Lecture 19, 20:

Non Silicon Dry Etching

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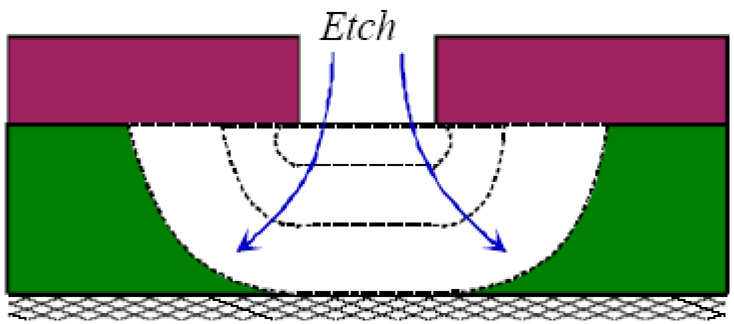
Etching Technology

- Wet etching
  - By Wet chemical solution
  - Isotropic etching



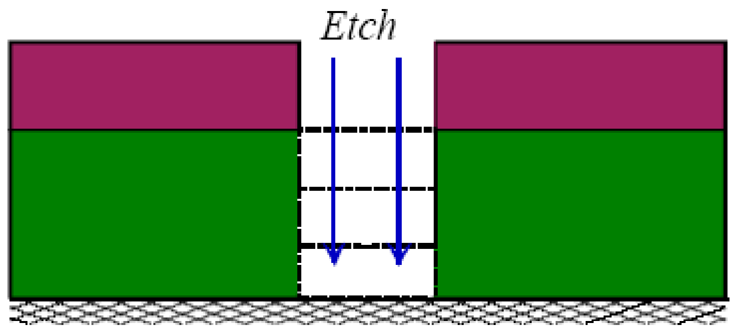
Vertical E/R = Horizontal E/R

Pure Chemical Reaction

High Selectivity

CD Loss or Gain

- Dry Etching
  - By Plasma
  - Anisotropic etching



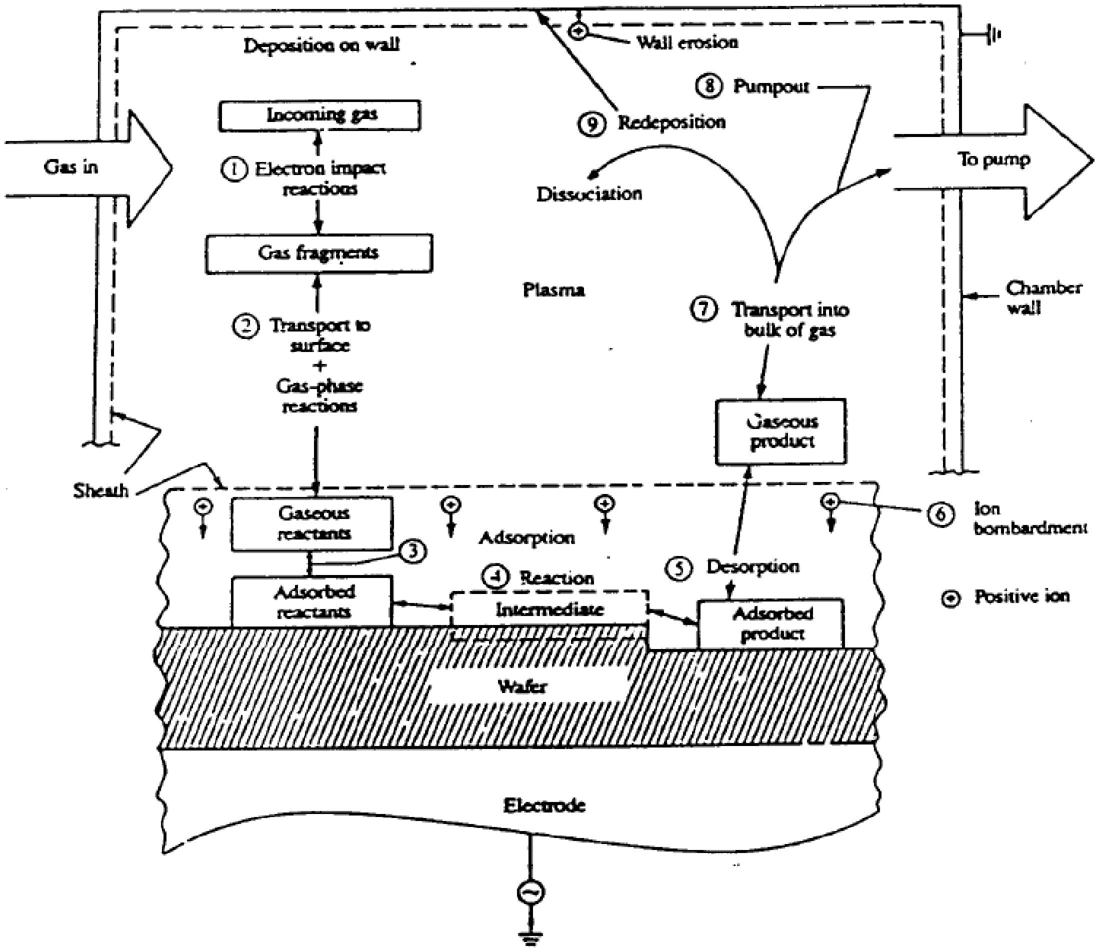
Vertical E/R >> Horizontal E/R

Ion assisted

Relatively low Selectivity

No CD bias

Plasma Etching Mechanism



- *Glow Discharge*
- *Transport*
- *Adsorption*
- *Etching Reaction*
- *Desorption*
