Drytech Quad Etch Recipes

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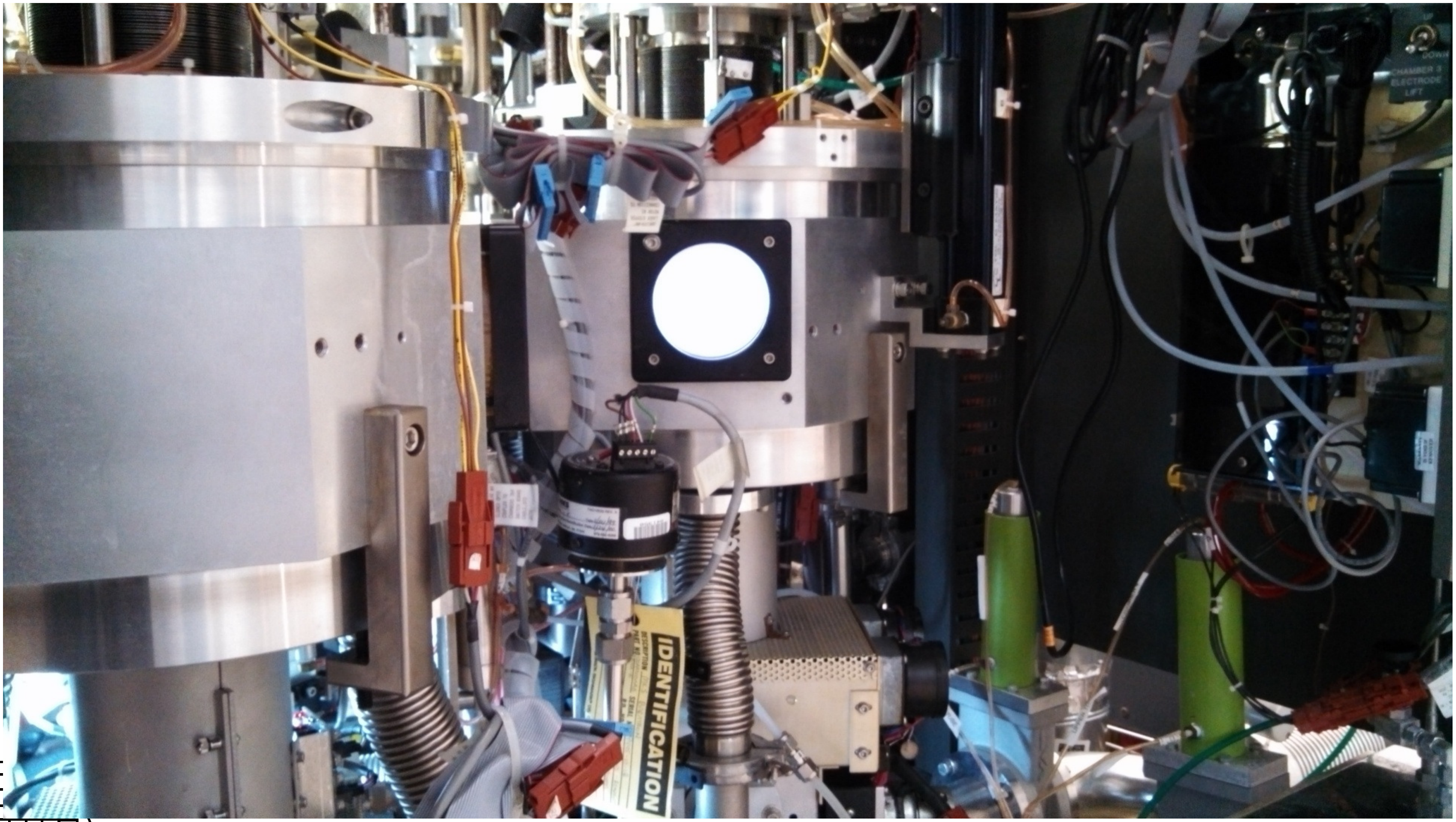
10-14-2013 Quad_Recipes.ppt

OUTLINE

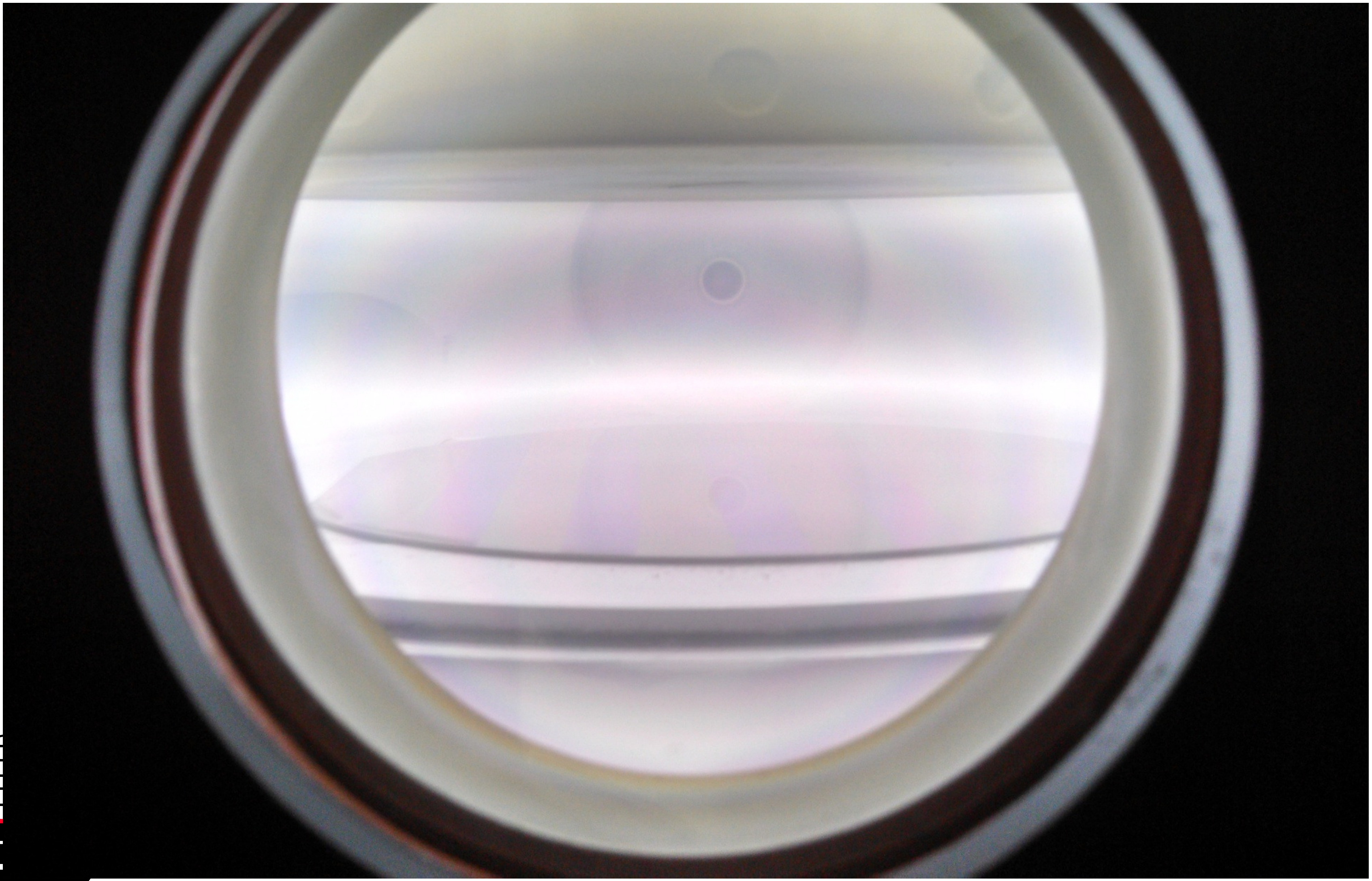
1500Å/3500Å Nitride Etch Recipe
6000Å Poly Etch Recipe
LTO/TEOS/Oxide Etch for Contact Cuts
Anisotropic Poly (2µm) Etch Recipe for MEMS
Anisotropic Poly (3000Å) Gate Etch Recipe for Advanced CMOS
Deep Silicon Etch for MEMS
Anisotropic Oxide Etch for Sidewall Spacer
Anisotropic Nitride Etch for Sidewall Spacer
ZeroEtch for ASML alignment marks
End point detection

