Plasma Etching

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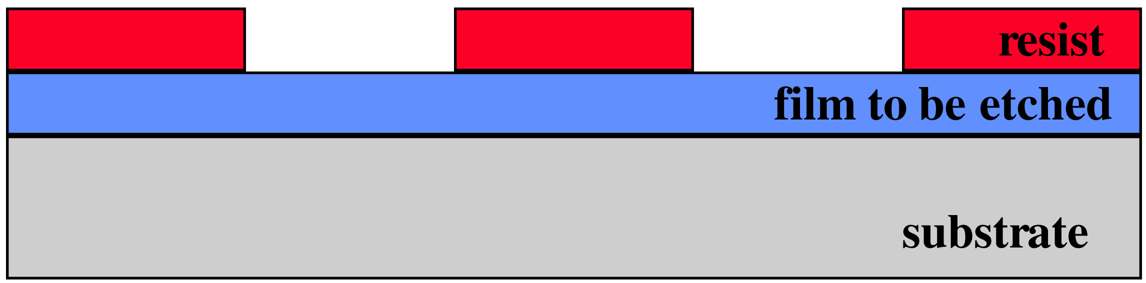
4-17-13 Plasma_Etch.ppt

OUTLINE

- Introduction
- Plasma Etching Metrics – Isotropic, Anisotropic, Selectivity, Aspect Ratio, Etch Bias
- Plasma and Wet Etch Summary
- The Plasma State - Plasma composition, DC & RF Plasma
- Plasma Etching Processes - The principle of plasma etching, Etching Si and SiO2 with CF4
- Other Plasma Processes - Sputtering, resist stripping, CVD
- Equipment
- Advanced Plasma Systems
- Trends, Recent Advances
- Summary

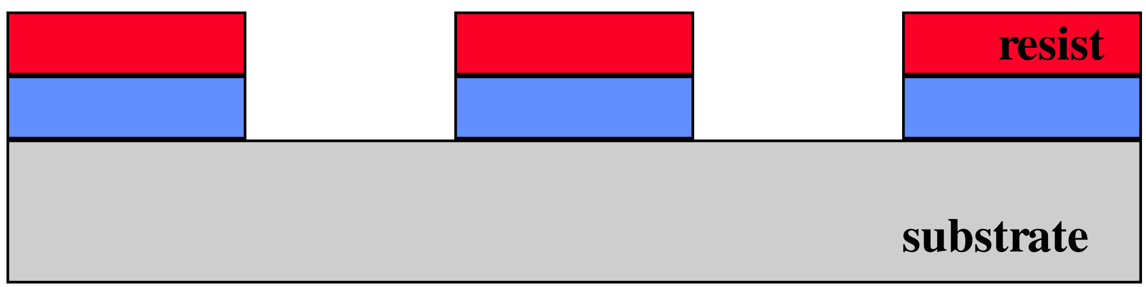
INTRODUCTION - IDEAL ETCHING PROCESS

Prior to etch



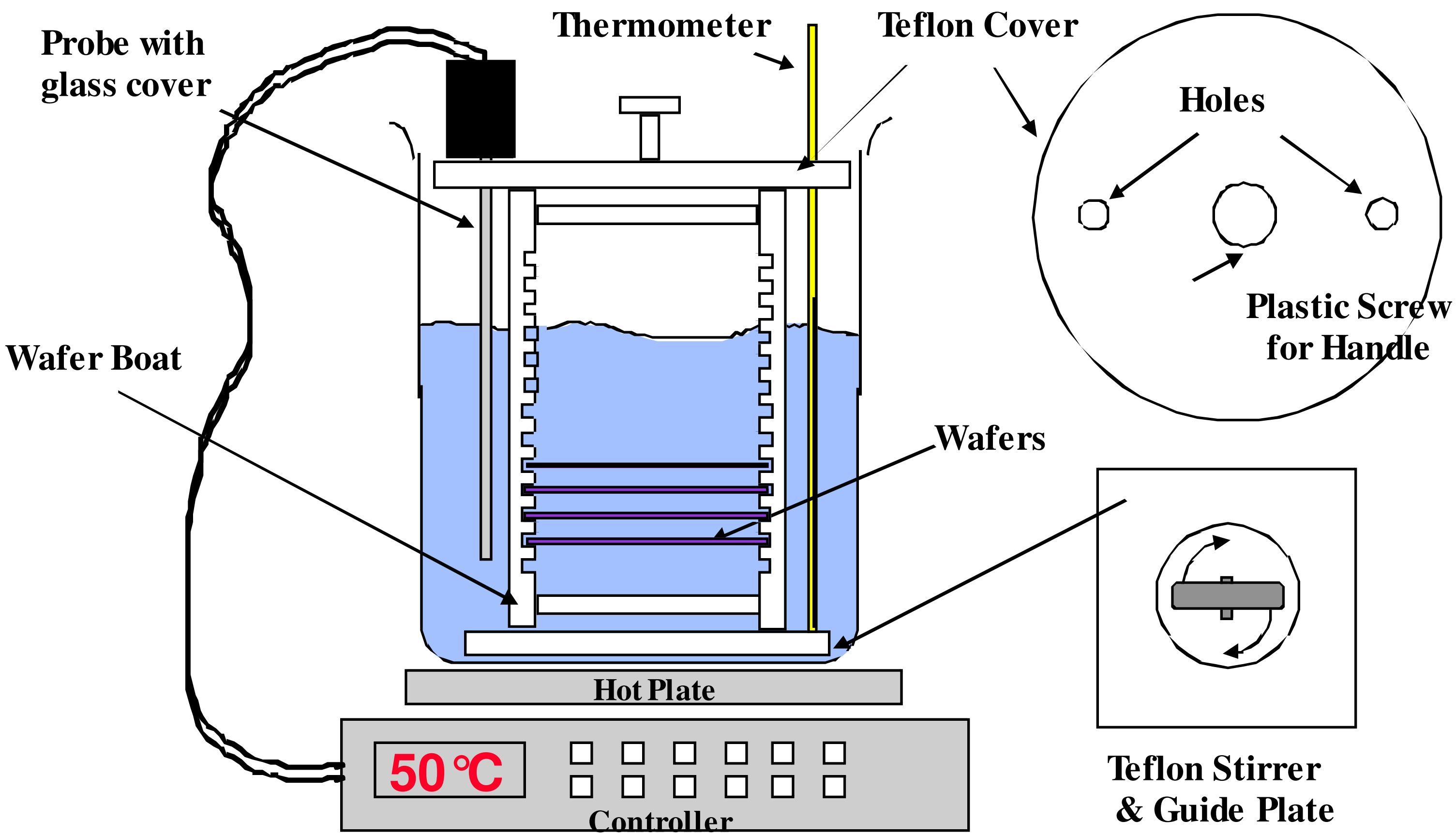
Ideal etching is the accurate transfer of the pattern to the underlying film

After etch



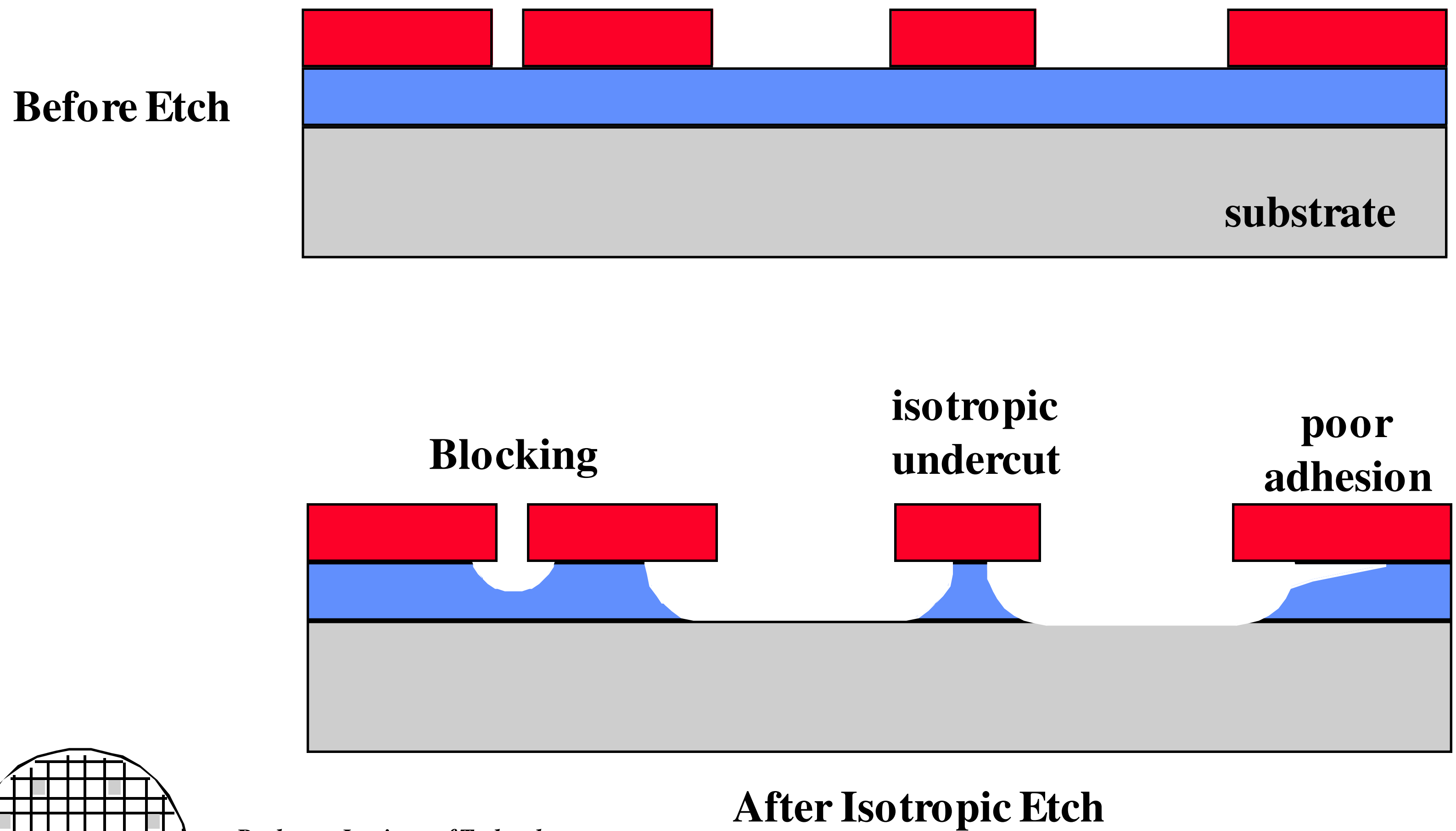
No process is ideal, some anisotropic plasma etches are close

WET ETCHNG



Generally Wet Etching is Isotropic

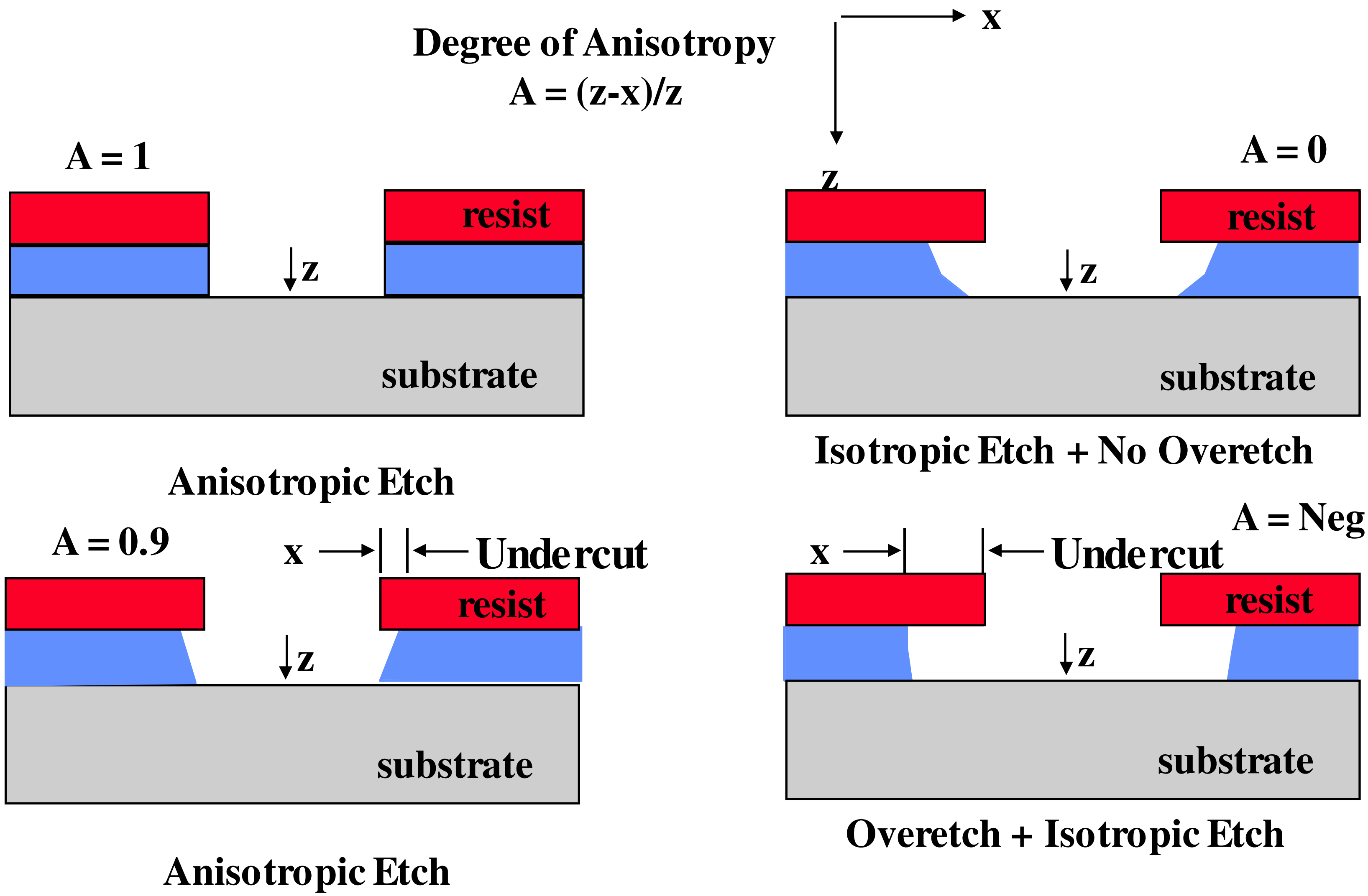
WET ETCHING


Before Etch
substrate
Blocking
isotropic
undercut
poor
adhesion
After Isotropic Etch

