Etching process characterization of nitride and polysilicon layer using trion III Etcher

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Project Objectives

Goal: Through multiple tests we hope to characterize and understand the Trion III etcher better for integration of etch recipes for nitride and polysilicon layers in future device etch steps.

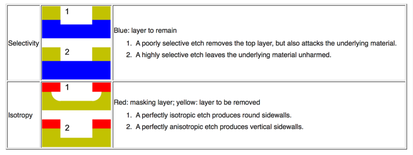
The target is to achieve anisotropic profile of nitride/polysilicon layer with good uniformity and selectivity.

Motivation

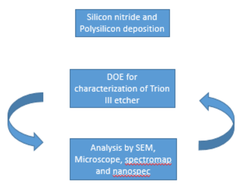
- As technology is evolving and we are pushing the boundaries of Node Scaling, Etch profile and etch control of sub nm layers are becoming critical for device yield and performance.
- Dry plasma Etching offers the capability of Anisotropic etching over Isotropic profiles which becomes a critical attribute as we go down the node scale.
- Factors used to characterize effectiveness of etch process:
    1. Etch-rate
    2. Etch-rate uniformity
    3. Etch profile(Isotropic or Anisotropic)
    4. Selectivity between films
    5. Etch bias

Anisotropy:

$$A = 1 - \frac{\text{Lateral Etch Rate}}{\text{Vertical Etch Rate}} \qquad S = \frac{r_1}{r_2}$$



Test Setup



Process Flow

Test setup process

Test setup Nitride:
Gas used: CF4, SF6 and O2
RIE Power: 125 - 250 Watts
Pressure: 75 mTorr - 150 mTorr

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

Test setup Polysilicon:
Gas used: CHF3, SF6 and O2
RIE Power: 120 - 160 Watts
Pressure: 60 mTorr - 120 mTorr

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

Trion III Dry Etching

- In this research the Trion III minilock etcher was used to characterize the Nitride and Polysilicon Layer.
- Dry etching is the preferred method going forward in this industry for most thin films because of its ability of anisotropic etching profiles.
- For the process of plasma etching an RF glow discharge is created which produce chemically reactive species (atoms, ions etc) these reactive species react with chosen gases to react with nitride or polysiliconlayer to etch them off.

Results

Nitride Experiment:
Nitride deposition was done on top of oxide wafer with target thickness of around 250 nm. From the data below of deposition its understood that the deposition uniformity across the wafer was around 1.2% with Std deviation of around 3 nm

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

Using the Nitride wafers, 780nm of photoresist were coated and exposed and developed using our in house GCA Stepper. The following data shows the etch selectivity between the layers and the separate etch rates

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
9	240	113	7.5

wafer ID	Thickness(nm)	Etched Photoresist(nm)	
8	750	50	3.3
9	750	44	3

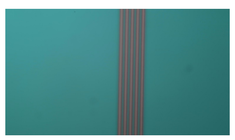
Nitride/Photoresist

Wafer ID	Etch selectivity
Wafer 8	1.39
Wafer 9	2.5

Below is further nitride etch rate data from different tests carried out on patterned wafers.

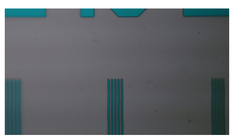
Test Type	SF6 (sccm)	CF4(sccm)	O2(sccm)	Pressure (mTorr)	Power (watts)	Time (sec)	Etch Rate(nm/s)
Etch selectivity/ETM	0	40	5	75	125	60	3.5
Etch selectivity/ETM	0	40	5	150	250	40	6
Etch selectivity/ETM	0	40	5	150	125	30	6
Etch selectivity/ETM	40	0	5	150	125	90	2.6

Below is the imaging of etch micrograph data showing etch profiles of around 1.2um.



Before Etch

After Etch



Resist removed after Etch

Results (cont)

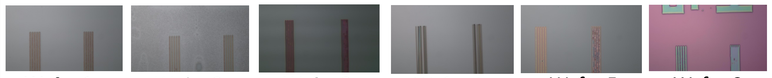
Polysilicon Experiment:
After the process of RCA clean of Bare silicon wafers, 250nm of oxide was deposited on top and then 500nm of polysilicon was deposited using LPCVD method. The table below shows the Non uniformity data of the polysilicon deposition layer

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

From previous data from now decommissioned Drytek Etcher we established a etch time of 5 min. This resulted in being over etching the wafers hence showing a variation between the tools. Below we show the new etch rate of the polysilicon layer.

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



Wafer 1 Wafer 2 Wafer 3 Wafer 4 Wafer 5 Wafer 6

V. Conclusions

- 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.

Future Work

- Next step of this study will be to have the profile checked using SEM and understand the impact of the gas combination to the power and pressure levels of the system.

References

- Dr Fullers powerpoint slides of CMOS factory process Microchip Manufacturing by S.Wolf
- Etching Wikipedia
- Dr Jacksons Thin films LPCD data

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