DRYTEK QUAD RIE TOOL

2 OF 4 CHAMBERS IN THE DRYTEK QUAD RIE TOOL



PLASMA ETCHING IN THE DRYTEK QUAD

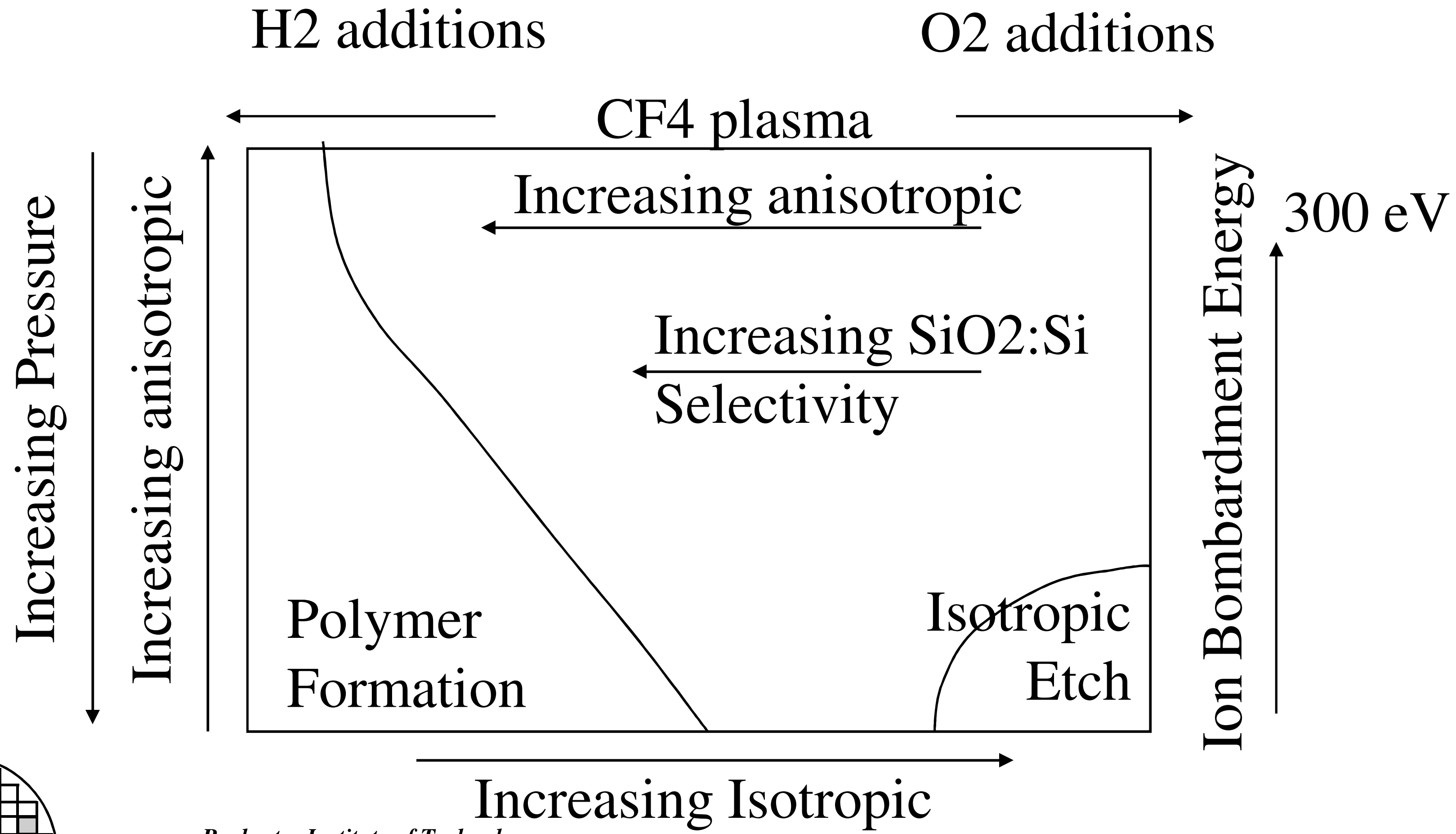


DRYTEK QUAD RIE TOOL

The Drytek Quad is a four chamber reactive ion etch (RIE) tool with recipe storage/selection and automatic sequencing for loading the wafers, pumping the chamber, running of the recipe and unloading the wafers. The emission spectra or specific peaks of the emission spectra can be manually monitored during the etch and the etch can be manually stopped, by pushing a button, providing a form of endpoint detection.

This is an RIE tool meaning that the electrode that the wafer sits on is the powered electrode providing the possibility of an anisotropic etch.