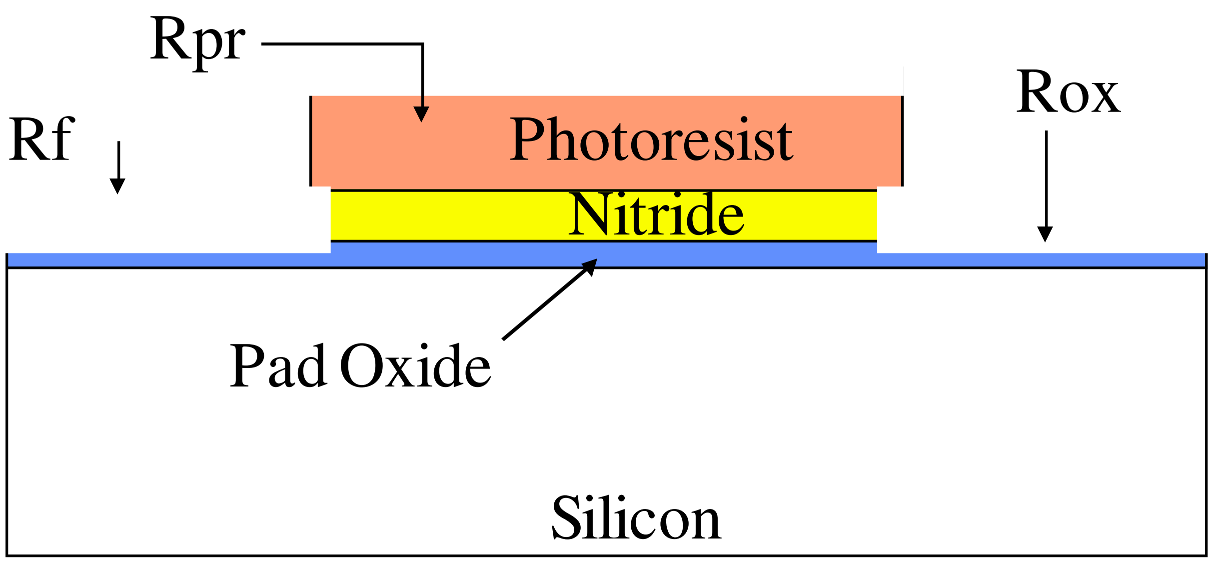
DIRECTIONALITY OF THE ETCH

Degree of Anisotropy

$$A = (z-x)/z$$



SELECTIVITY



Rf = etch rate for nitride film
Rpr = etch rate for photoresist
Rox = etch rate for pad oxide

We want Rf high and Rpr, Rox low

Selectivity of film to Photoresist = Rf/Rph

Selectivity of film to pad oxide = Rf/Rox

UNIFORMITY

$$\text{Etch rate non-uniformity (\%)} = \frac{\text{(Maximum etch rate-Minimum etch rate)}}{\text{(Maximum etch rate+Minimum etch rate)}} \text{ x100\%}$$

Example: Calculate the average etch rate, etch rate uniformity given the etch rates at center, top left, top right, bottom right, bottom left are 750, 812, 765, 743, 798 nm

Answer: 773.6 nm and 4.4%

WET ETCHING CHARACTERISTICS

Advantages:

- Simple equipment
- High throughput (batch process)
- High selectivity

Disadvantages:

- Isotropic etching leads to undercutting
- Uses relatively large quantities of etch chemicals, must immerse wafer boats, must discard partially used etch to maintain etch rate
- Hot chemicals create photoresist adhesion problems
- Small geometries difficult, etch block caused by surface tension
- Critical Etch time, dimensions change with etch time, bias develops
- Chemical costs are high
- Disposal costs are high

THE NEED FOR PLASMA ETCHING

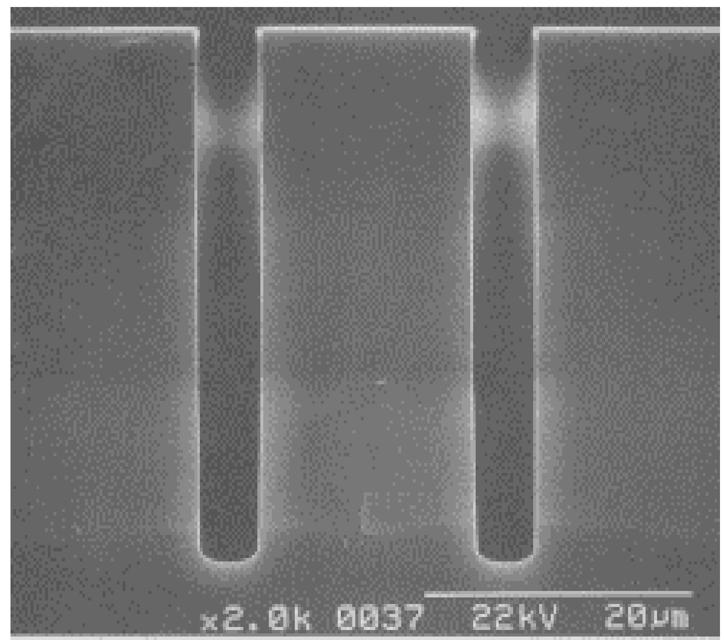
Advanced IC Fabrication with small geometries requires precise pattern transfer

Sub Micrometer Geometry is common

Line widths is often comparable to film thickness

Some applications require high aspect ratio

Some materials wet etch with difficulty



High aspect ratio, anisotropic etch; only possible through plasma etch

PLASMA ETCHING CHARACTERISTICS

Advantages:

- No photoresist adhesion problems
- Anisotropic etch profile is possible
- Chemical consumption is small
- Disposal of reaction products less costly
- Suitable for automation, single wafer, cassette to cassette

Disadvantages:

- Complex equipment, RF, gas metering, vacuum, instrumentation
- Selectivity can be poor
- Residues left on wafer, polymers, heavy metals
- Particulate formation
- Stringers, profile effects

GEC CELL

SF6
CF4
CHF3
O2
H2
Ar
He

THE PLASMA STATE

Plasma - A partially ionized gas with equal numbers of positive and negative particles. Overall the plasma remains electrically neutral.

Glow Discharge - A non-ideal plasma. Some regions are positively charged, others are negative. A wide variety of particles exist in the discharge in addition to ions and electrons, including for example, radicals, excited species, and various fractured gas molecules created by collisions between electronics and gas molecules or atoms. Overall, the discharge system must remain electrically neutral even though some portions of it are not. (Glow Discharge and Plasma are terms that are used interchangeably in dry etching)

Collisions – Ions and electrons are accelerated by the electric field, and collide with other gas particles and bombard all surfaces.

THE PLASMA STATE

Ion, (Positive) - A positively charged particle - a gas molecule or atom with and electron removed.

Radical - A neutral gas particle (atom or molecule) that exists in a state of incomplete chemical bonding and is therefore chemically reactive. It is formed by the fracturing of a gas molecule by a high energy electron collision.

Example: $O2 + e- \rightarrow 2O$

PLASMA COMPOSITION

A typical plasma contains:

Neutral Molecules at a density of	10e16/cm3
Radicals	10e14/cm3
Electrons	10e8/cm3
Positive ions	10e8/cm3

There are a million times more radicals than ions or electrons. Radicals form more easily and their lifetime is much longer.

Ions don't etch, radicals do. Ions affect the process by energetic (physical) bombarding of the surface, influencing the chemical processes of etching.

Radicals are responsible for the dry etching process. They are chemically active and react with the surfaces to produce volatile products.

BASICS OF PLASMA ETCHING

CF_4 is inert gas

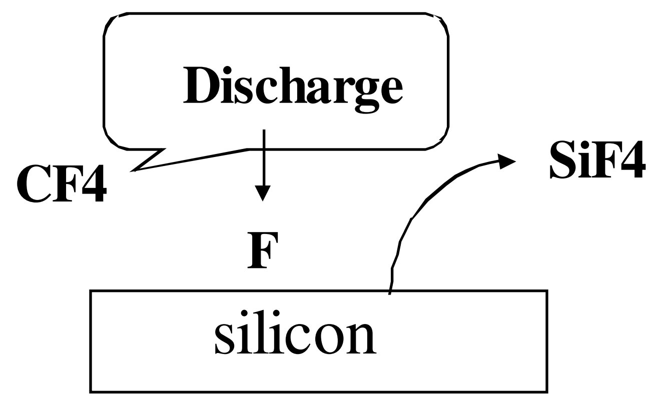
add electron impact to produce fluorine radicals:

$CF_4 + e \Rightarrow CF_3^{+} + F + 2e$ (Dissociative Ionization)

$CF_4 + e \Rightarrow CF_3 + F + e$ (impact dissociation)

Then chemically form volatile SiF_4:

$Si + 4F \Rightarrow SiF_4$ (gas)



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ADDED GASES

Hydrogen - reduces fluorine concentration by combination to form HF

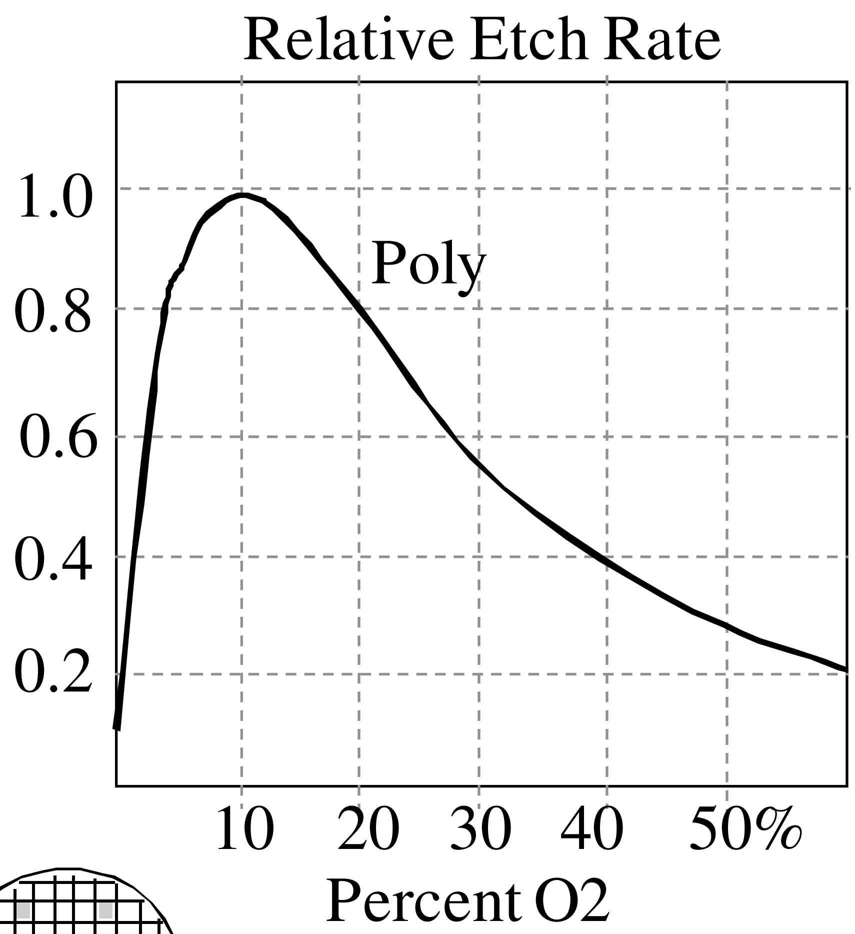
Oxygen - Increases fluorine concentration by combining with carbon which would otherwise require fluorine or reacting with CF3 to liberate F

