etch selectivity test was done on photoresist on Nitride wafers

Wafer ID	Test Type	Nitride	Thickness	Non Uniformity	Std Dev
1	Nitride etch rate	Yes	2770	1.3	35.3
2	Nitride etch rate	Yes	2763	1.3	34.7
3	Nitride etch rate	Yes	2419	1.2	30.5
4	Nitride etch rate	Yes	2413	1.3	31.5
5	Etch Selectivity/ETM	Yes	2425	1.2	29.2
6	Etch Selectivity/ETM	Yes	2067	1	20.6
7	Etch Selectivity/ETM	Yes	2430	1.3	31.9
8	Etch Selectivity/ETM	Yes	2448	1.2	30.1
9	Etch Selectivity/ETM	Yes	2437	1.2	28.4

NITRIDE ETCH

- From the Data results we can see the etch rates improve when using CF4 because the use of the Carbon atoms, which break through the nitride layer.
- The Oxygen helps control the Etch rate as you can see with out O2 the etch rate drops for CF4 gas while the SF6 increases immensely (with etch rates of around 6.7 nm per second)
- Although wafer 4 had a fast etch rate compared to the rest, but this came at the cost of Non uniformity.

Nitride Etch Rate						
Wafer ID	SF6(sccm)	CF4(sccm)	O2(sccm)	Pressure(mTorr)	Power (watts)	Time(sec)
1	0	40	5	150	125	30
2	40	0	5	150	125	30
3	0	40	0	150	125	30
4	40	0	0	150	125	30

After Etch Data				
Wafer ID	Nitride Removed (nm)	Non Uniformity	STD DEV	Etch Rate (nm/s)
1	143	4.153	5.5	4.77
2	100	4.5	8	3.33
3	50	1.203	2.2	1.67
4	200	18.881	7.2	6.67

ETCH SELECTIVITY PATTERN

- For Etch selectivity test between Photoresist and Nitride a clear field mask was used to make a open shot/close shot imaging on a wafer as you can see on the right.
- The Open nitride layer and the photoresist was measured
- Giving nitride etch rate to photoresist etch rate at the same time
- Different gas combination were run to get preliminary etch rate data

PATTERNED WAFER NITRIDE ETCH SELECTIVITY

- From the Data results we can see 60 second of etching results in complete removal of the nitride layer. (does not Allow for calculation of etch rate)
- Wafer 5 was developed using the same chemicals as 8 and 9 except for PEB and HARDBAKE was not carried out. (resulting in higher etch rate)
- From wafer 8 and 9 we can see a huge difference between nitride etch rates due to gas combinations while the photoresist etch rate remains the same.