POLYMER FORMATION



H2 additions

O2 additions

CF4 plasma

Increasing Pressure

Increasing anisotropic

Increasing anisotropic

Increasing SiO2:Si Selectivity

Polymer Formation

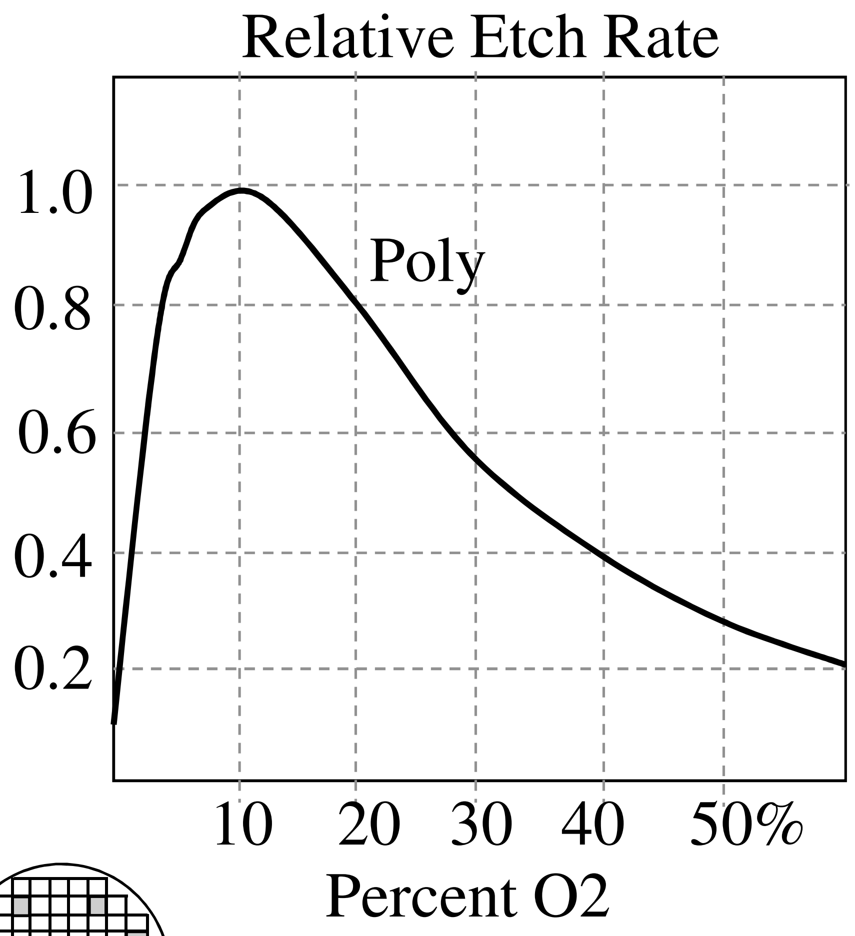
Isotropic Etch

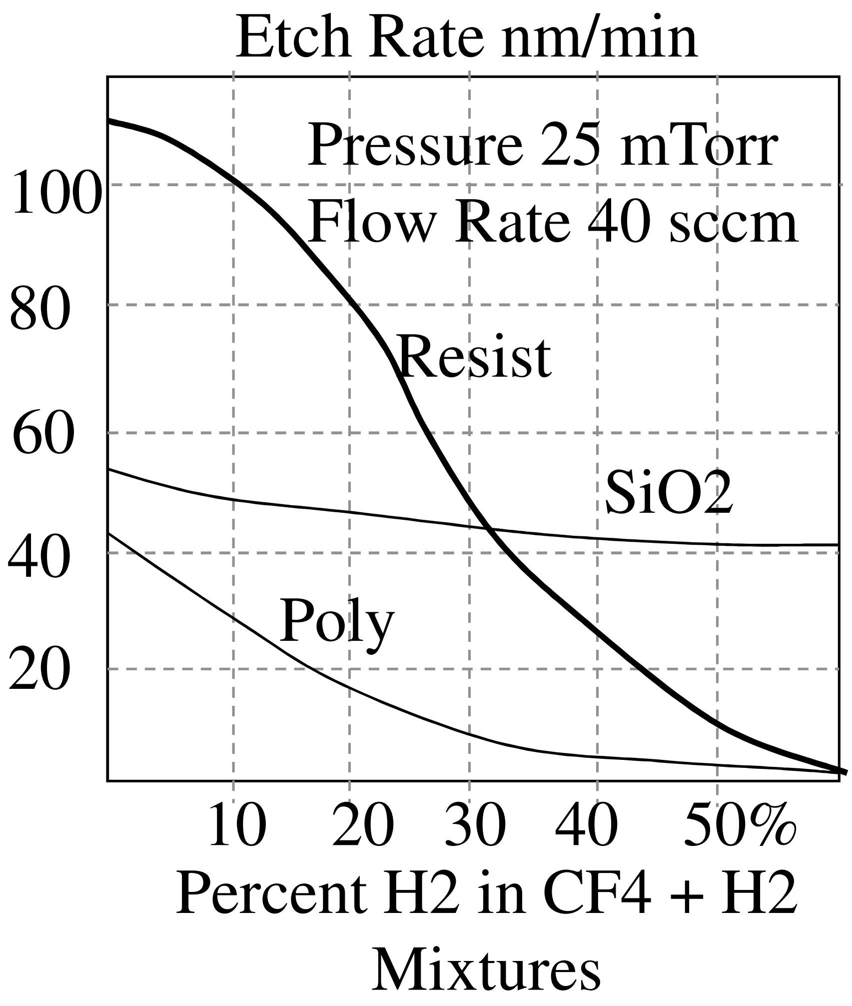
Ion Bombardment Energy

300 eV

Increasing Isotropic

ETCH RATE


Relative Etch Rate
1.0
0.8
0.6
0.4
0.2
Poly
10
20
30
40
50%
Percent O2


Etch Rate nm/min
Pressure 25 mTorr
Flow Rate 40 sccm
100
80
60
40
20
Resist
SiO2
Poly
10
20
30
40
50%
Percent H2 in CF4 + H2 Mixtures

ISOTROPIC 6000Å POLY ETCH RECIPE

6000Å Isotropic Poly Etch
SF6 84 sccm, O2 15 sccm, RF Power300 w, Pressure 400 mTorr, 4950 A/min (Isotropic), Resist Etch Rate ?, Oxide Etch Rate ?

Recipe Name:	FACPOLY Step 1
Chamber	2
Power	300W
Pressure	300 mTorr
Gas	SF6
Flow	100 sccm
Gas	O2
Flow	10 sccm
Metal Plate	Yes
Poly Etch Rate	6000 Å/min
Photoresist Etch Rate:	??? Å/min
Oxide Etch Rate:	??? Å/min

ANISOTROPIC POLY GATE ETCH RECIPE

Anisotropic Poly Gate Etch Recipe

SF6 30 sccm, CHF3 30 sccm, O2 5 sccm, RF Power 160 w, Pressure 40 mTorr, 1900 A/min (Anisotropic), Resist Etch Rate 300 A/min, Oxide Etch Rate 200 A/min

Recipe Name:	FACPOLY Step 2
Chamber	2
Power	160 watts
Pressure	40 mTorr
Gas	SF6
Flow	30 sccm
Gas	CHF3
Flow	30 sccm
Gas	O2
Flow	5 sccm
Poly Etch Rate	1150 Å/min
Photoresist Etch Rate:	300 Å/min
Oxide Etch Rate:	200 Å/min

ANISOTROPIC MEMS POLY ETCH RECIPE

Anisotropic Poly MEMS Etch

SF6 30 sccm, CHF3 30 sccm, O2 0 sccm, RF Power 200 w, Pressure 100 mTorr, 1900 A/min (Anisotropic), Resist Etch Rate 200 A/min, Oxide Etch Rate 300 A/min

Recipe Name:	FACPOLY Step 2
Chamber	2
Power	200W
Pressure	100 mTorr
Gas	SF6
Flow	30 sccm
Gas	CHF3
Flow	30 sccm
Gas	O2
Flow	0 sccm
Poly Etch Rate	2000 Å/min
Photoresist Etch Rate:	??? Å/min
Oxide Etch Rate:	??? Å/min

Needs work

DEEP SILICON ETCH FOR MEMS

CONTACT CUT ETCH RECIPE

Theory: The CHF3 and CF4 provide the F radicals that do the etching of the silicon dioxide, SiO2. The high voltage RF power creates a plasma and the gasses in the chamber are broken into radicals and ions. The F radical combines with Si to make SiF4 which is volatile and is removed by pumping. The O2 in the oxide is released and also removed by pumping. The C and H can be removed as CO, CO2, H2 or other volatile combinations. The C and H can also form hydrocarbon polymers that can coat the chamber and wafer surfaces. The Ar can be ionized in the plasma and at low pressures can be accelerated toward the wafer surface without many collisions giving some vertical ion bombardment on the horizontal surfaces. If everything is correct (wafer temperature, pressure, amounts of polymer formed, energy of Ar bombardment, etc.) the SiO2 should be etched, polymer should be formed on the horizontal and vertical surfaces but the Ar bombardment on the horizontal surfaces should remove the polymer there. The O2 (O radicals) released also help remove polymer. Once the SiO2 is etched and the underlying Si is reached there is less O2 around and the removal of polymer on the horizontal surfaces is not adequate thus the removal rate of the Si is reduced. The etch rate of SiO2 should be 4 or 5 times the etch rate of the underlying Si. The chamber should be cleaned in an O2 plasma after each wafer is etched.

US Patent 5935877 - Etch process for forming contacts over Titanium Silicide

DRYTEK QUAD ETCH RECIPE FOR CC AND VIA

Recipe Name:		FACCCUT
Chamber		3
Power		200W
Pressure		100 mTorr
Gas 1	CHF_3	50 sccm
Gas 2	CF_4	10 sccm
Gas 3	Ar	100 sccm
Gas 4	O_2	0 sccm

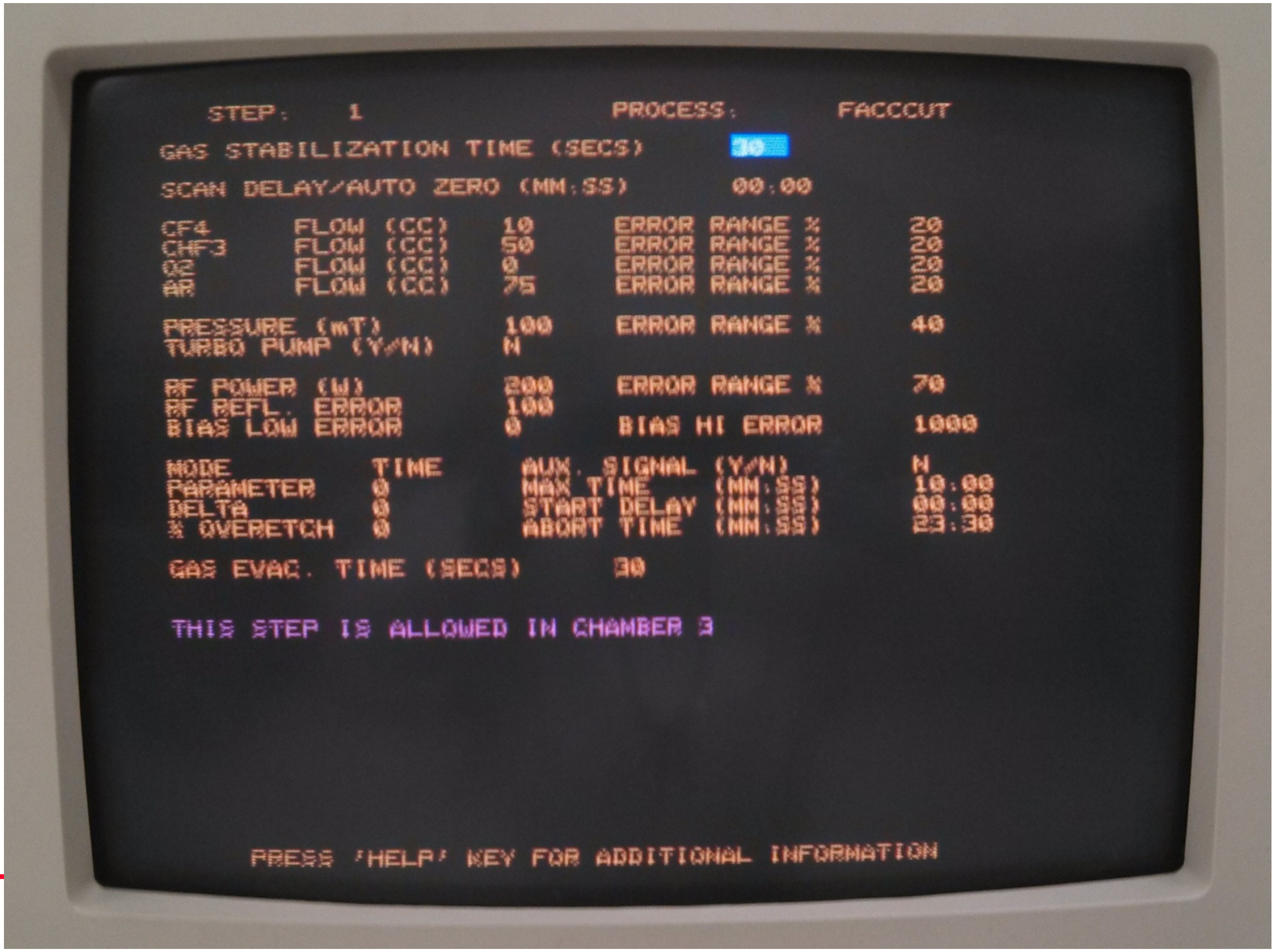
(could be changed to N_2)