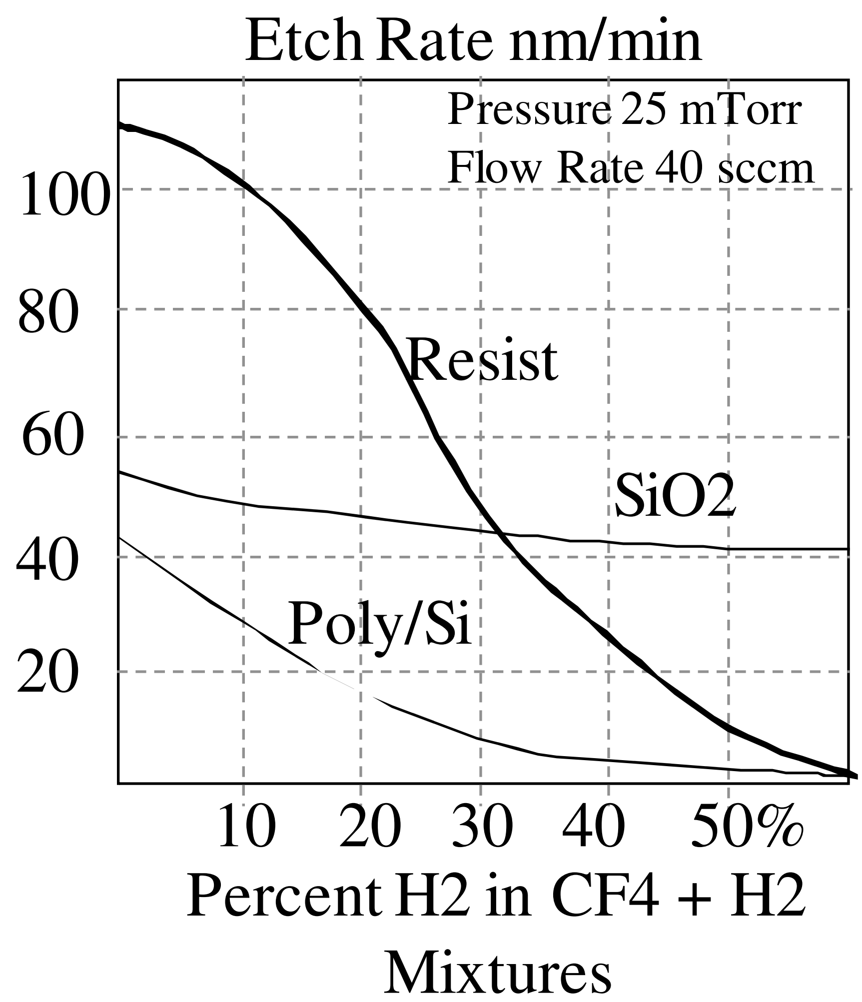
Argon – Increases plasma density increasing fluorine radical conc.

Helium – Carries heat away and helps photoresist survival

Gas	C:F Ratio	SiO2:Si Selectivity
CF4	1:4	1:1
C2F6	1:3	3:1
C3F8	1:2.7	5:1
CHF3	1:3	10:1

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/Si
10
20
30
40
50%
Percent H2 in CF4 + H2
Mixtures

SILICON ETCHING MECHANISM

CF4 is Freon 14 F/C ratio is 4

CF4 + e- --> CF3 + F e-

F radicals adsorb on silicon surface; SiF4 desorbs

CF3 radicals also adsorb

CF3 + F --> C4 desorbs

The presence of carbon on the surface reduces the amount of fluorine available to etch silicon. Carbon will leave the surface by combining with F reducing fluorine, carbon can remain on the surface forming C-F polymers which in turn inhibits etching. High F/C ratio favors etching. Adding O2 can increase etch rate and increases selectivity over oxide.

SILICON DIOXIDE ETCHING MECHANISM

C_3 and F radicals adsorb. C bonds with oxygen at the surface F bonds with Si. By-products are CO, CO_2, COF_2, SiF_4. The addition of H_2 removes F from the system by forming stable HF gas. Addition of H_2 therefore decreases the effective F/C ratio and increases selectivity of SiO_2 with respect to silicon. As H_2 is increased, it begins to consume fluorine H + F = HF This slows the formation of SiF_4 and slows the removal of Silicon. Polymerization will be promoted on all surfaces, which tends to inhibit etching. On horizontal surfaces however, ionic bombardment provides enough energy to cause the carbon/hydrogen to combine with surface oxygen. Released CO and H_2O expose the surface silicon which is removed by combining with released fluorine radicals. Silicon will not be etched because of the absence of oxygen at the surface.

DRYTEK QUAD ETCH RECIPE FOR CC AND VIA

Recipe Name:		FACCUT
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
TiSi2 Etch Rate	1	Å/min

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

Drytek Quad

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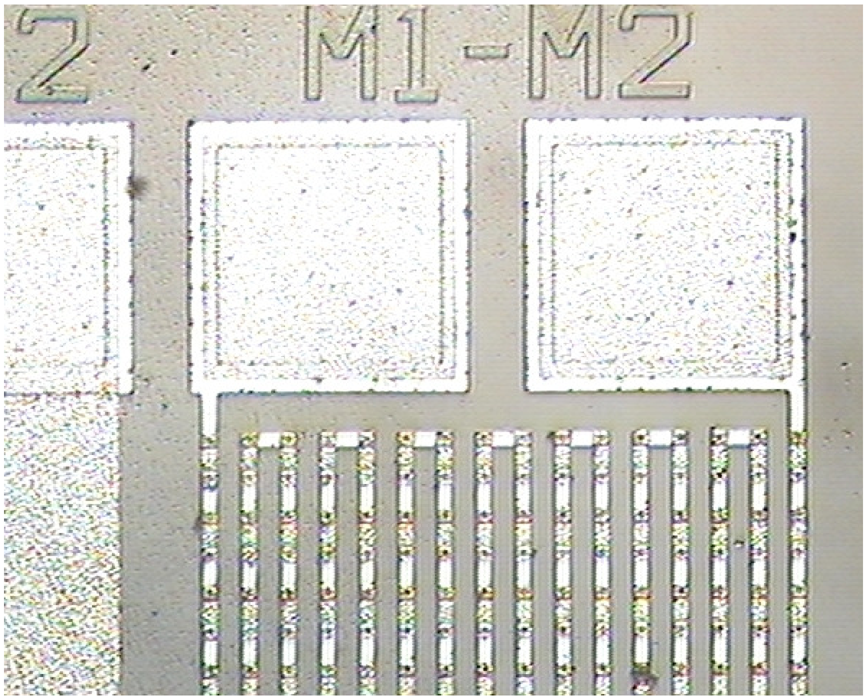
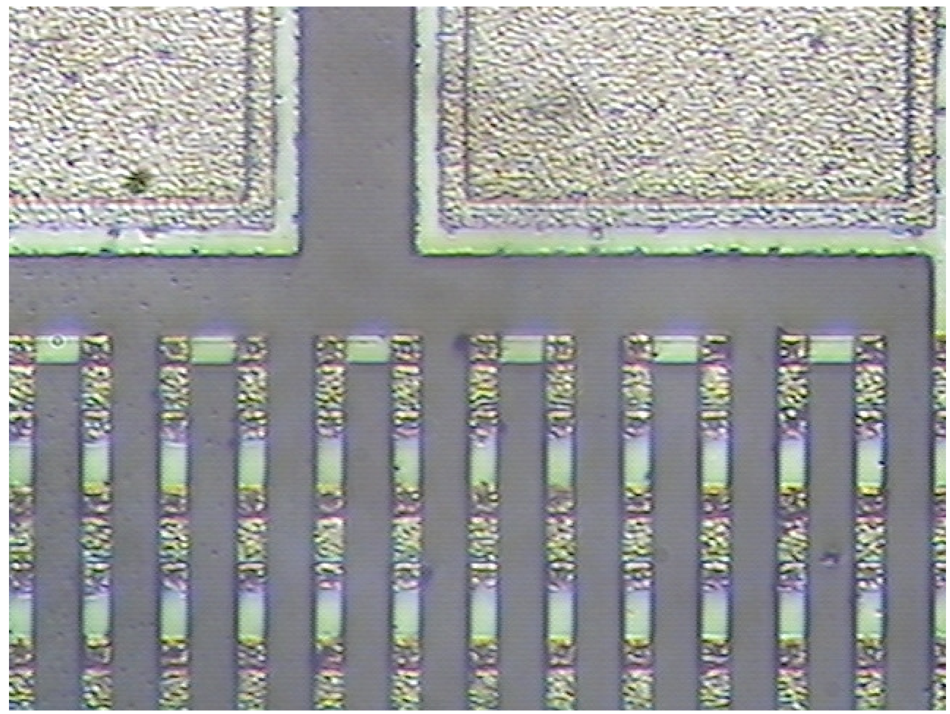
CONTACT CUT ETCH RECIPE

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

PICTURES OF M1-M2 VIA CHAIN





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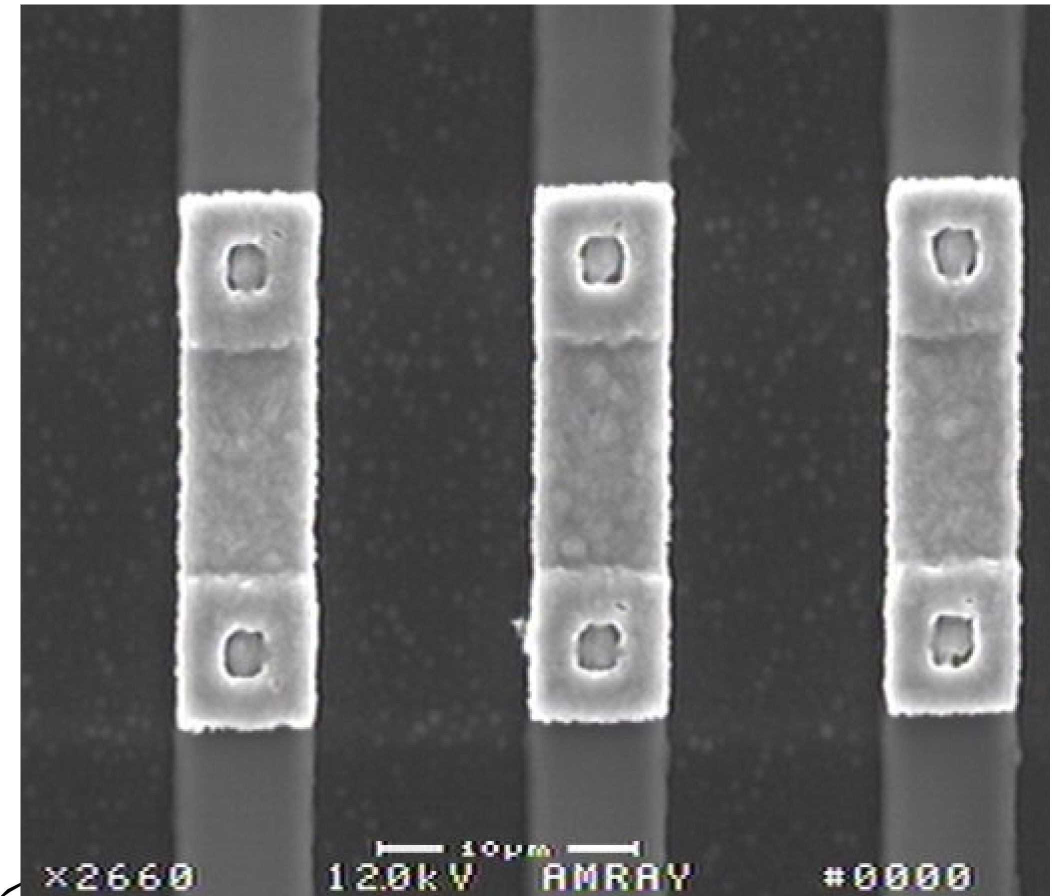
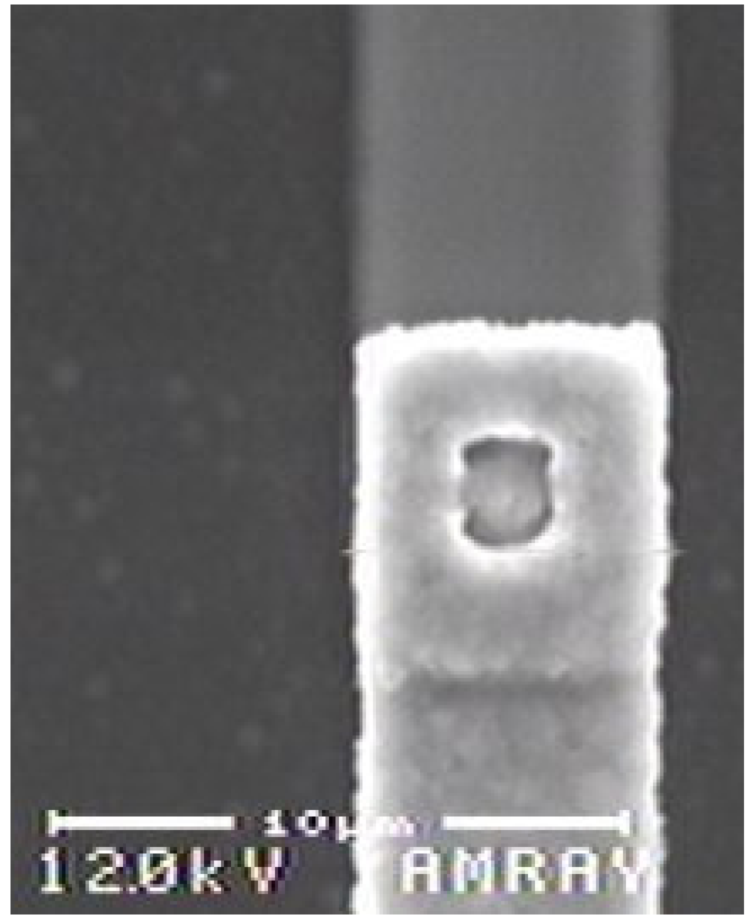
SEM OF 6μm LINES / 2X2μm VIAS