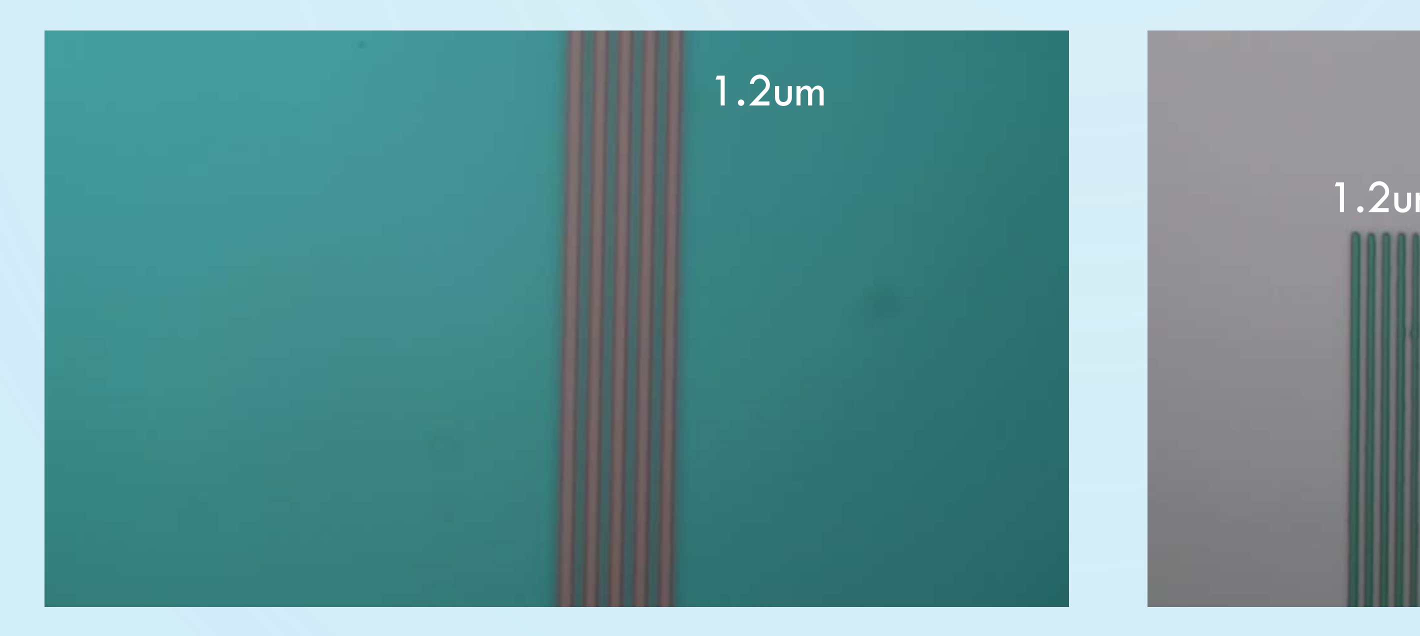
Patterned wafer Nitride Etch data						
Wafer ID	SF6 (sccm)	CF4(sccm)	O2(sccm)	Pressure (mTorr)	Power (watts)	Time (sec)
8	40	0	5	150	125	15
9	0	40	5	150	125	15
wafer ID	Thickness(nm)	Etched Nitride(nm)	Etch Rate(nm/s)			
8	240	70	4.6	Nitride/Photoresist		
9	240	113	7.5	Wafer ID	Etch selectivity	
				Wafer 8	1.39	
wafer ID	Thickness(nm)	Etched Photoresist(nm)		Wafer 9	2.5	
8	750	50	3.3			
9	750	44	3			

ETCH RATE

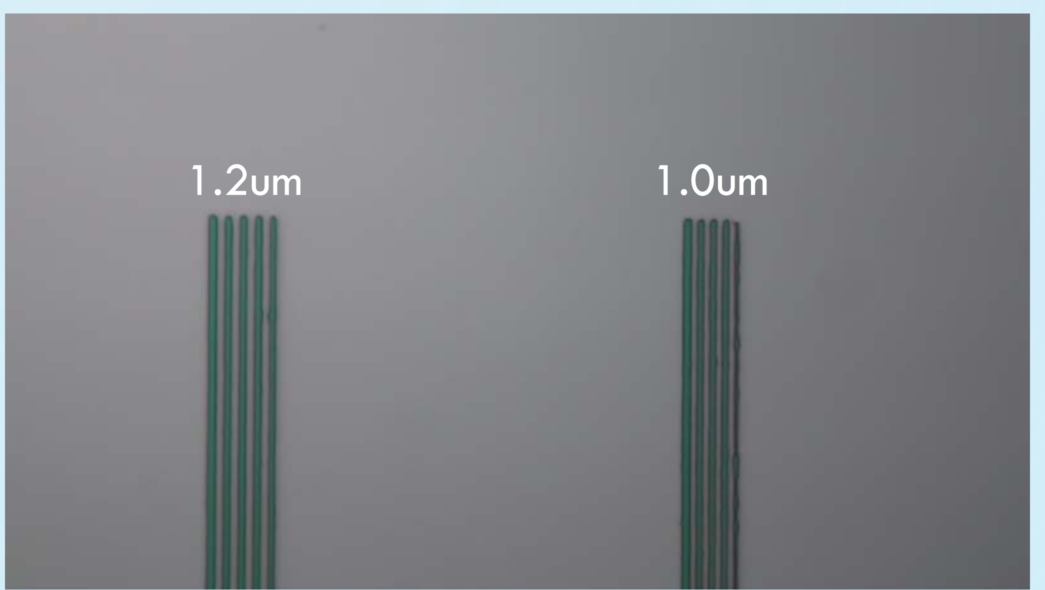
- ETM mask was used to expose various sized line/space imaging for profile testing and etch selectivity testing.
- The Etch rate slowed down with lowering of the base pressure level, while increased with change in power.
- Etch rate slowing down compared to the patterned wafer could be due to surface area covered by structures hence slowing down the selectivity and etch rate.