TEOS Etch Rate	494	Å/min
Annealed TEOS	450	Å/min
Photoresist Etch Rate:	117	Å/min
Thermal Oxide Etch Rate:	441	Å/min
Silicon Etch Rate	82	Å/min
$TiSi_2$ Etch Rate	1	Å/min

US Patent 5935877 - Etch process for forming contacts over titanium silicide


Drytek Quad

FACCCUT RECIPE



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   STEP:    1                        PROCESS:       FACCCUT

 GAS STABILIZATION TIME (SECS)          30

 SCAN DELAY/AUTO ZERO (MM:SS)           00:00

 CF4       FLOW (CC)     10      ERROR RANGE %        20
 CHF3      FLOW (CC)     50      ERROR RANGE %        20
 O2        FLOW (CC)     0       ERROR RANGE %        20
 AR        FLOW (CC)     75      ERROR RANGE %        20

 PRESSURE (mT)           100     ERROR RANGE %        40
 TURBO PUMP (Y/N)        N

 RF POWER (W)            200     ERROR RANGE %        70
 RF REFL. ERROR          100
 BIAS LOW ERROR          0       BIAS HI ERROR        1000

 MODE          TIME     AUX. SIGNAL (Y/N)             N
 PARAMETER     0        MAX TIME     (MM:SS)          10:00
 DELTA         0        START DELAY  (MM:SS)          00:00
 % OVERETCH    0        ABORT TIME   (MM:SS)          23:30

 GAS EVAC. TIME (SECS)        30

 THIS STEP IS ALLOWED IN CHAMBER 3



      PRESS 'HELP' KEY FOR ADDITIONAL INFORMATION
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CONTACT CUT ETCH RECIPE IN P-5000

This etch can also be done in the P-5000. The main difference between the Drytek Quad and the P-5000 etch chamber is that the P-5000 has Magnetic Field enhancement of the plasma density increasing the etch rates taking less time per wafer making the process more suitable for manufacturing.

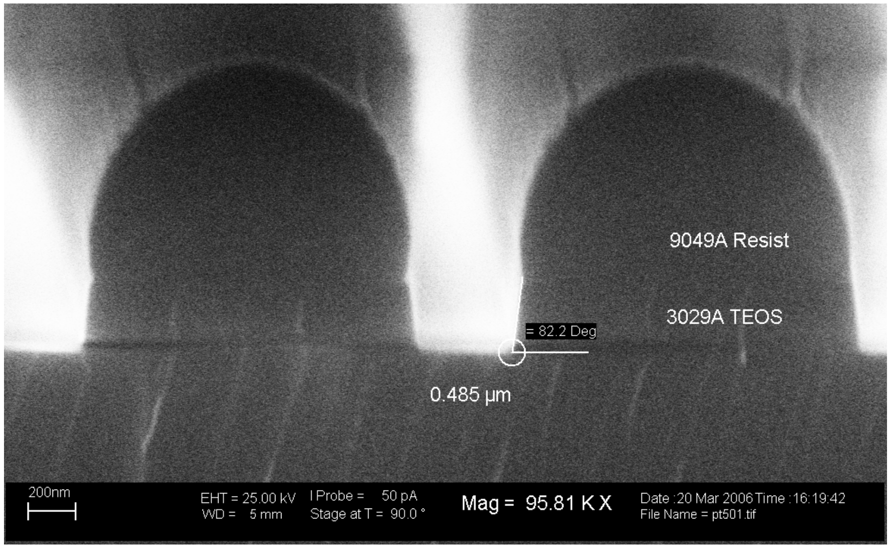


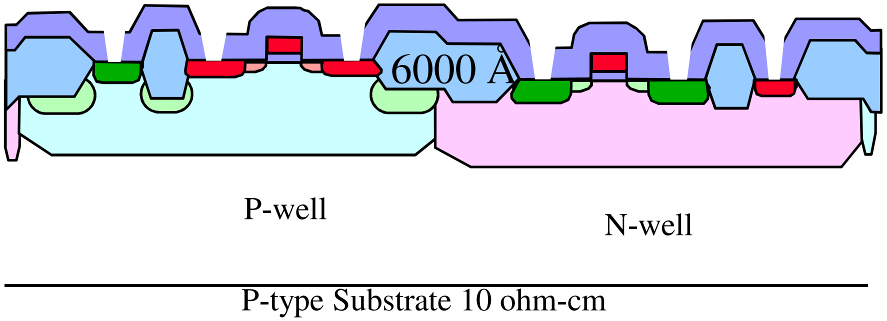
Figure 26: Contact Cut RIE

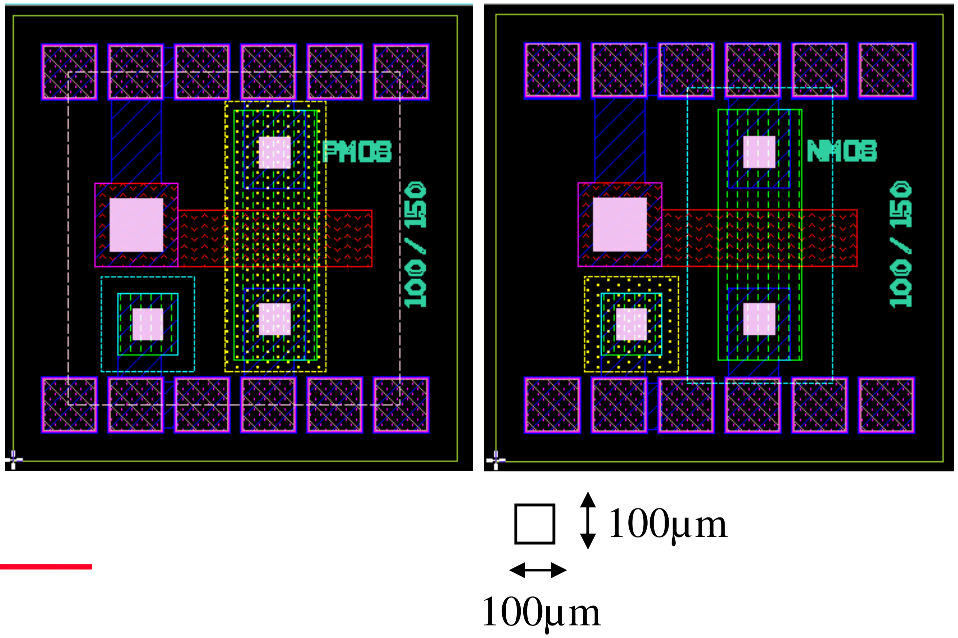
SiO_2 Etch Rate = 1850 Å/min
Si Etch Rate = 320 Å/min
SiO_2/Si Selectivity = 5.78