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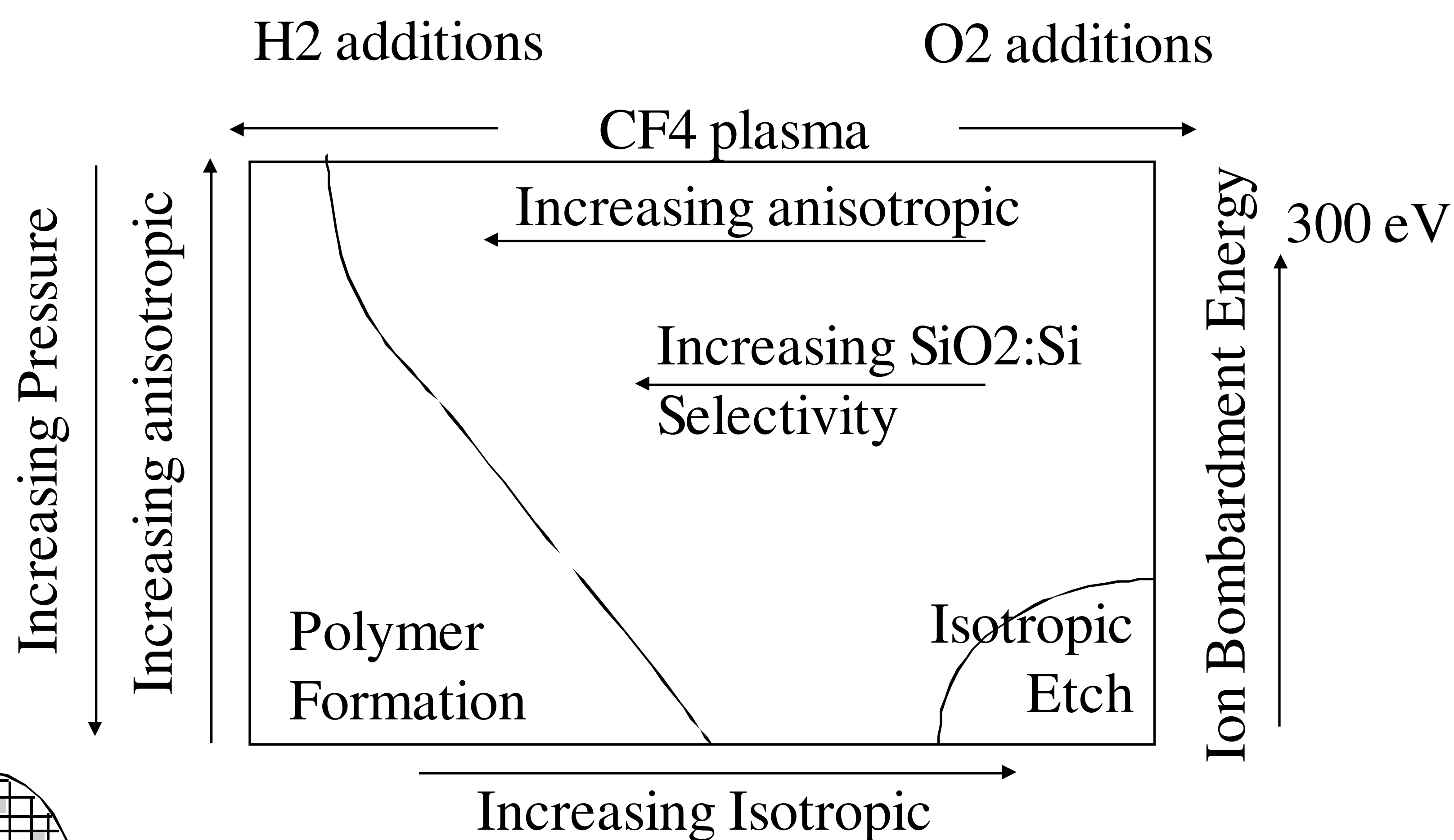
POLYMER FORMATION



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DRY ETCHING SPECTRUM

Pressure

Low
<100 mTorr

100 mTorr

400 mTorr

Physical (Sputtering)
Momentum Transfer
Directional Etch Possible
Poor Selectivity
Radiation Damage Possible

Reactive Ion Etching
Physical and Chemical
Variable Anisotropy
Variable Selectivity

Chemical Plasma Etching
Fast
Isotropic
High Selectivity
Low radiation Damage

Energy

High Energy

Low Energy

PLASMA ETCHING OF VARIOUS MATERIALS

Material	Kind of Gas Plasma	Remark
Si	CF_4, $CF_4 + O_2$, CCl_2F_2, SF_6	
poly-Si	CF_4, $CF_4 + O_2$, $CF_4 + N_2$, SF_6	doped or undoped
SiO_2	CF_4, $CF_4 + O_2$, HF* ,SF_6	*selective
	CCl_2F_2, C_3F_8**, $C_2F_6 + H_2$**	
Si_3N_4	CF_4, $CF_4 + O_2$, SF_6	
Mo	CF_4, $CF_4 + O_2$	
W	CF_4, $CF_4 + O_2$	
Au	$C_2Cl_2F_4$	
Pt	$CF_4 + O_2$, $C_2Cl_2F_4 + O_2$, $C_2Cl_3F_3 + O_2$	
Ti	CF_4	
Ta	CF_4	
Cr	Cl_2, CCl_4, CCl_4 + Air	evaporate or sputter
Cr_2O_3	Cl_2 + Ar, CCl_4 + Ar	oxidation method
Al	CCl_4, CCl_4 + Ar, BCl_3	
Al_2O_3	CCl_4, CCl_4 + Ar, BCl_3	
GaAs	CCl_2F_2	

ION ASSISTED ANISOTROPIC ETCHING

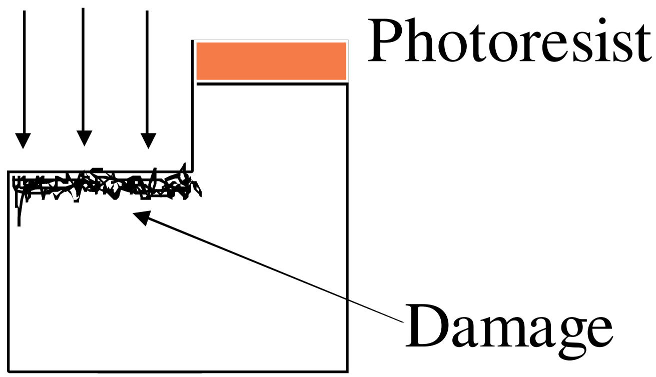
Two mechanisms are proposed to explain the phenomenon of ion assisted anisotropy. Anisotropic etching is believed to result from a combination of physical and chemical removal processes. The ratio of vertical etch rate to horizontal etch rate may be increased either by reducing the horizontal rate or by increasing the vertical rate.

ION INDUCED DAMAGE MECHANISM:
In this model, bombarding ions have sufficient energy to break crystal bonds, making the film more accessible and the surface more reactive to the active chemical etchants. At the sidewalls, where there is essentially no ion bombardment, the etching process proceeds at the nominal chemical etch rates.

SURFACE INHIBITOR MECHANISM:
In some etch chemistries, the surface exposed to the plasma is likely to become coated with a chemisorbed film of etchant radicals and unsaturated species, which polymerize and adhere tenaciously to the material being etched. The resulting polymer coating inhibits the chemical reactions necessary to etch. Ion bombardment can cause the polymers to desorb, exposing horizontal surfaces to the etching gas. Vertical surfaces experience little or no bombardment, therefore etching in the horizontal direction can be completely blocked.

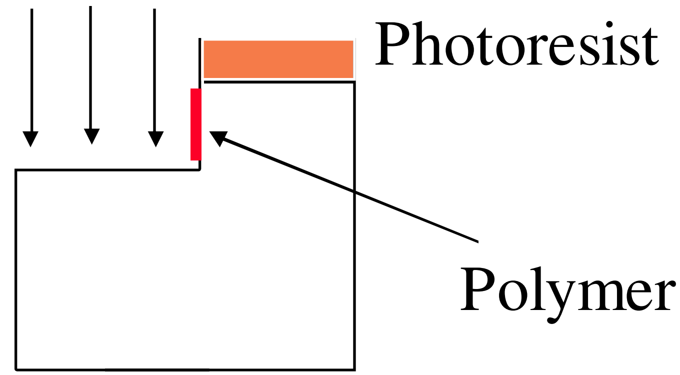
ION ASSISTED ANISOTROPIC ETCHING

SURFACE DAMAGE



Speeds chemical reaction
on horizontal surfaces

SURFACE INHIBITOR



Slows chemical reaction
on vertical surfaces

POLYMER FORMATION

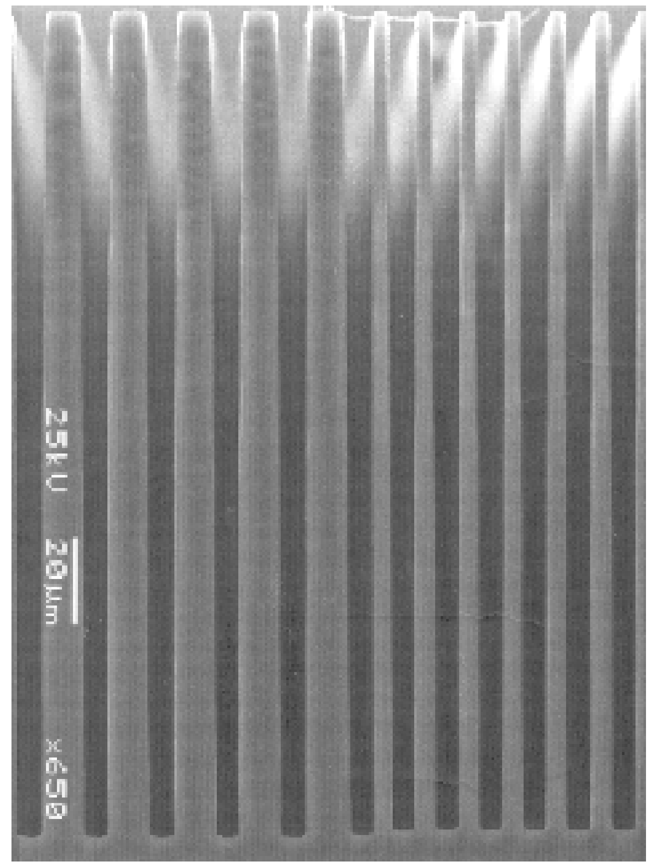
It is known that flourocarbon gases such as CHF3, CF4, C3F8 etc. product unsaturated compounds in the plasma, leading to polymer formation and deposition on the wafer surface and electrodes. Polymer formation and the boundary between polymerization and etching conditions depend upon the fluorine to carbon (F/C) ratio. Addition of oxygen to the plasma chemistry increases F/C ratio and reduces polymer formation. The addition of oxygen, unfortunately also increases the removal rate of photoresists. Energetic ion bombardment will shift the polymerization-etching boundary to lower F/C ratios.

PROBLEMS WITH POLYMERS:
Deposits cam form on all surfaces of the chamber, affecting reproducibility of the etch process.
Polymers are a source of particulate contamination.
Cleaning of chambers must be performed regularly in order to prevent build up. This represents reduced up-time.

ADVANTAGES OF POLYMERS:
Properly controlled polymer deposition can allow anisotropic etching with otherwise purely chemical isotropic etch chemistries.

BOSCH ICP (PLASMA THERM)

The Bosch process uses two chemistries, one to generate polymers and the other to etch silicon. The etch machine switches between the two every few seconds to ensure that the sidewalls are covered with polymer allowing fast, deep trench etching. (the substrate is on a chuck that is cooled by liquid nitrogen.



SURFACE TECHNOLOGY SYSTEMS

- 5µm spaces
- 200µm etch depth
- 40:1 aspect ratio
- 2µm/min Si etch rate
- >75:1 selectivity to photoresist

STS ETCH SYSTEM AT RIT

SF6 and C4F8
1 to 10 um/min,
Oxide, Nitride or Photoresist masks.