Test Type	SF6 (sccm)	CF4(sccm)	O2(sccm)	Pressure (mTorr)	Power (watts)	Time (sec)	Etch Rate(nm/s)
Etch selectivity/ETM	0	40	5	75	125	60	3.5
Etch selectivity/ETM	0	40	5	150	250	40	6
Etch selectivity/ETM	0	40	5	150	125	30	6
Etch selectivity/ETM	40	0	5	150	125	90	2.6

ETCH MICROGRAPHS

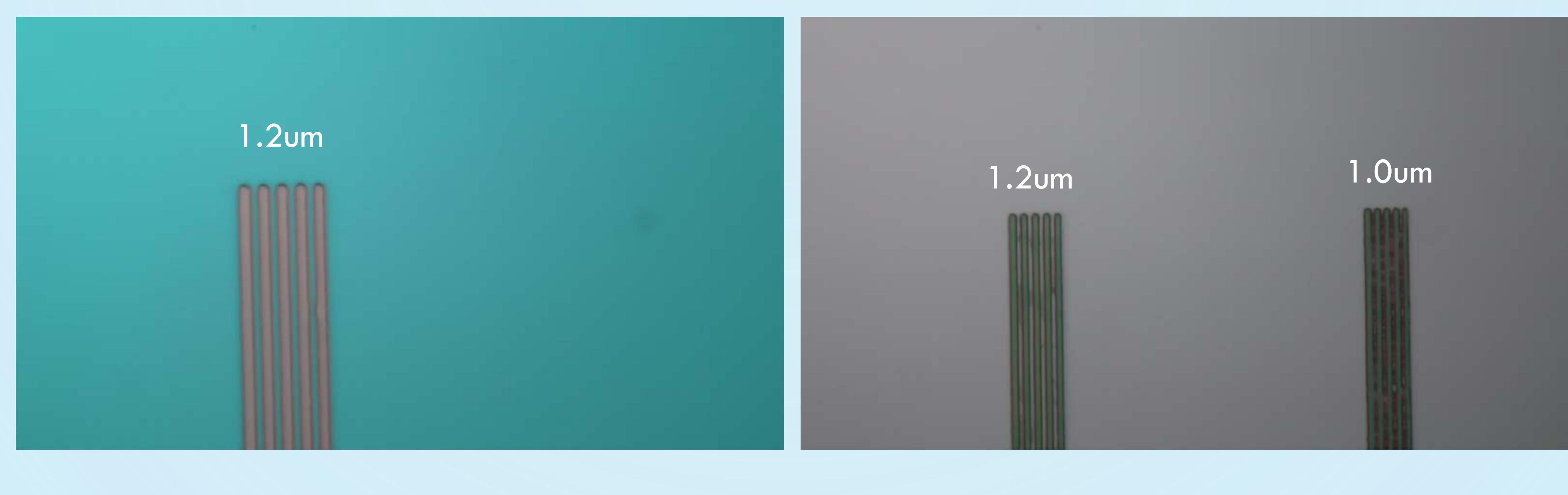


Before Etch



After etch

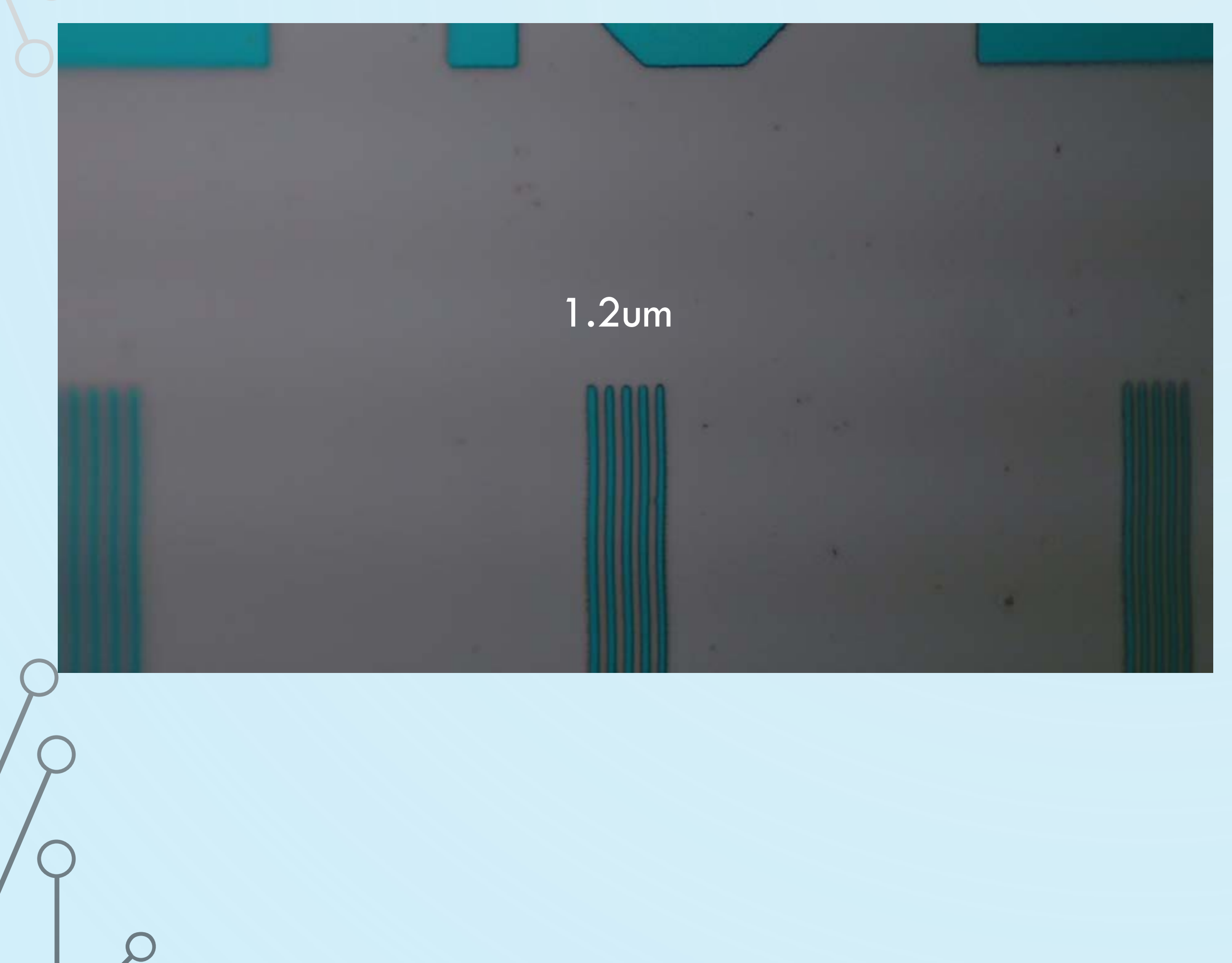
ETCH MICROGRAPHS

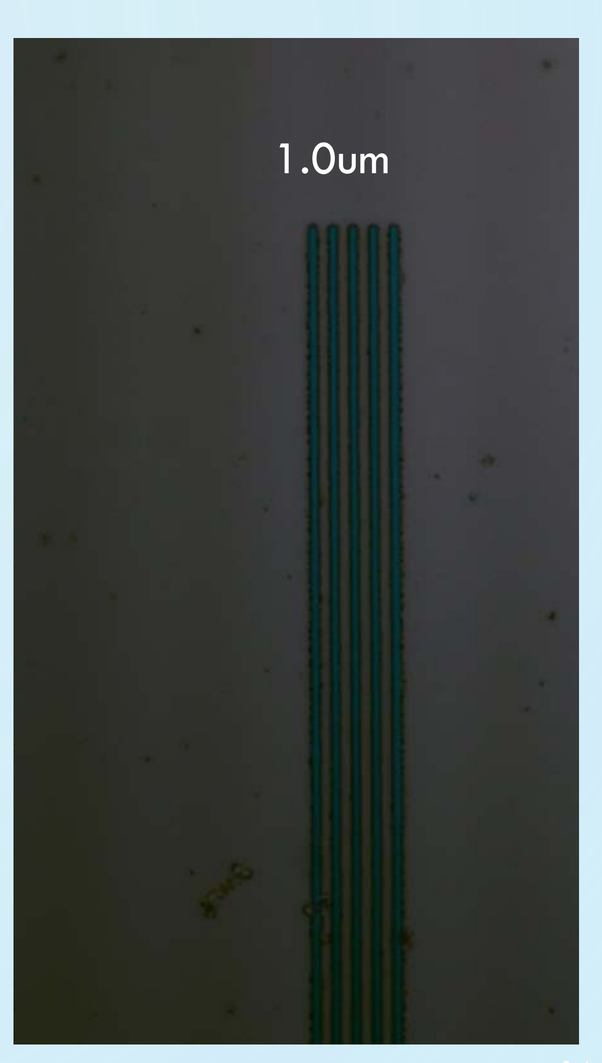


Before etch

After etch

ETCH MICROGRAPHS (RESIST REMOVED)





TEST SETUP: POLYSILICON