<u>Recipe Parameters:</u>
Applied Materials P-5000
Recipe = C6 – Oxide Etch
Power = 650 W
Pressure = 250 mTorr
CHF_3 = 100 sccm
CF_4 = 50 sccm
B = 40 Gauss

CONTACT CUT ETCH RECIPE

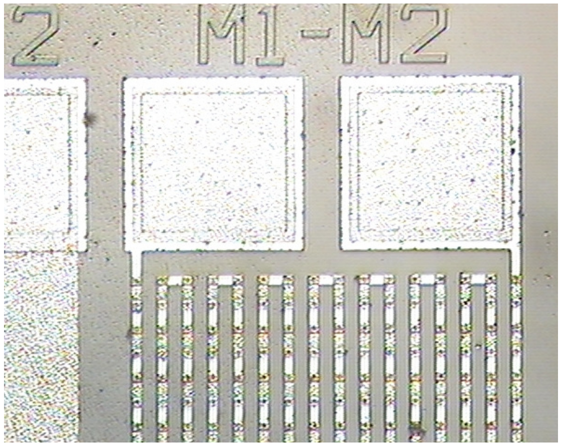
The John Galt chip designs have structures that have drain and source contacts are about 100x100 µm making it easy to measure remaining oxide on device wafers.

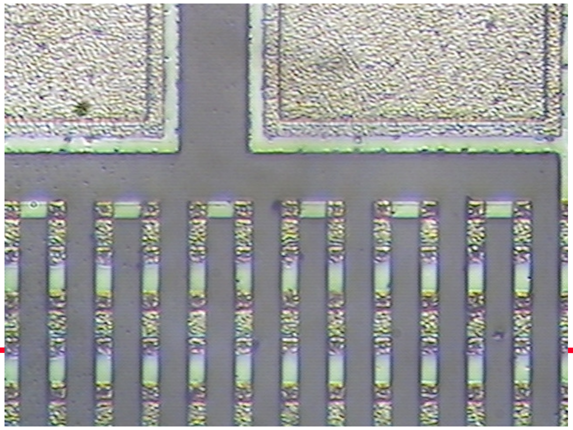


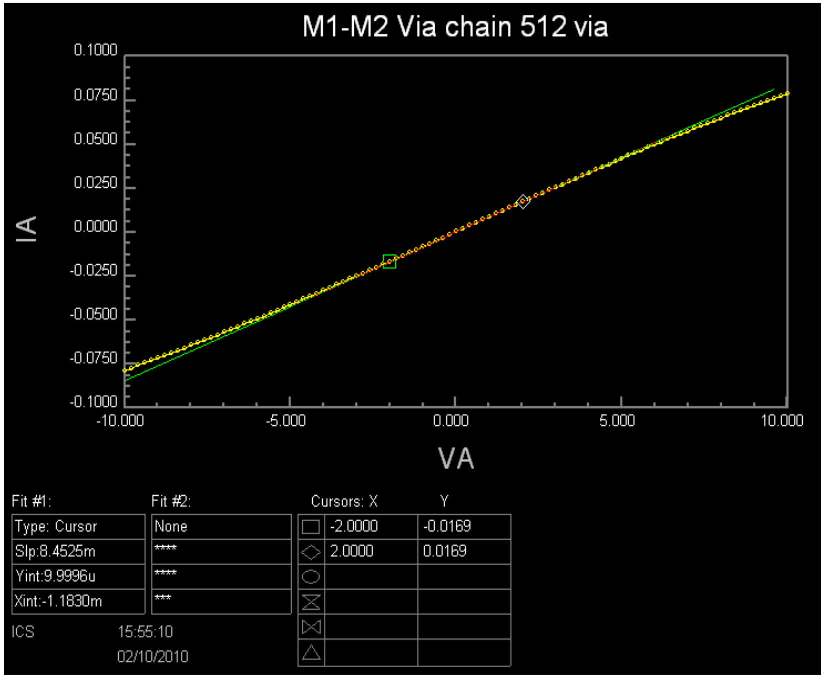


RESISTANCE MEASUREMENTS FOR M1-M2 VIA CHAIN

F081201 - M1-M2 Via chain with 512 Vias and total resistance of 118 ohms or 0.231 ohms per contact







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Yint:9.9996u     ****        ○
Xint:-1.1830m    ***         ⧗
ICS        15:55:10          ⋈
           02/10/2010        △
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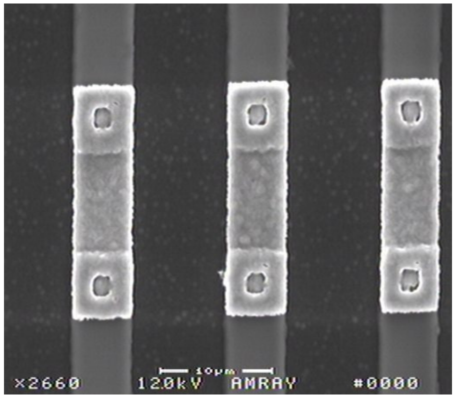
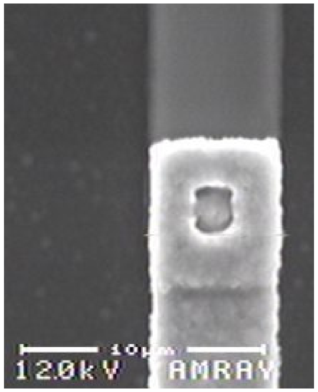




ISOTROPIC 1500/3500 Å NITRIDE ETCH RECIPE

Isotropic 1500/3500 Å Nitride Etch
SF6 60 sccm, RF Power 300 w, Pressure 300 mTorr, Nitride Etch Rate 600 A/min, Resist Etch Rate ?, Oxide Etch Rate ?

Recipe Name:	FACSI3N4 Step 2
Chamber	2
Power	200W
Pressure	100 mTorr
Gas	SF6
Flow	20 sccm
Nitride Etch Rate	1236 Å/min
Photoresist Etch Rate:	1580 Å/min
Oxide Etch Rate:	480 Å/min
uniformity	

OXIDE SIDEWALL SPACER ETCH RECIPE

LTO Spacer
65 sccm Ar, 65 sccm CHF3, 5 sccm O2, 200 watts 70 mTorr Photoresist etch rate 200 A/min, LTO 1000 A/min, Thermal Oxide 330 A/min

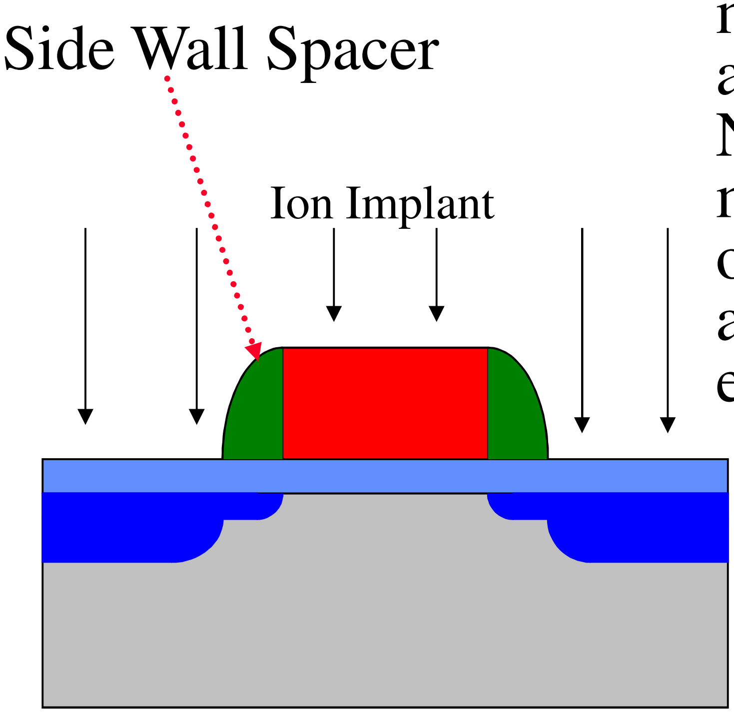
Recipe Name:	FACSPCR Step 1
Chamber	2
Power	200W
Pressure	70 mTorr
Gas	CHF3
Flow	65 sccm
Gas	Ar
Flow	65 sccm
Gas	O2
Flow	5 sccm
LTO/TEOS Etch Rate	1000 Å/min Annealed TEOS ~400 Å/min
Photoresist Etch Rate:	200 Å/min
Thermal Oxide Etch Rate:	330 Å/min