- *Ion Bombardment*
- *Bulk Gas Stream*
- *Pumping Out*
- *Redeposition*

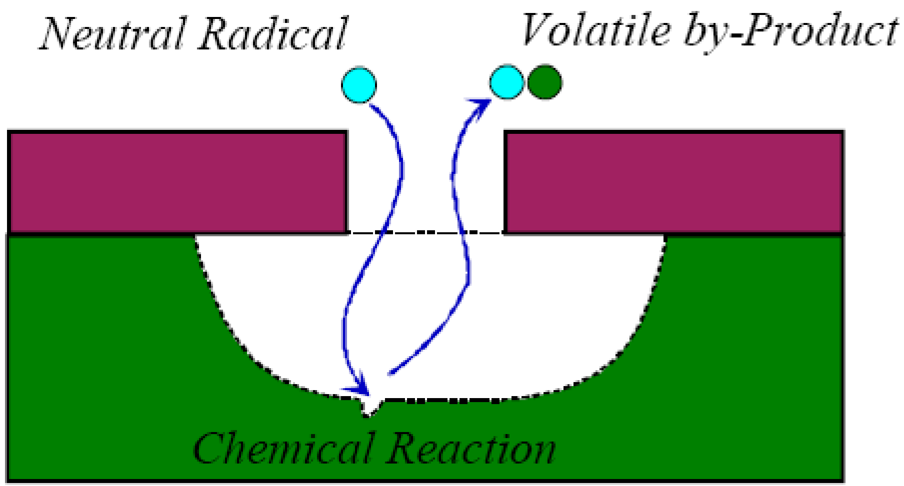
What is Plasma Etching

Take a Molecular Gas (Usually Relatively Inert)	$Cl_{2(gas)}$
Establish a Glow Discharge & (Ion and Elctron Formation)	$e + Cl_2 \rightarrow Cl_2^+ + 2e$
Create Reactive Species	$e + Cl_2 \rightarrow 2Cl + e$
Chemical Reaction to form A VOLATILE product	$Si + 4Cl \rightarrow SiCl_4$
Product Desorption & Pumping Away Volatile Product	$SiCl_{4(ads)} \rightarrow SiCl_{4(gas)}$

Basic Method of Plasma Etching(1)

Chemical

Thermalized neutral radicals chemically combine with substrate material formaing volatile products