- Gas used: CF4, SF6 and O2
- RIE Power: 120 - 160 Watts
- Pressure: 60 mTorr - 120 mTorr
- Etch rate was tested between polysilicon and photoresist layer
- Etch selectivity and profile tests were carried out using line/space features exposed on polysilicon

Test type	SF6	CHF3	O2	Pressure	Power
Wafer 1	30	30	5	60	160
Wafer 2	15	45	5	60	160
Wafer 3 (etch rate test)	45	15	5	60	160
Wafer 4	30	30	5	60	160
Wafer 5	30	30	5	120	160
Wafer 6	30	30	5	60	120

POLYSILICON DEPOSITION

- First all wafers were RCA Cleaned before the Oxide was deposited
- 2500 A of oxide was grown on top of bare silicon using the P5000
- Polysilicon was deposited on top of the oxide layer using LPCVD method ~ target thickness of around 5000A

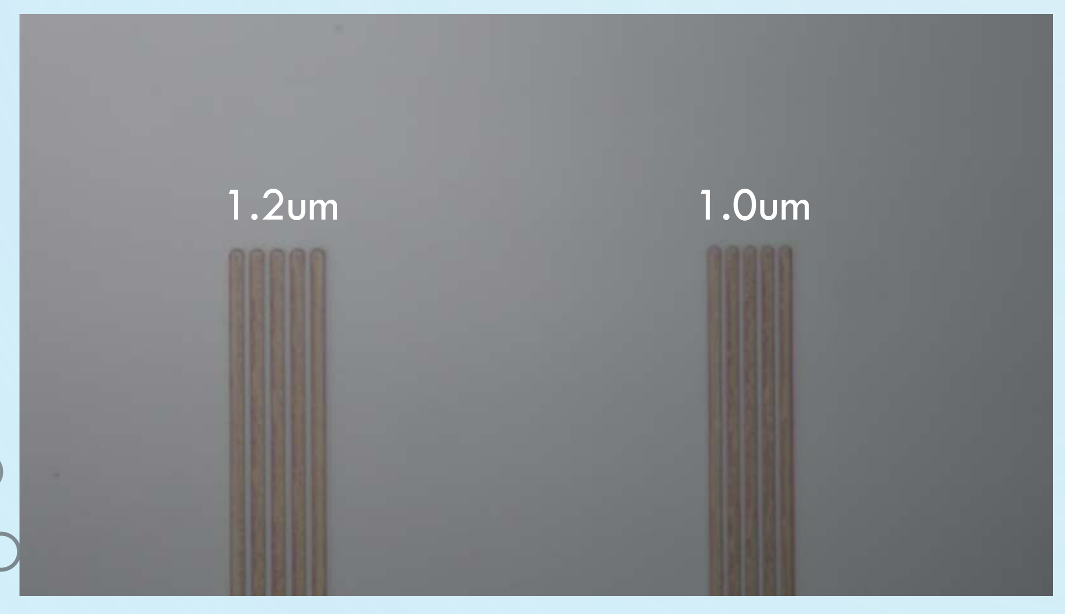
Wafer ID	Test Type	polysilicon	Thickness A	Non Uniformity	Std Dev
1	Etch Selectivity/ETM	Yes	4968	8.84	439
2	Etch Selectivity/ETM	Yes	4805	9.13	439
3	Etch Rate test	Yes	5157	11.5	594
4	Etch Selectivity/ETM	Yes	4830	9.97	481
5	Etch Selectivity/ETM	Yes	4954	10.1	501
6	Etch Selectivity/ETM	Yes	5019	12.59	632