NITRIDE SIDEWALL SPACER ETCH RECIPE

Nitride Spacer

Recipe Name:	FACSPCR Step 2
Chamber	2
Power	250W
Pressure	40 mTorer
Gas	SF6
Flow	30 sccm
Gas	CHF3
Flow	30 sccm
Metal Plate	Yes
Nitride Etch Rate	1250 Å/min
Photoresist Etch Rate:	?? Å/min
Oxide Etch Rate:	950 Å/min
Uniformity	4%

NITRIDE SIDE WALL SPACERS

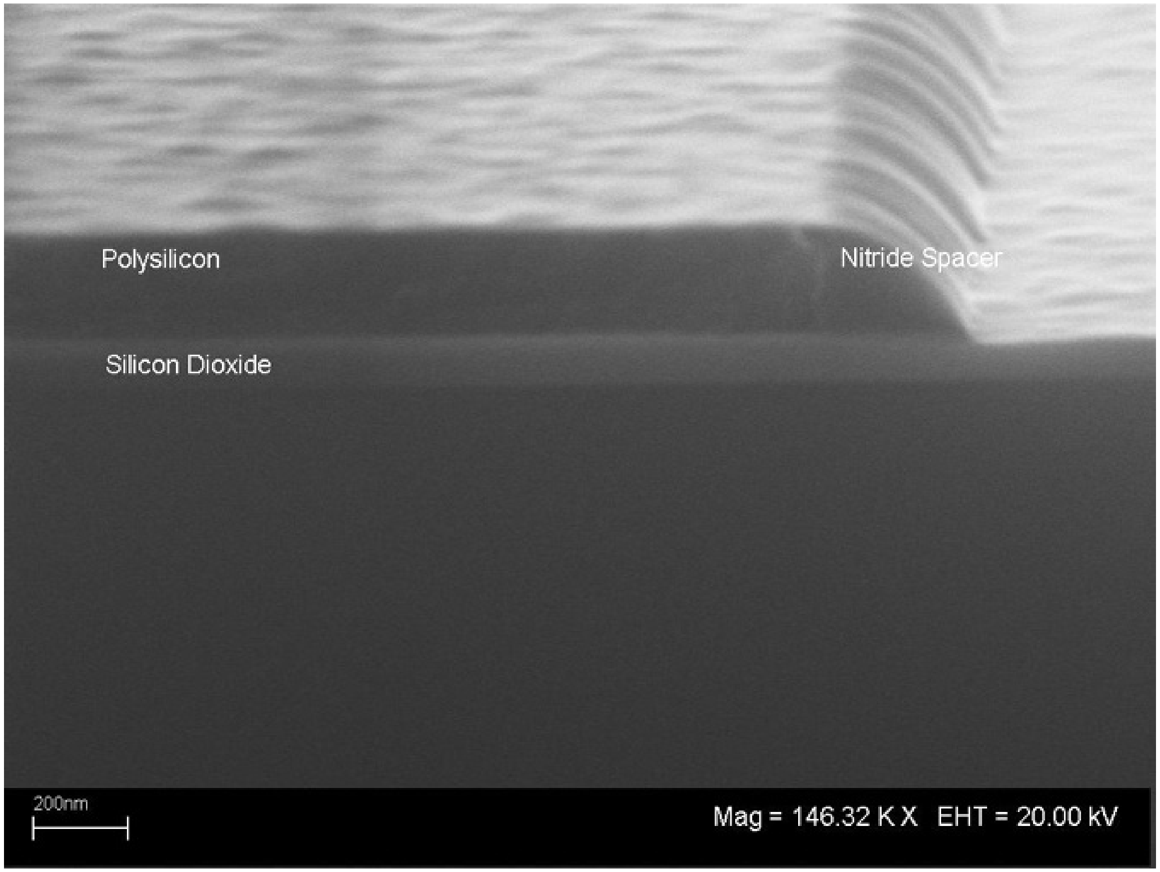


Nitride as a side wall spacer in deep sub micron transistor fabrication has some advantages over oxide side wall spacers. Nitride LPCVD is a more uniform and more conformal film than LTO. Nitride offers the possibility of end-point detection and higher selectivity during the plasma etch, while an oxide spacer does not.

Power	**250 Watts**
Pressure	**40 mTorr**
SF6	**30 sccm**
CHF3	**30 sccm**
Nitride Etch Rate	**1250 A/min**
Nitride Etch %NU	**~ 4% ***
Oxide Etch Rate	**~ 950 A/min ***
Oxide Etch %NU	**~ 10% ***
Selectivity Nitride:Oxide	**1.3:1**

Drytek Quad

NITRIDE SIDE WALL SPACERS



Poly thickness = 2300 A
Oxide thickness = 1000A
Spacer Height = 2300 A
Spacer Width = 0.3 um

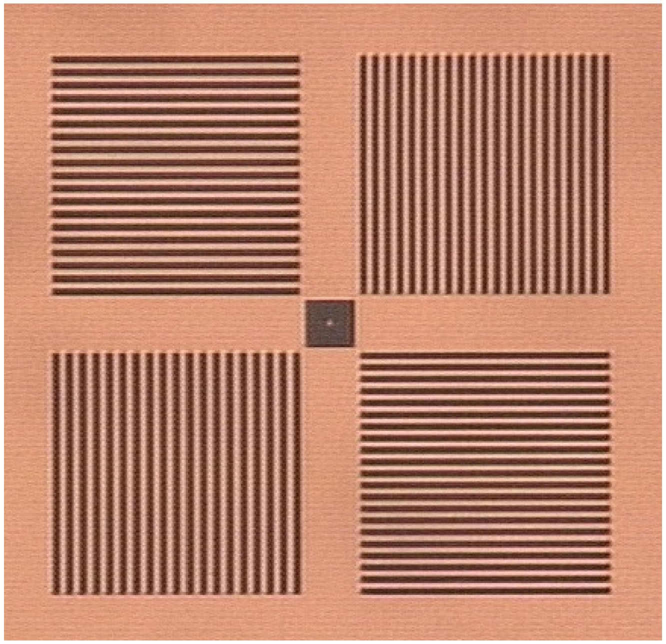
Special thanks to Dr. Sean Rommel for help in using the new LEO SEM

ZERO ETCH FOR ASML ALIGNMENT MARKS

Recipe Name:		ZEROETCH
Chamber		3
Power		200W
Pressure		100 mTorr
Gas 1	CHF_3	50 sccm
Gas 2	CF_4	25 sccm
Gas 3	Ar	0 sccm
Gas 4	O_2	10 sccm

Max Time = 120 seconds

Silicon Etch Rate	650	Å/min



44 um L/S 40 um L/S

DRYTEK QUAD MANUAL COMMANDS

(Note: Can use the * key above the exit key)

AFO	Arm Fast Out to get arm to return wafer to cassette (usually after you've pressed *G2 and TCR)
AFI	Arm Fast In
***G2**	to retrieve wafer from chamber 2 (usually followed by TCR and AFO)
***IC**	brings cassette elevator to the top (initialize elevator height – do before running recipe)
IMO and ICO	allows you to check what actual pressures are in diagnostic mode – always have open
NTPC, NCVC, NTVC	closes Nitrogen
NTPO, NCVO, NTVO	opens up Nitrogen
***P2**	to put in Chamber 2
P2U	moves pedestal up in chamber 2
P2D	moves pedestal down in chamber 2
***PC1**	Put in cassette slot 1, and the arm retracts
PTE	Pedestal Test End
PTS	Pedestal Test Start
SCC	closes slot door to cassette chamber
S1C	closes slot door to chamber 1
S1O	opens slot door to chamber 1
TCR	to have robot arm move from facing Chamber 2 to facing front of Drytek
VTO	Start pump down
VTC	Stop pump down