STS ETCH SYSTEM AT RIT

13 sec etch in SF_6 at 130 sccm plus O_2 at 13 sccm
7 sec polymer deposition in C_4F_8 at 80 sccm

600 watts RF power
45 mTorr Pressure during etch
100 V wafer bias during etch

3 um/min etch rate

ALUMINUM ETCHING

PRECONDITIONING OF ETCH CHAMBER -

BREAKTHROUGH - This is to remove native aluminum oxide (Al_2O_3) from the surface of the wafer by reduction in Hydrogen or by Sputtering by bombardment with Argon at high energies or both. Water vapor will scavenge Hydrogen and grow more Al_2O_3 causing non reproducible initiation times.

ALUMINUM ETCHING – because AlF3 is not volatile, a Chlorine based etch is needed to etch aluminum. BCl_3, CCl_4, $SiCl_4$ and Cl_2 are all either carcinogenic or highly toxic. As a result the pump oils, machine surfaces and any vapors must be treated carefully. $AlCl_3$ will deposit on chamber walls. $AlCl_3$ is hygroscopic and absorbs moisture that desorbed once a plasma is created causing Al_2O_3 breakthrough problems.

ALLOYS - Aluminum often has a few percent of Silicon or Copper. Silicon is removed by the Chlorine, Copper is not and requires a special process.

PUMPS - BCl_3 form nonvolatile residue upon contact with oxygen or water and causes filters and exhaust ducts to clog readily.

LAM 4600 ALUMINUM ETCHER

Plasma Chemistry

Cl_2 – Reduces Pure Aluminum

BCl_3 – Etches native Aluminum Oxide

-Increases Physical Sputtering

N_2 – Dilute and Carrier for the chemistry

Chloroform – Helps Anisotropy and reduces Photoresist damage

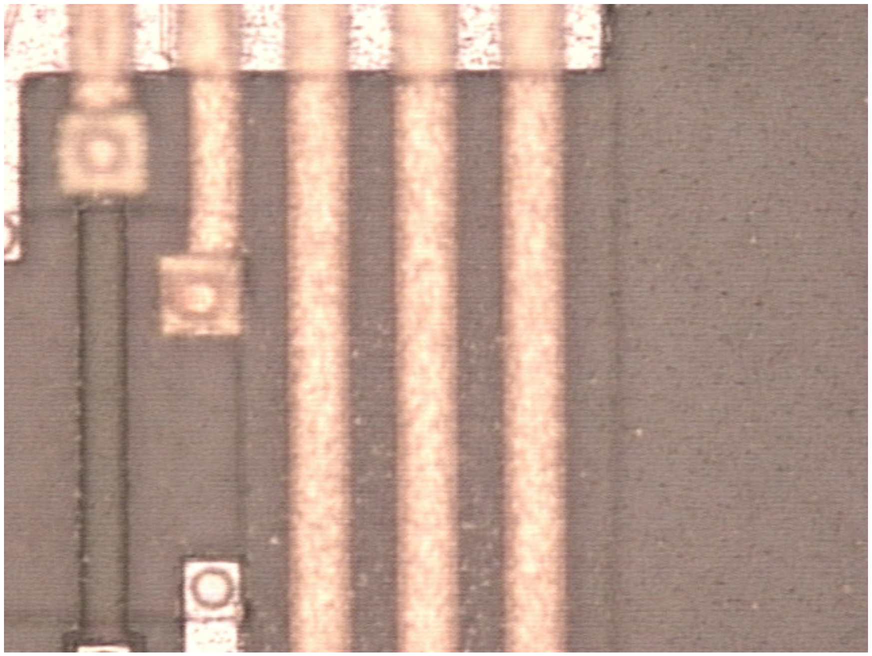
LAM4600 ANISOTROPIC ALUMINUM ETCH

Step	1	2	3	4	5
Pressure	100	100	100	100	0
RF Top (W)	0	0	0	0	0
RF Bottom	0	250	125	125	0
Gap (cm)	3	3	3	3	5.3
N2	13	13	20	25	25
BCl	50	50	25	25	0
Cl2	10	10	30	23	0
Ar	0	0	0	0	0
CFORM	8	8	8	8	8
Complete	Stabl	Time	Endpoint	Oetch	Time
Time (s)	15	8	180	10%	15

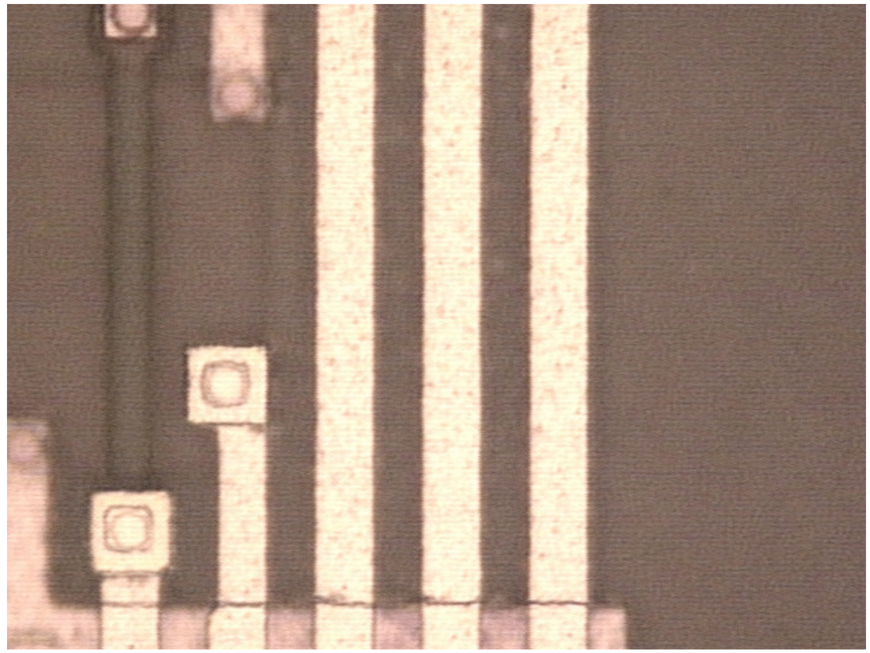
Channel	B
Delay	130
Normalize	10 s
Norm Val	5670
Trigger	105%
Slope	+

Fuller, December 2009

RESULTS FROM NEW ALUMINUM PLASMA ETCH



Photoresist on Metal Two



Photoresist Removed

COPPER ETCHING

1. Copper does not form any volatile compounds with known plasma etch gases, and therefore cannot be RIE etched.
2. Copper can be sputter etched, but this technique has no selectivity.
3. Contamination of the fab with copper is a serious concern.

The Damascene process has become an attractive enabling method for patterning copper by CMP.

PLASMA STRIPPING

Goal: Complete removal of resist without damage

Problems: Conventional ashing may not work because of:

Resist Hardening in High Dose Implants and in Sylation

Residues and polymers from plasma processes

Metals remain behind from resist

More Aggressive Plasma Processes can Damage Devices

Ion Bombardment in RIE and even in barrel etchers

Oxide charging

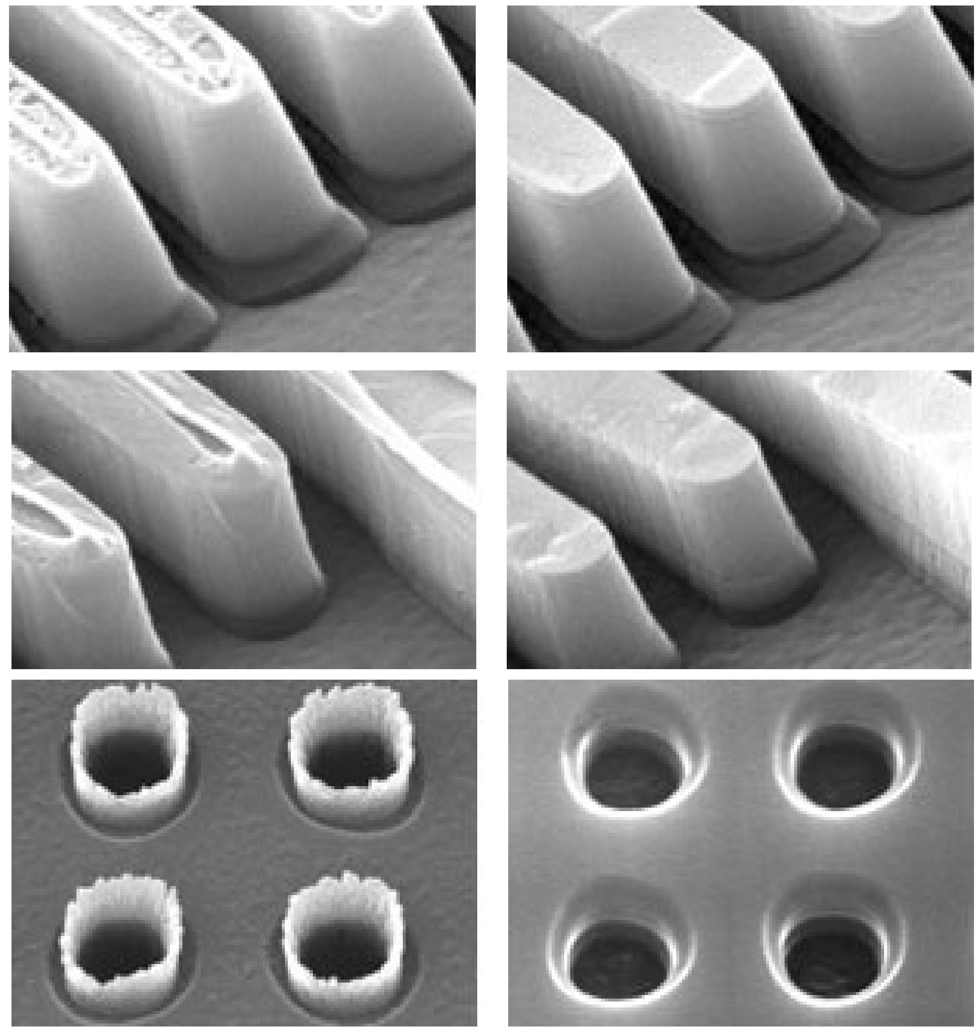
UV and soft x-ray

Solutions: Enhance plasma density, microwave, magnetic

Temperature control in downstream etchers

PICTURES OF RESIST RESIDUE PROBLEMS

Pictures on left show resist residue after ashing. Pictures on right show effectiveness of ACT 935 solvent strip process.



From: [ACT-CMI Data Sheet]

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PARTICLE GENERATION AND CONTROL

Sources of Particles

- Polymer deposits on chamber
- Gas mixture itself
- Substrate, Film type
- Long etch duration
- Low flow rates
- High Pressures

Particle Reduction Techniques

- Lower pressure, increased flow
- Add noble gases, e.g. Argon
- Equipment design, wafers face down

PATTERN FACTOR DEPENDANT ETCHING

THE TYPICAL PATTERN HAS:

A range of opening sizes

A range of aspect ratios(largest aspect ratios are in the smallest features)

OBSERVATIONS:

Non-uniform etch depth for different opening sizes.

Large overetches required to achieve complete etching of small features.

High selectivity processes are required to prevent etching into the underlying layer.

These observations are called PATTERN FACTOR DEPENDING ETCHING or "RIE LAG" and are becoming more important as submicron geometries are utilized.

POSSIBLE CAUSES:

Slower transport of reactive species to the bottom and removal of products.

Polymerization effects.

Angular distribution of ion flux.

(is believed to be the prime reason for RIE lag).

PLASMA ETCH EQUIPMENT

The major types of dry etching equipment are Barrel, Ion Beam Milling, Reactive Ion Beam, Plasma (High Pressure) and Reactive Ion (Low Pressure) reactors.

Barrel - in a Barrel reactor, the wafers do not rest on one of the electrodes. Etching often takes place at high pressure. Energetic particles hit the wafer surface at random angles and etching is isotropic.

Planar Plasma Etchers - wafers on one of the electrodes (usually the grounded electrode)

RIT PLASMA ETCH TOOL LAM 490

This system has filters at 520 nm and 470 nm for end point detection. In any case the color of the plasma goes from pink/blue to white/blue once the nitride is removed.