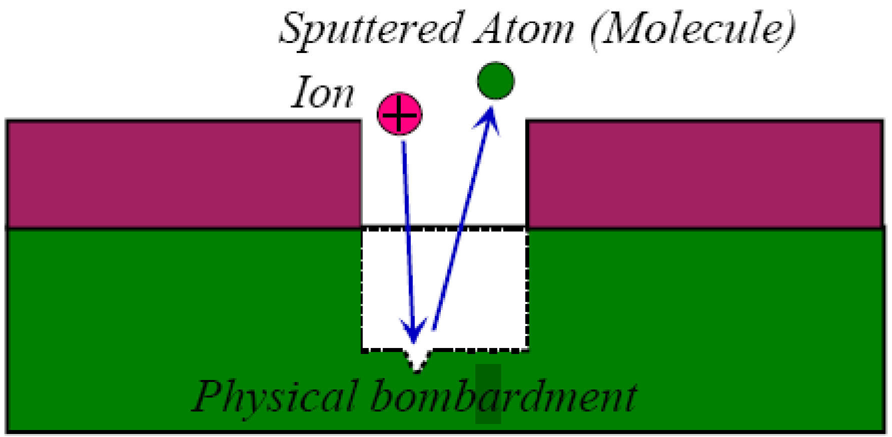


- Isotropic
- Purely Chemical Reaction
- High Pressure
- Batch Wafer Type
- Less Electrical Damage

Basic Method of Plasma Etching(2)

Sputtering

The ion energy mechanically ejects substrate material



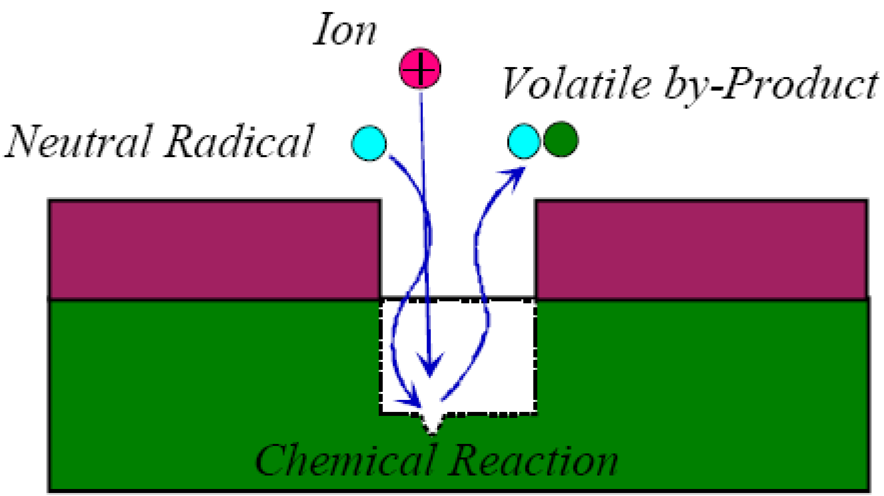
- Anisotropic
- By Purely Physical Process
- High Directionality
- Low Pressure
  : long mean free path
- Single Wafer Type
- Low Etch rate

Basic Method of Plasma Etching(3)

Energetic Ion Enhanced

Ion bombardment enhances or promotes the reaction

Between an active species and the substrate material

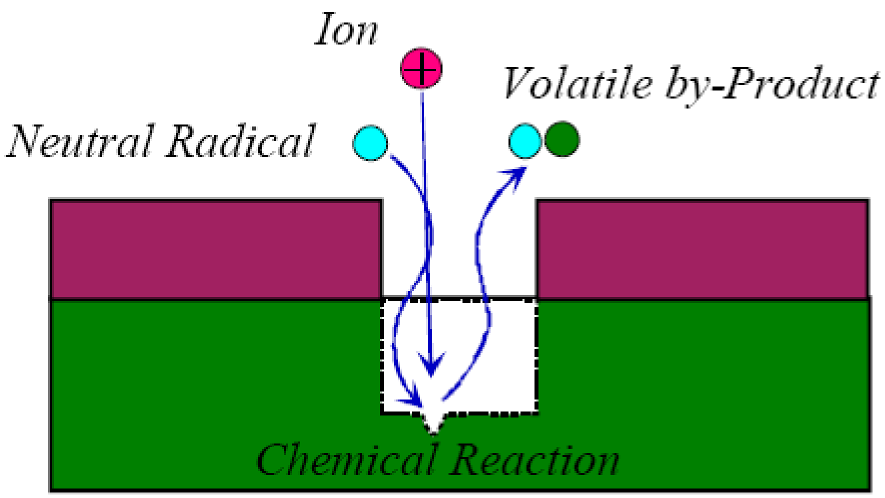


- Damage Enhanced Chemical Reactivity
- Chemical Sputtering
- Chemically Enhanced Physical Sputtering
- Ion Reaction