From: Patricia Meller

END POINT DETECTION

Time

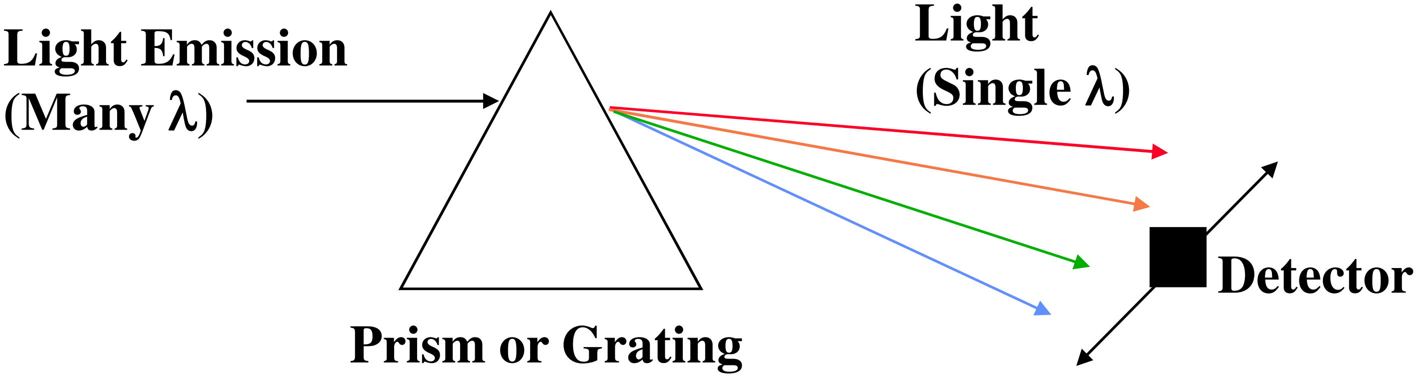
Plasma Brightness

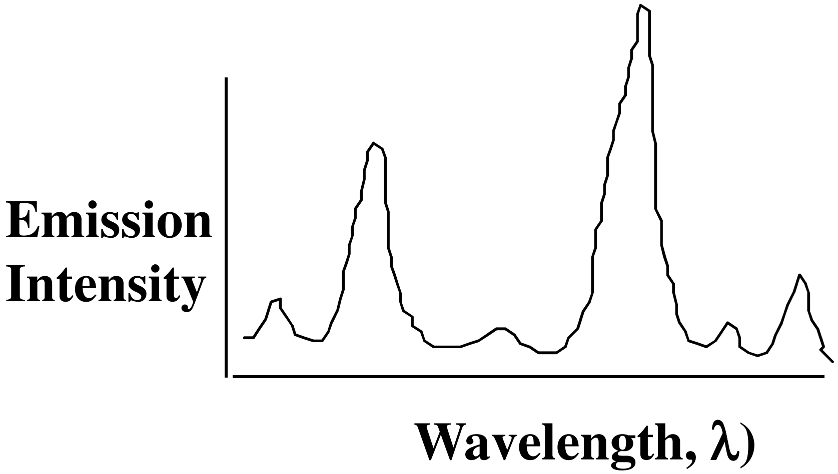
Changes in Emission Spectrum

EMISSION SPECTRUM

The emission of light occurs when electrons, ions or molecules in a high energy state relax to a lower energy state. In a plasma, gas molecules are broken into fragments and excited to high energy states by the applied radio frequency power. These fragments recombine giving off photons equal in energy to the difference between the excited state and the relaxed state called an emission spectrum. In general plasmas are quite complex and the emission spectrum has many spikes and peaks at different wavelengths. Some of these spikes and peaks change as the chemistry of the plasma changes. For example in etching silicon nitride once the etching is complete the amount of nitrogen in the plasma goes to zero and peaks associated with nitrogen disappear. If the nitride is over oxide than once the nitride is gone the amount of oxygen in the plasma will increase and peaks associated with oxygen will appear. Usually several signals are watched at the same time to determine end point in plasma etching.

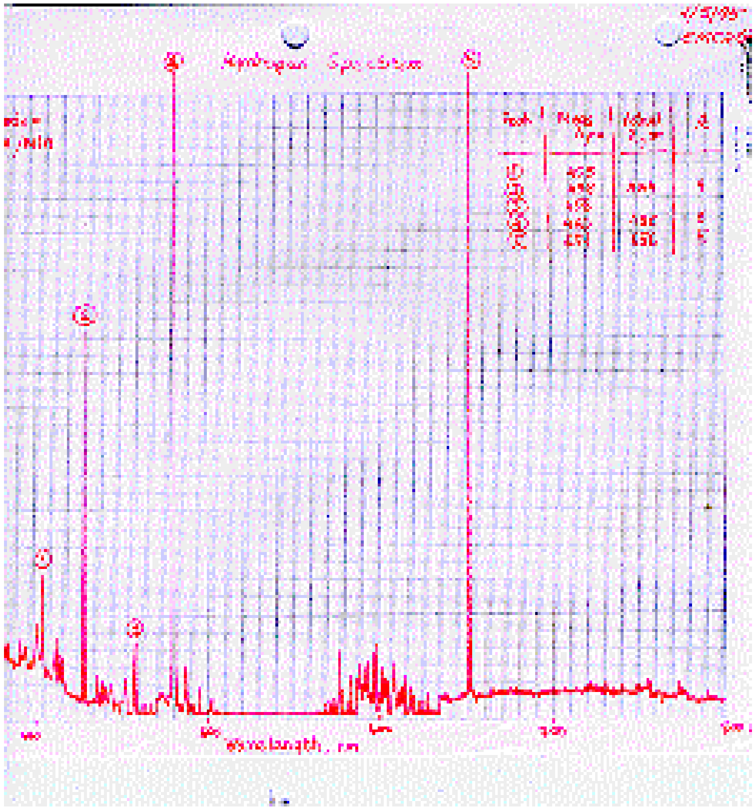
EMISSION SPECTROSCOPY





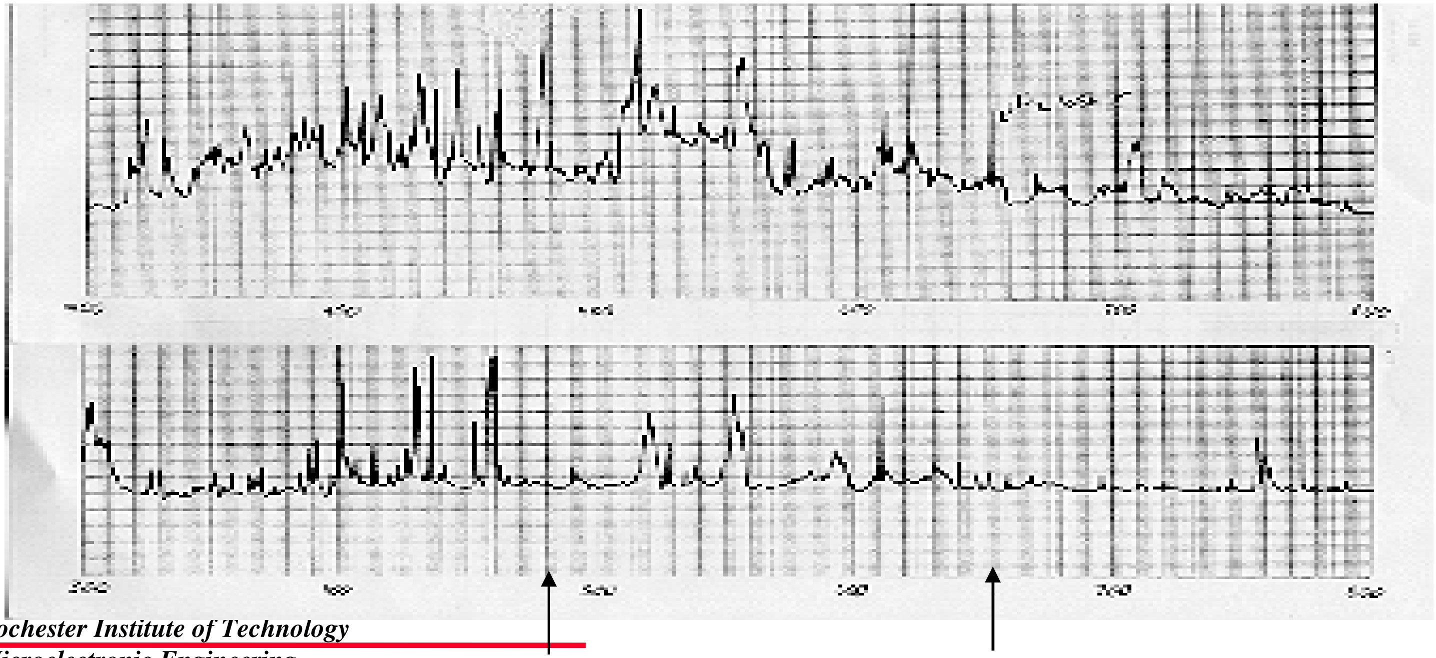
CALIBRATION

Your emission spectrometer can be calibrated by looking at well known emission spectra such as Hydrogen, which has peaks at 405, 438, 458, 486, and 656 nm.