LAM 490 PLASMA ETCH

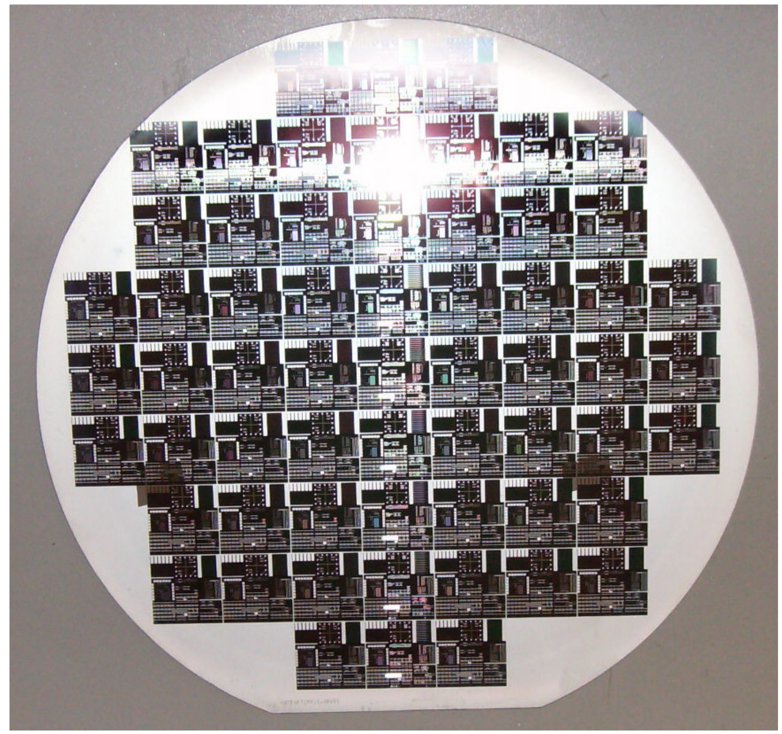
RIT RIE ETCH TOOLS

RIE – Reactive Ion Etching

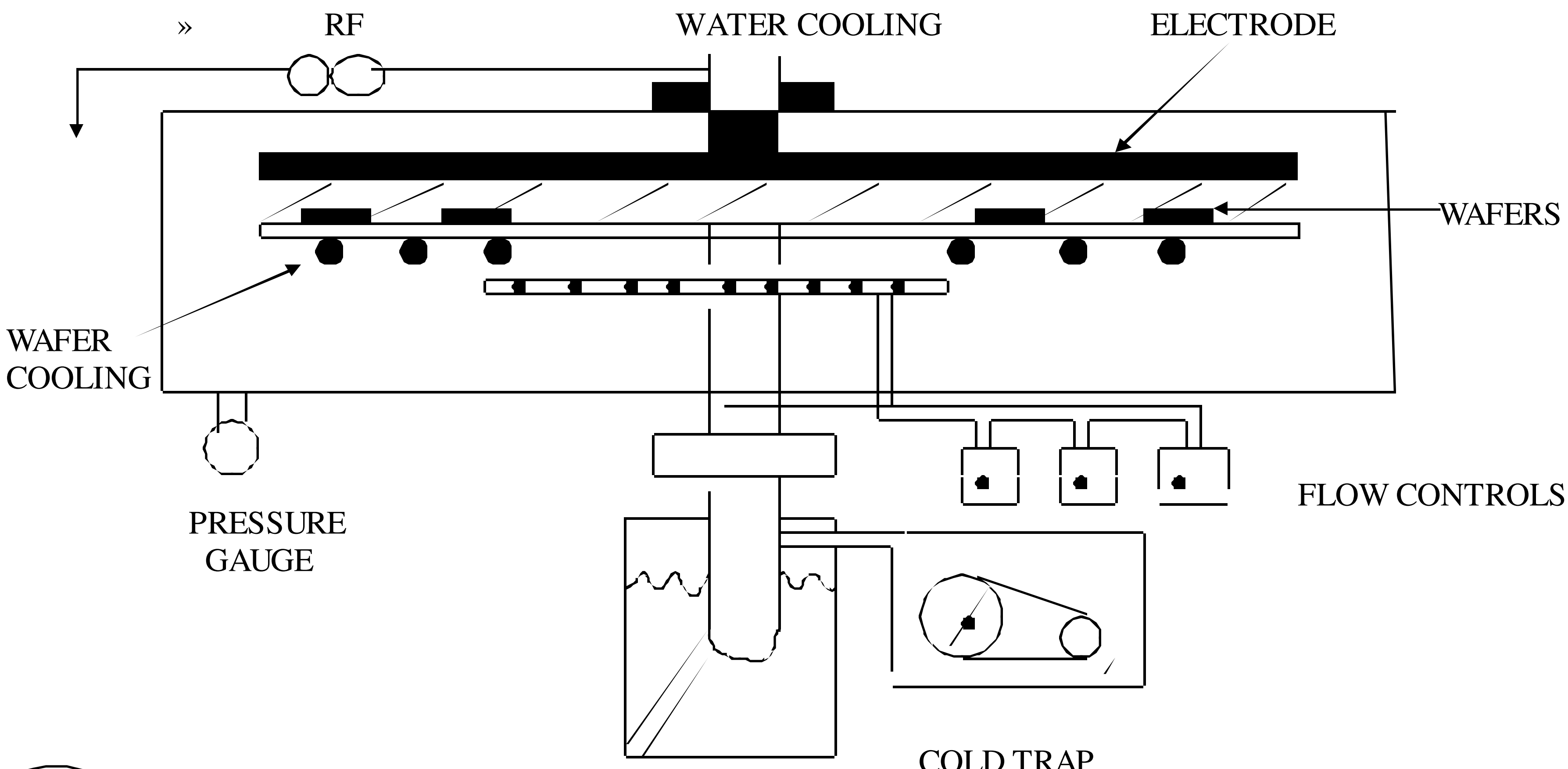
DRYTECH QUAD RIE

ALUMINUM ETCH USING LAM4600

LAM4600

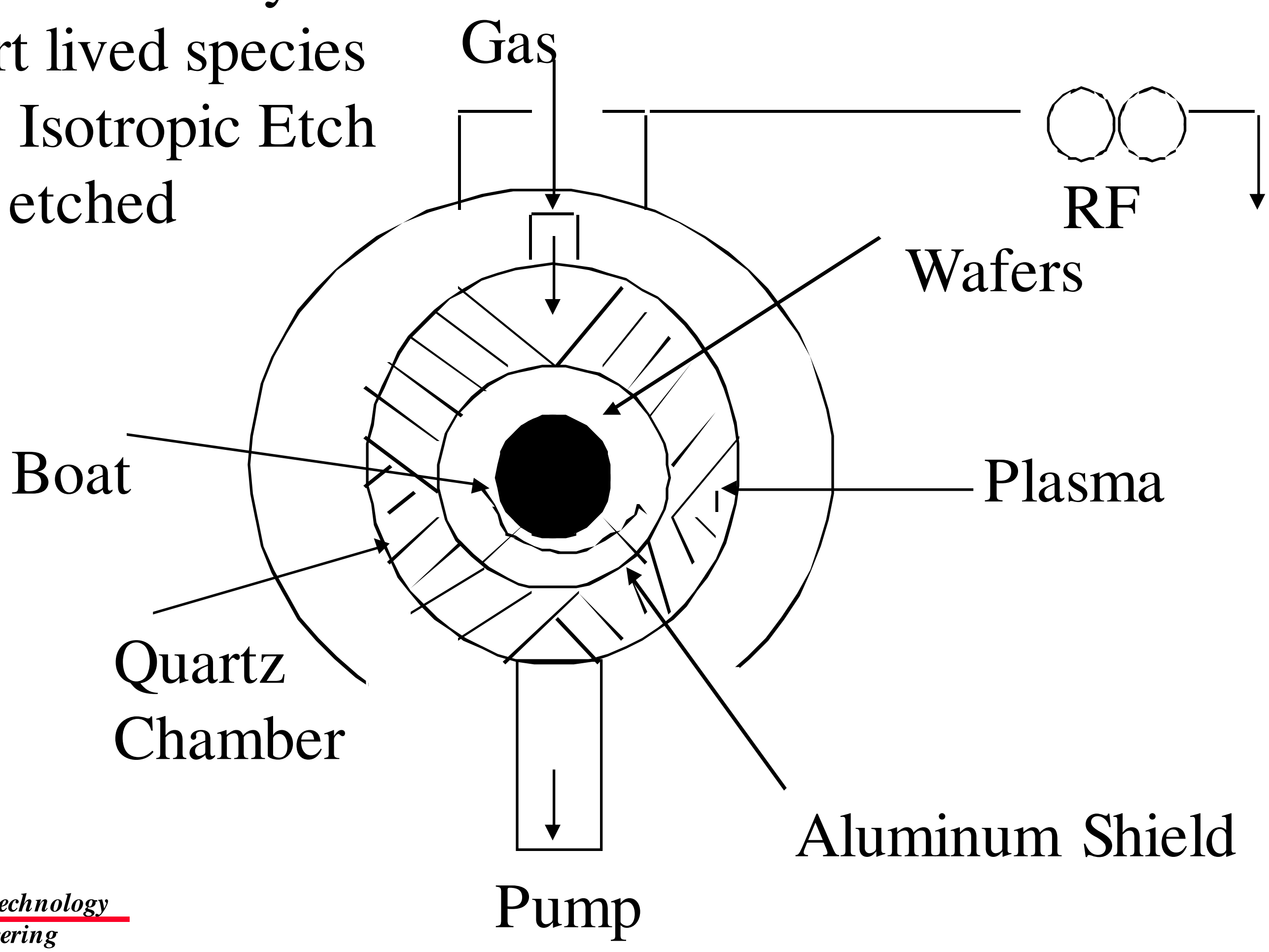


PLANAR REACTOR RADIAL FLOW REACTOR

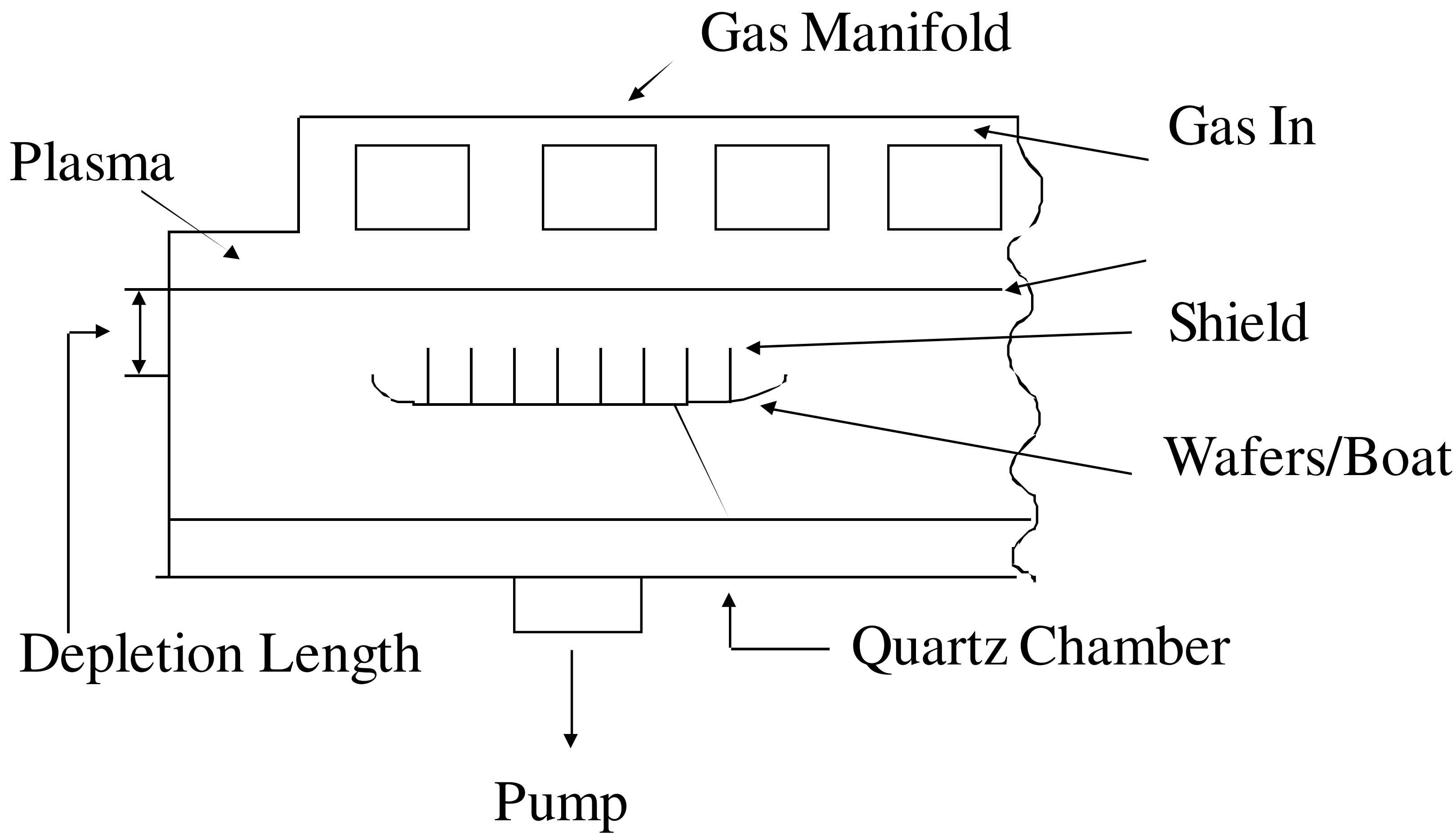


TUBULAR REACTORS
ISOTROPIC ETCHING

Shield needed to get uniformity
Shield stops all short lived species
High pressure gives Isotropic Etch
Both sides of wafer etched



TUBULAR REACTORS ISOTROPIC ETCHING (cont'd)