ETCH RATE

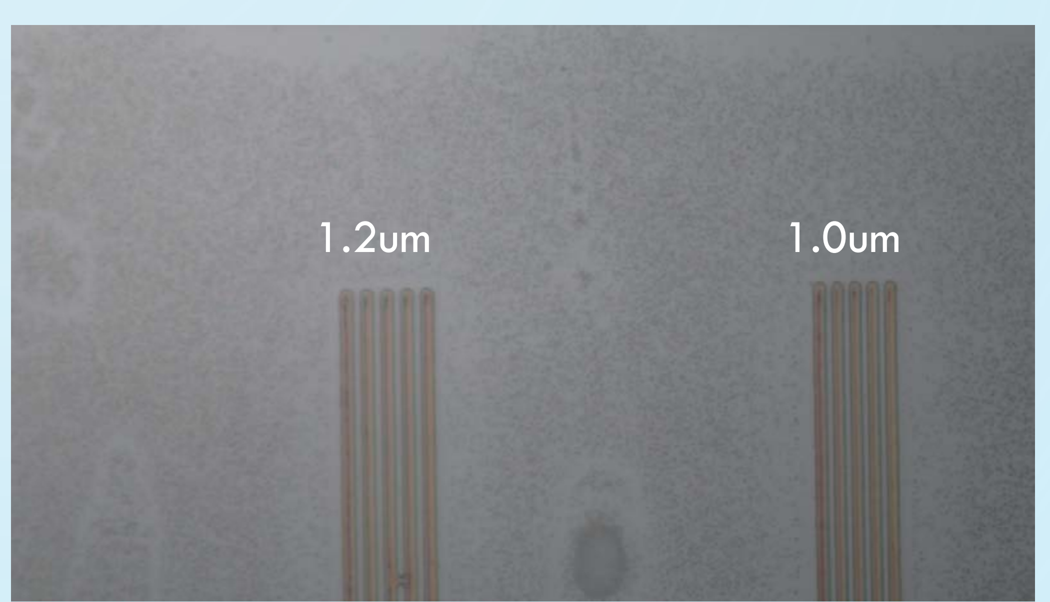
- First all wafers were RCA Cleaned before the Oxide was deposited
- 2500 A of oxide was grown on top of bare silicon using the P5000
- Polysilicon was deposited on top of the oxide layer using LPCVD method ~ target thickness of around 5000A

Polysilicon etch rate data								
Wafer ID	SF6 (sccm)	CHF3 (sccm)	O2 (sccm)	Pressure (mtorr)	Power (watts)	Time (sec)	Etched poly	Etch rate (nm/sec)
1	30	30	5	60	160	300	500	NA
2	40	0	5	60	160	300	500	NA
3	30	30	5	60	160	60	400	6.666666667
4	45	15	5	60	160	300	500	NA
5	30	30	5	120	160	120	470	3.916666667
6	30	30	5	60	120	120	410	3.416666667