EXAMPLES OF EMISSION SPECTRA MEASURED AT RIT

Compare the emission spectra with no wafer to the spectra with a film being etched. Find a peak that represents a byproduct of the etch. Set the spectrometer on one or more of these characteristic peaks and monitor etch completion as these peaks change. For example in O_2 plasma etch of photoresist there is a peak at 483.5 nm associated with CO which disappears at the end of the etch.



O_2 Plasma Wafer with Photoresist

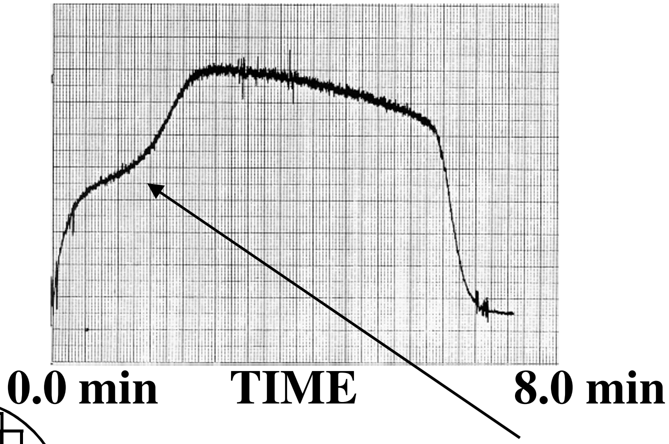
O_2 Plasma No Wafer in the System

CO peak at 483.5 nm

H_2 peak at 656.5 nm

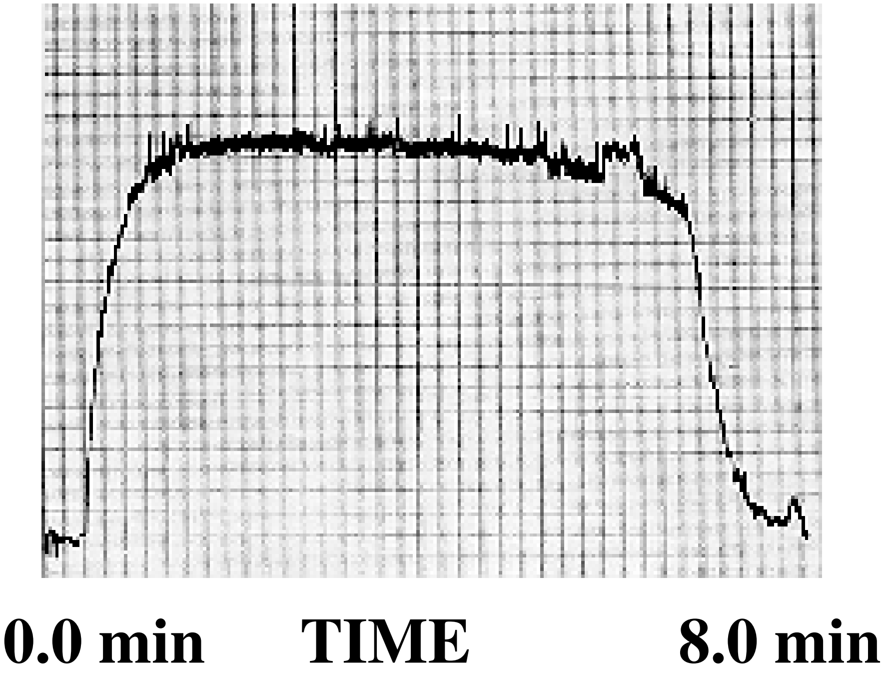
O2 PLASMA STRIP END POINT DETECTION

Monitor the CO peak at 483.5 nm. During photoresist stripping there are large numbers of CO molecules. At end of Photoresist stripping the number of CO molecules is reduced.



BF2 heavy dose implant causes the surface to strip more slowly than bulk, thus initial CO emission is lower

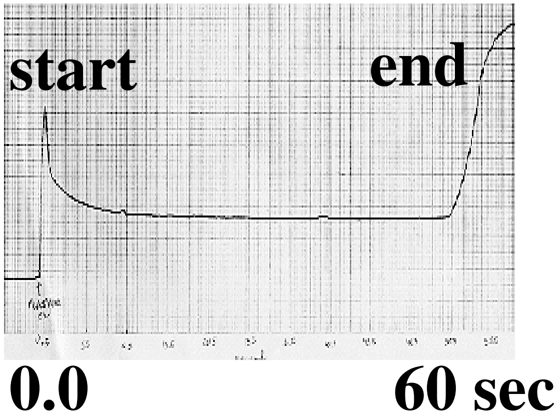
O2, 30 sccm, 50 watts, 300 mTorr



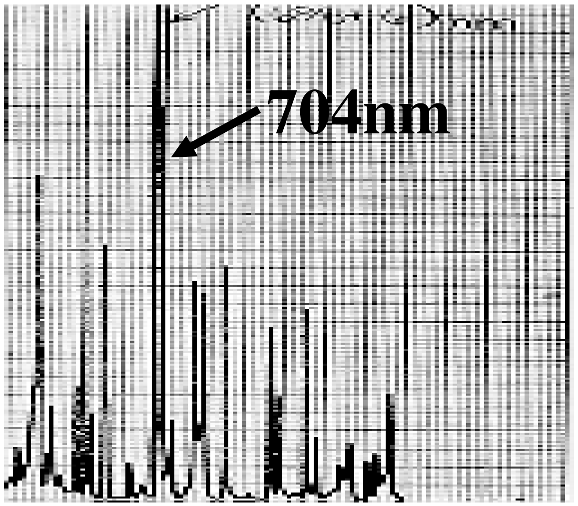
POLY ETCH END POINT EXAMPLE

End Point

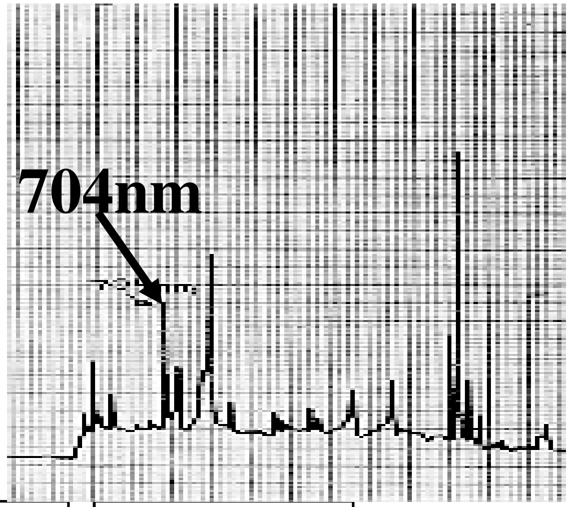
SF6 + O2
704nm Line



Emission Spectra
in SF6 + O2 Plasma
No Silicon Wafer
in System



Emission Spectra
During Etching
of Poly
in SF6 + O2 Plasma



OCEAN OPTICS SPECTROMETER

REFERENCES

1. McGuire, Gary E, Semiconductor Materials and Process Technology Handbook, Chap. 5. “Plasma Processing” and Chap. 6, “Physical Vapor Deposition”, Noyes Publications, Park Ridge, NJ, 1988.
2. Wolf, S. and Tauber, R.N., Silicon Processing for the VLSI Era, Vol 1, Chap. 10, “Physical Vapor Deposition”, and Chap. 16, “Dry Etching for VLSI”, Lattice Press, Sunset Beach, CA, 1986.
3. Morgan, Russ, Plasma Etching in Semiconductor Fabrication, Elsevier Press, New York, 1985.
4. Manos, D. and Flamm, D. eds., Plasma Etching, an Introduction, Academic Press, Inc., New York, 1989.
5. US Patent 5935877 - Etch process for forming contacts over titanium silicide