DOWNSTREAM ETCHER

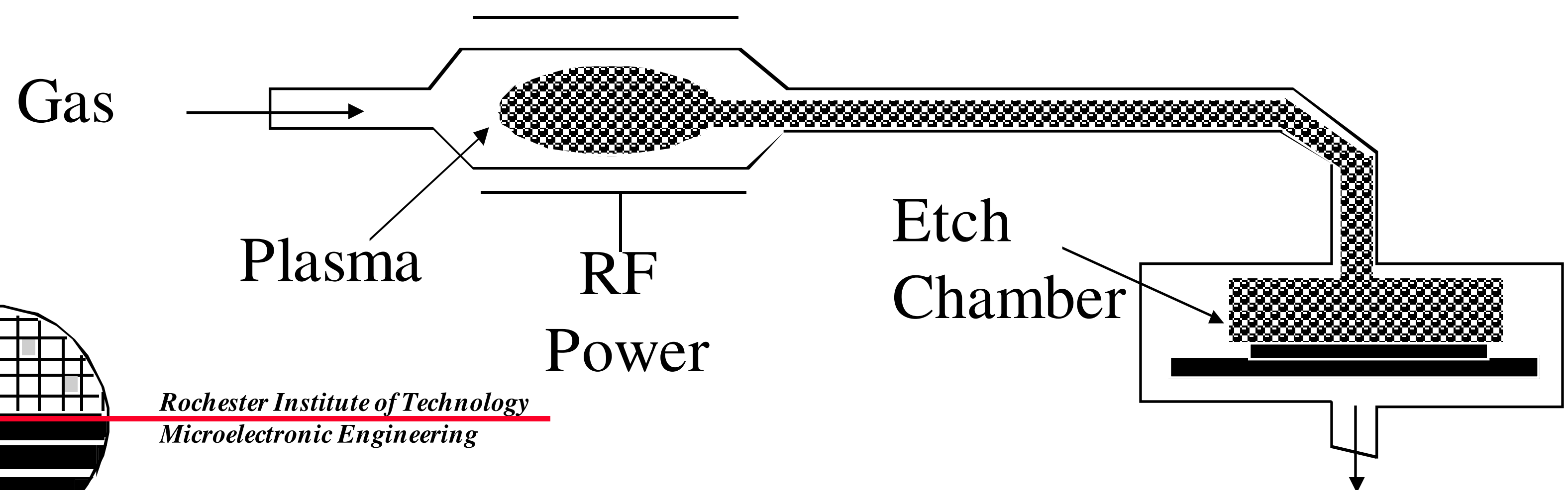
Plasma is formed in a cavity which is separated from the etching chamber.

Wafers are shielded from bombardment. Only radicals reach wafers.

Etching is completely chemical and isotropic

High selectivity achievable; Si:SiO2 = 50:1

Plasma may be generated by RF or by microwave, as in a CHEMICAL DRY ETCHER.



ADVANCED PLASMA SYSTEMS

Submicron features may require unusually low pressures for acceptable etching. Conventional plasma systems etch very slowly because of the low plasma density. Advanced systems utilize various techniques to increase the plasma density at low pressures.

Techniques to increase plasma density:

- Magnetic field to confine electrons
- Microwave excitation of electrons
- Downstream system to control ion energy

Examples:

- Electron Cyclotron Resonance (ECR)
- Inductively Coupled Plasma (ICP)
- Magnetically Enhanced RIE (MERIE)
- Reactive Ion Beam Etching (RIBE)

PATTERN FACTOR DEPENDANT ETCHING

THE TYPICAL PATTERN HAS:

A range of opening sizes

A range of aspect ratios(largest aspect ratios are in the smallest features)

OBSERVATIONS:

Non-uniform etch depth for different opening sizes.

Large overetches required to achieve complete etching of small features.

High selectivity processes are required to prevent etching into the underlying layer.

These observations are called PATTERN FACTOR DEPENDING ETCHING or "RIE LAG" and are becoming more important as submicron geometries are utilized.

POSSIBLE CAUSES:

Slower transport of reactive species to the bottom and removal of products.

Polymerization effects.

Angular distribution of ion flux. (This latter is believed to be the prime reason for RIE lag).

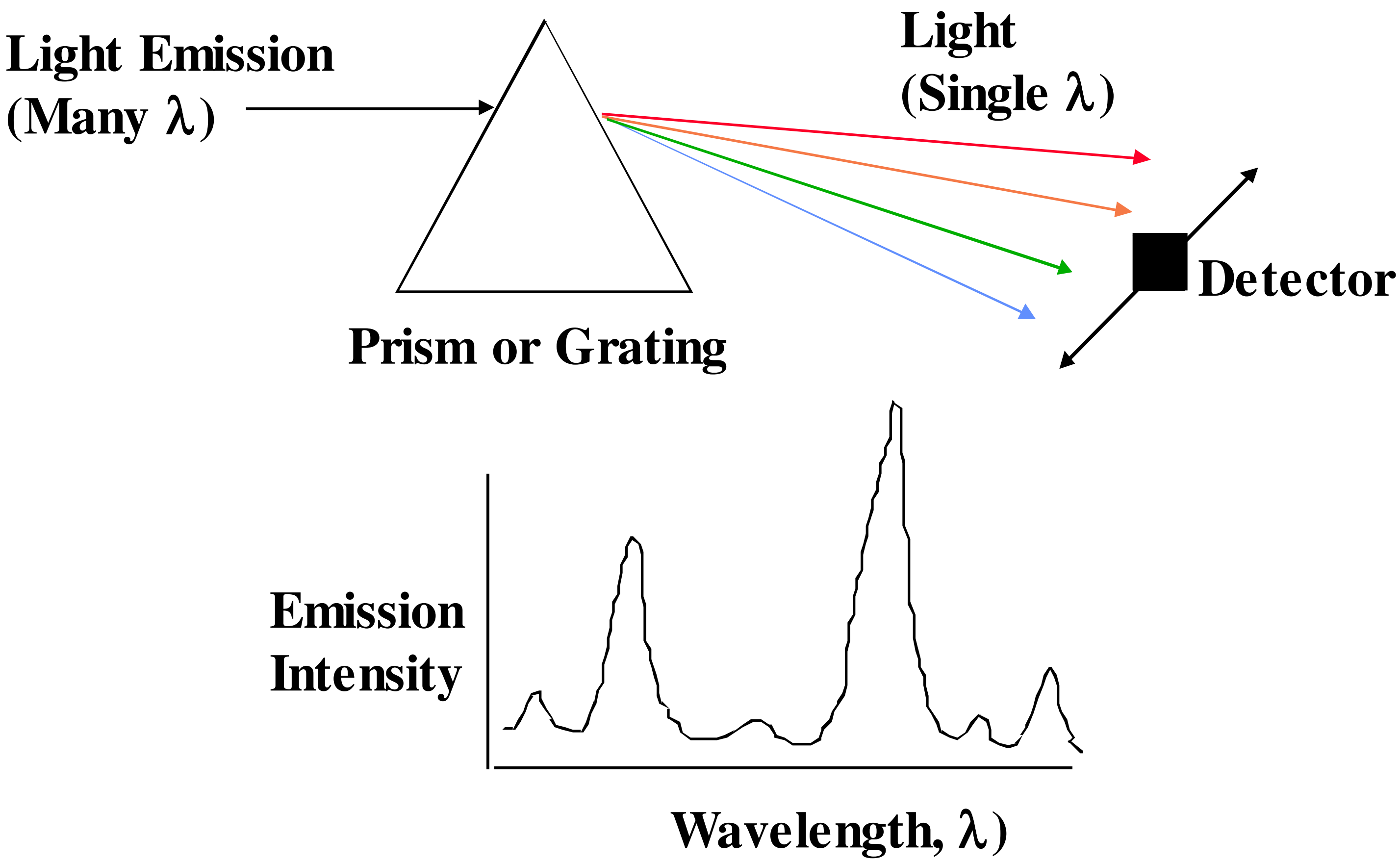
END POINT DETECTION

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



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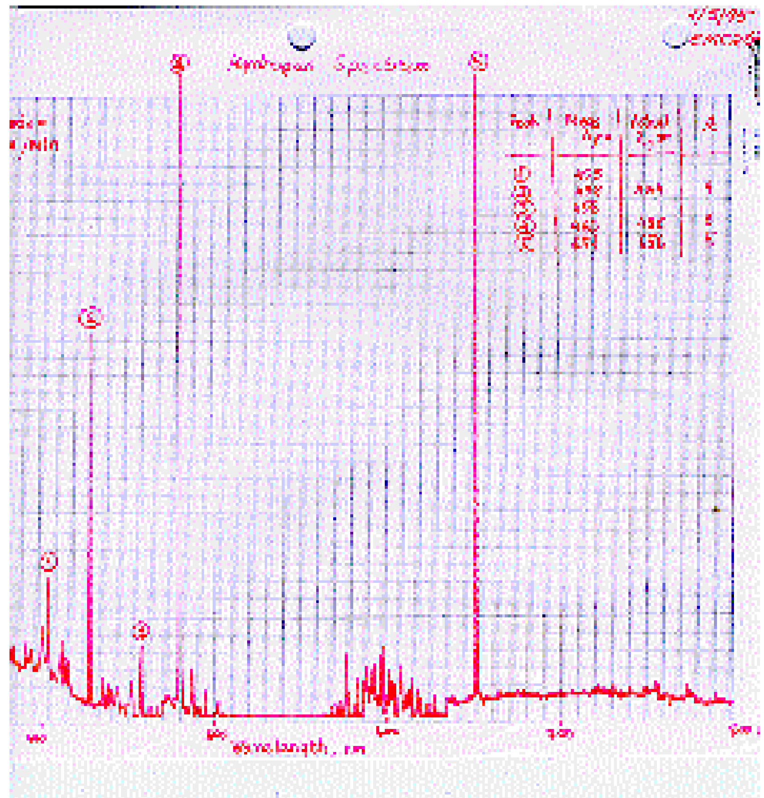
CALIBRATION

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.

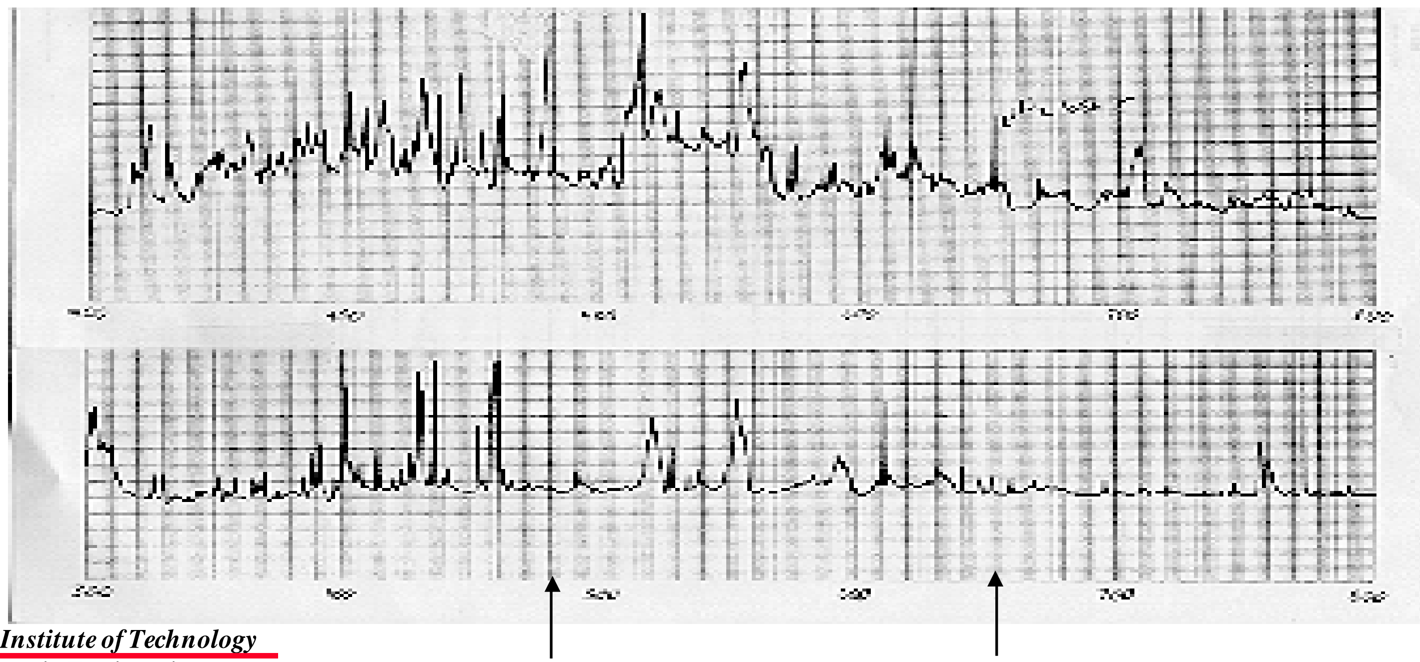


EXAMPLES OF EMISSION SPECTRA MEASURED AT RIT

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 O2 plasma etch of photoresist there is a peak at 483.5 nm associated with CO which disappears at the end of the etch.