ETCH MICROGRAPHS

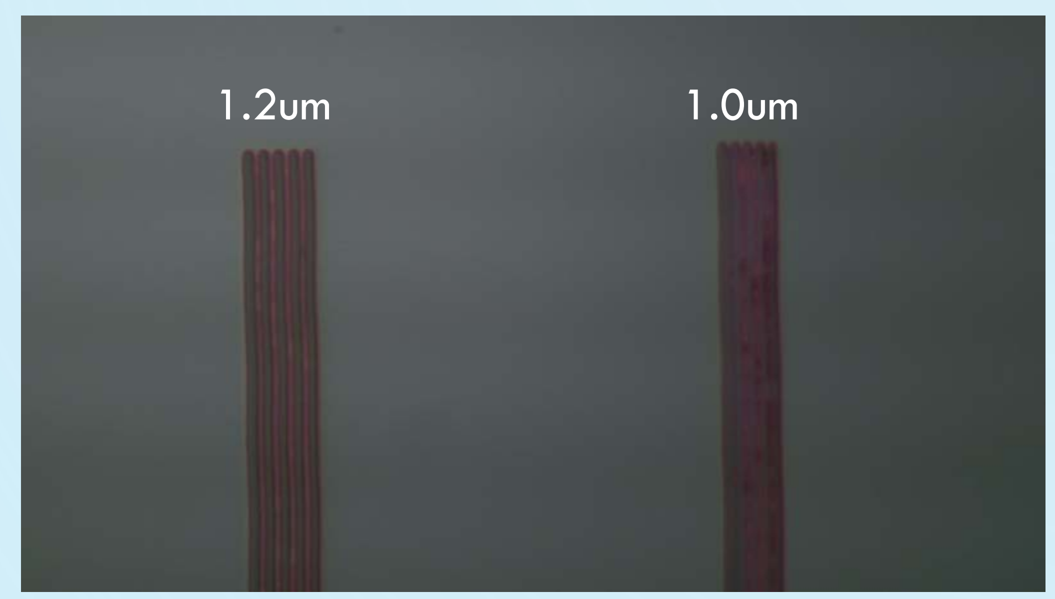


Wafer 1

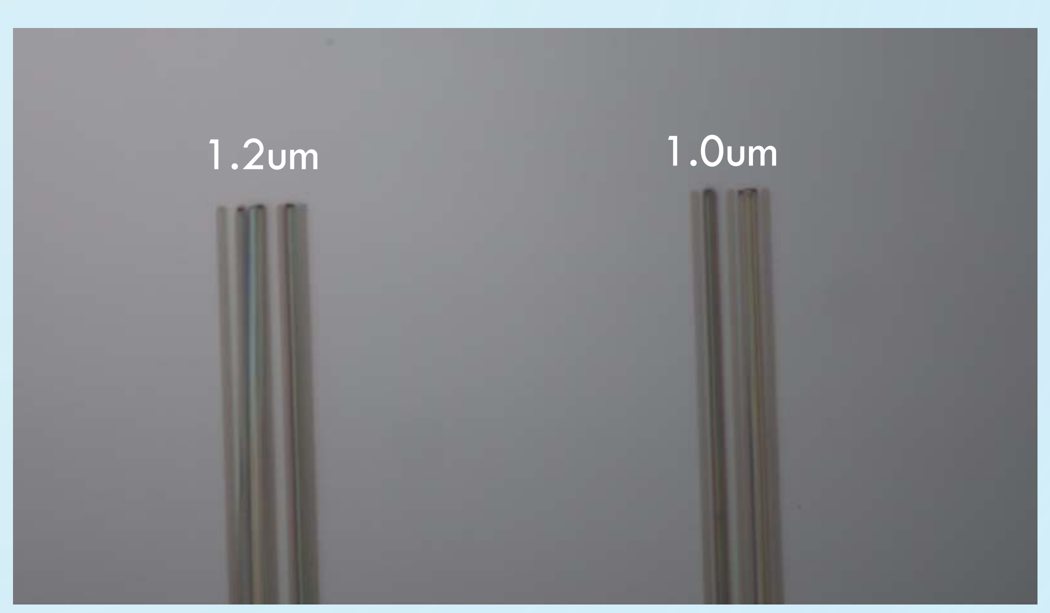


Wafer 2

ETCH MICROGRAPHS

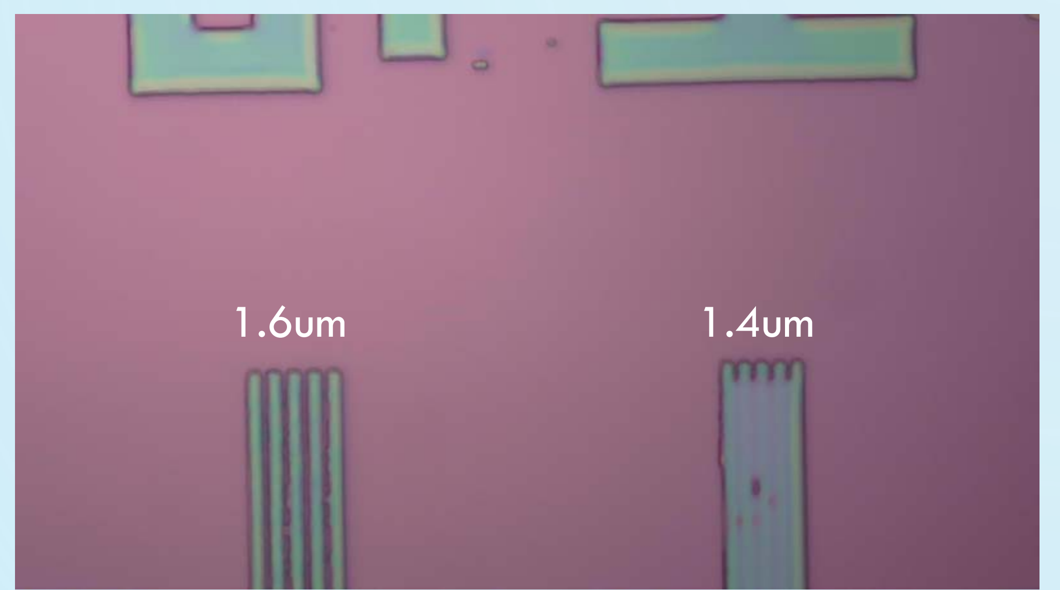


Wafer 3

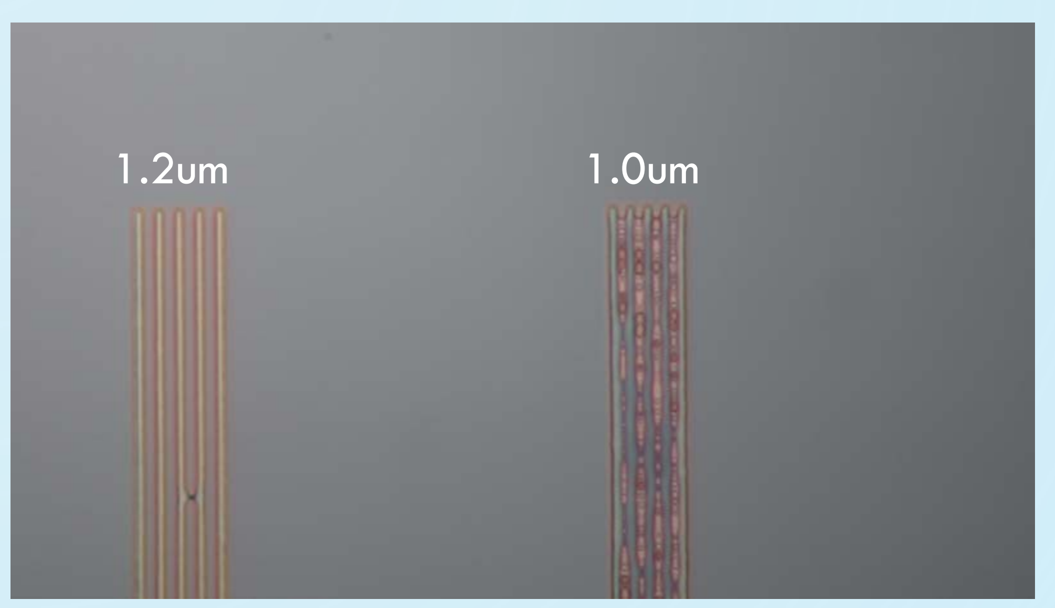


Wafer 4

ETCH MICROGRAPHS



Wafer 5



Wafer 6

CONCLUSION

- Nitride data showed varied difference in etch rate with the change in gas combination and percentage of oxygen present in chamber.
- Low base pressure lead to slow etch rates where as high RIE forward power resulted in high etch rate with more directionality
- Polysilicon etch rates showed faster etch rates across the DOE compared to previous data gathered from DryTek Quad.
- Next step of this study will be to have the profile checked and understand the impact of the gas combination to the power and pressure levels.

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- Furthermore I would like to thank Sean O'Brian and the rest of the SMFL staff for their ever whelming support
- I would like to thank the whole of the Senior class for supporting each other over the last few years.

REFERENCES

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- Dr Jacksons Thin films LPCD data