O2 Plasma Wafer with Photoresist

O2 Plasma No Wafer in the System



CO peak at 483.5 nm

H2 peak at 656.5 nm

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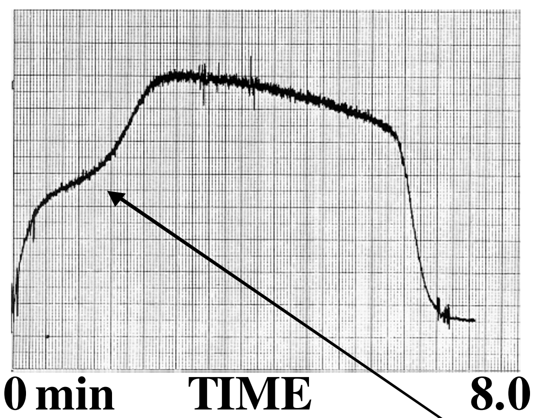
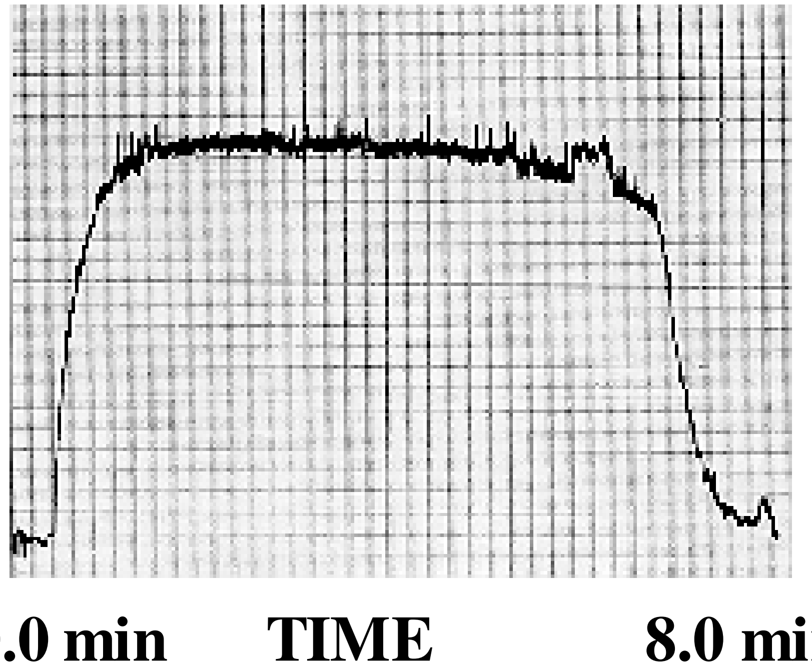
O2 PLASMA STRIP END POINT DETECTION

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.



O2, 30 sccm, 50 watts, 300 mTorr



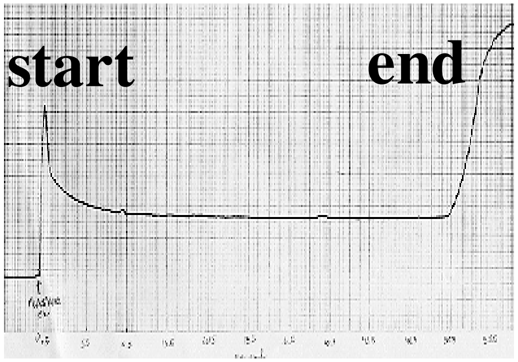
BF2 heavy dose implant causes the surface to strip more slowly than bulk, thus initial CO emission is lower

POLY ETCH END POINT EXAMPLE

End Point

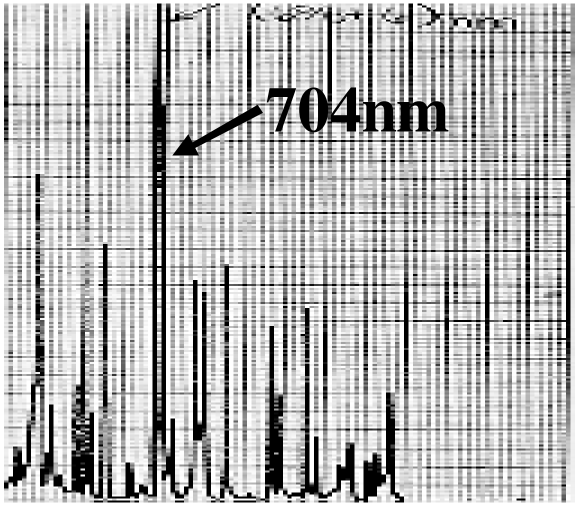
SF6 + O2

704nm Line

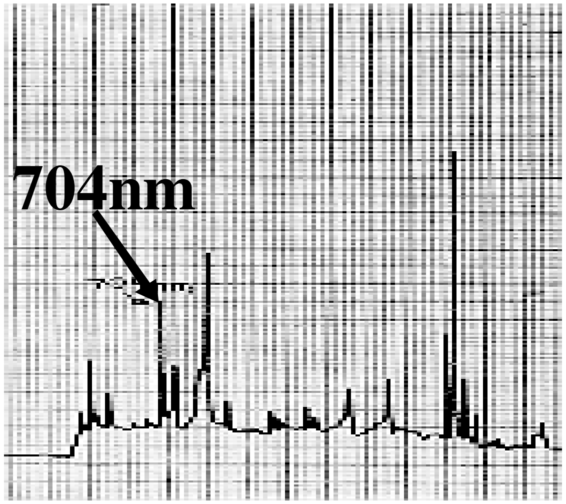


0.0 **60 sec**

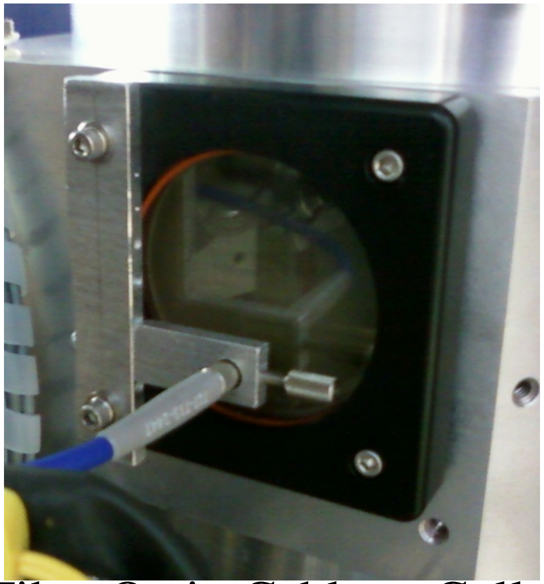
Emission Spectra
in SF6 + O2 Plasma
No Silicon Wafer
in System



Emission Spectra
During Etching
of Poly
in SF6 + O2 Plasma

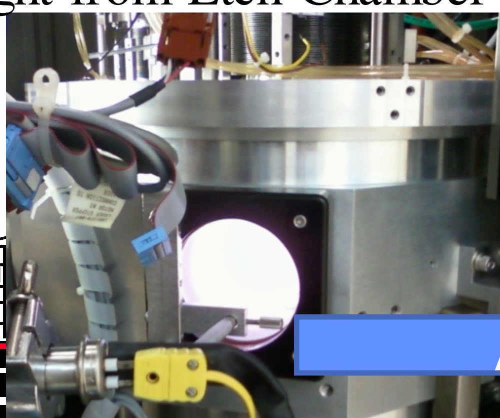


ENDPOINT DETECTION IN DRYTEK QUAD



Manual End Buttons

Fiber Optic Cable to Collect Light from Etch Chamber



Spectrometer

FACCUT RECIPE

FACCUT

Factory contact cut

Etch TEOS

SUB-CMOS 150 Factory process

FACCCUT

Gas Stabilization Time	30	sec
Scan Delay/Auto Zero	00:00	(MM:SS)

CF4	10	sccm	error range	20	%
CHF3	50	sccm	error range	20	%
O2	0	sccm	error range	20	%
AR	100	sccm	error range	20	%

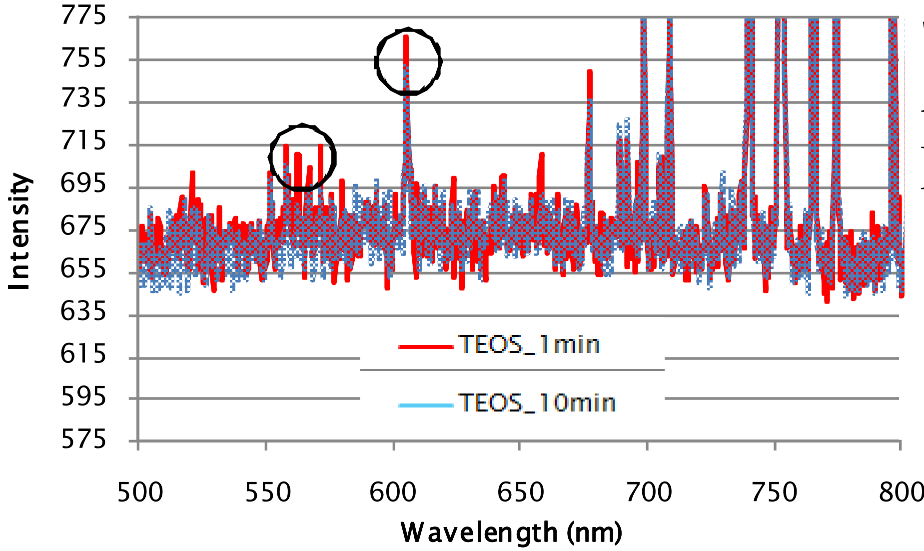
Pressure	100	mT	error range	40	%
Turbo Pump	N	(Y/N)			

RF Power	200	W	error range	70	%
RF Refl. Error	100				
Bias Low error	0				

Mode	Time		Aux. Signal	N	(Y/N)
Parameter	0		Max. Time	10:00	(MM:SS)
Delta	0		Start Delay	00:00	(MM:SS)
% Overetch	0		Abort Time	00:00	(MM:SS)

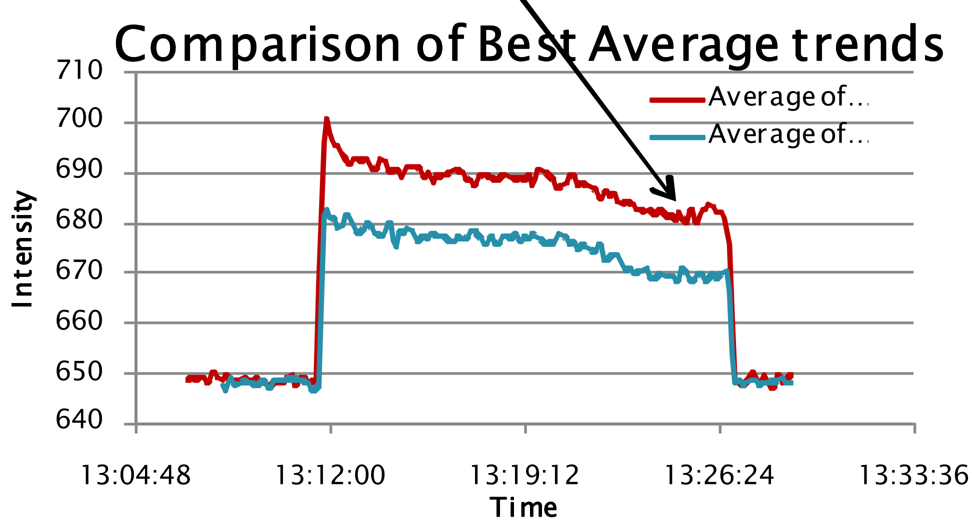
Gas Evac. Time	30	sec
This Step is allowed in Chamber 3.		

EMISSION SPECTRA FOR FACCUT RECIPE



Select 658.25nm And 520.59nm to Monitor for Endpoint

Endpoint



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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. Chapman, Brian, Glow Discharge Processes, John Wiley and Sons, New York, 1980.
4. Morgan, Russ, Plasma Etching in Semiconductor Fabrication, Elsevier Press, New York, 1985.
5. Manos, D. and Flamm, D. eds., Plasma Etching, and Introduction, Academic Press, Inc., New York, 1989.

HOMEWORK – PLASMA PROCESSES

1. Draw lines to connect the processes below with the most appropriate description of the plasma mechanism:

Sputtering	Combination of Physical and Chemical Effects
RIE	Purely Chemical Process
Photoresist Stripping in a Barrel Reactor	Purely Physical Process

2. Plasma etching has become very important to integrated circuit manufacture because: (circle all correct answers)
   (a) it has a high selectivity (b) it can etch anisotropically (c) disposal of waste products is easier and less costly than wet etching (d) sub micron features can be etched
3. Ion bombardment energy in an RF plasma etcher may be increased by: (circle all correct answers) (a) decreasing pressure (b) increasing gas flow rates (c) placing the wafer to be etched on the large electrode (d) increasing the power
4. At a pressure of 0.25 torr, the molecular density of a plasma is about 1E16 molecules per cubic centimeter. What is the typical density of the following species in the plasma? Electrons, Radicals, Ions, Original gas molecules
5. Anisotropy in plasma etching is achieved by: (choose all correct answers)
   (a) Increasing ion energy (b) Causing a controlled amount of polymer deposition to prevent sidewall etching (c) Introducing a highly reactive gas into the etching chamber.