Basic Method of Plasma Etching(4)

Protective Ion Enhanced

An inhibitor film coats the surface forming a protective barrier which excludes the neutral etchant



- Sidewall Passivation
- Stopping lateral attack by neutral radical
- Ion directionality
- Involatile polymer film
- Additive film former

  (N_2, HBr, BCl_3, CH_3F)

Non Silicon Materials

- Silicon dioxide (SiO_2)
  - Insulator, sacrificial layer, passivation film, mask for dry or wet etch
- Silicon nitride (Si_xN_y)
  - Insulator, structure layer, passivation film, mask for wet etch
- Polymer
  - Mask in photolithography, sacrificial layer
  - AZ series, SU-8, etc.
- Metal (Al, Ti, Au, Cu, Ni…)
  - Structure layer, electric line

Purpose of Etch Gases (1)

- Oxygen (O_2)
  - Pure O_2 plasma is used to etch PR.
  - In plasmas involving CF_4, O atoms displace F in the CF_4 → generating more free F.
- Sulfur Hexafluoride (SF_6)
  - SF_6 is one source of very reactive F atoms that etch all of the materials.
  - F atoms are not very selective.
- Tetrafluoromethane (CF_4)
  - CF_4 is a source of C and F.
  - C-F sidewall-polymer formation.
- Trifluoromethane (CHF_3)
  - CHF_3 is a source of C and F → with a lower ration of F to C.

Purpose of Etch Gases (2)

- Chlorine (Cl_2)
  - Cl_2 dissociated into Cl atoms.
  - Like F, Cl etches most materials, including aluminum.
- Trichloromethane ($CHCl_3$)
  - $CHCl_3$ supplies chlorine for etching.
  - $CHCl_3$ supplies carbon and chlorine for sidewall polymer.
- Boron Trichloride (BCl_3)
  - BCl_3 etches the native Al oxide on Al.
  - BCl_3 scavenges O_2 and H_2O in the vacuum system.
- Helium (He)
  - He is used in plasma system as a diluent and a plasma stabilizer.
- Nitrogen (N_2)
  - N_2 is used in plasma system as a diluent.

Fluorocarbon-Plasma SiO_2 Etches

- Overall reactions

$$3SiO_2 + 4CF_3 \rightarrow 2CO + 2CO_2 + 3SiF_4$$

$$SiO_2 + 2CHF_2 \rightarrow 2CO_2 + H_2 + SiF_4$$

- Etch conditions
  - CF_4+CHF_3+He (90:30:130 sccm), 450 W, 2.8 Torr, gap: 0.38 cm, 13.56 MHz, parallel-plate configuration
    - This etch target is SiO_2, but also etches silicon nitride well.
    - This etch is anisotropic.
  - CF_4+CHF_3+He (90:30:130 sccm), 850 W, 2.8 Torr, gab: 0.38 cm, 13.56 MHz, parallel-plate configuration
    - This is the faster etch rate than the previous case.
    - Lower selectivity to PR

Fluorine-Atom-Plasma Nitride Etches (1)

- Reaction
  - Fluorine atoms are absorbed onto the surface one at a time
  - In a surface reaction, volatile products are formed
  - Overall reactions

$$Si_3N_4 + 12F \rightarrow 3SiF_4 + 2N_2$$

- Etch conditions
  - SF_6+He (13:21 sccm), 100 W, 250 mTorr, 50 kHz, gap: 2.6 cm, parallel-plate configuration
    - This etch is used to plasma etch silicon nitride
    - Plasma etching, especially at higher power, heats the chamber, which can effect etch rates and thus selectivity

Fluorine-Atom-Plasma Nitride Etches (2)

- Etch conditions
  - CF_4+CHF_3+He (10:5:10 sccm), 200 W, 250 mTorr, 50 kHz, gap: 2.6 cm, parallel-plate configuration
    - This nitride plasma etch uses fluorocarbons rather than SF_6 as the source of F atoms.
  - SF_6+He (175:50 sccm), 150 W, 375 mTorr, 13.56 kHz, gap: 1.35 cm, parallel-plate configuration
    - Slow etch rate → for thin nitride film etch
    - The etch is anisotropic.
  - SF_6+He (175:50 sccm), 250 W, 375 mTorr, 13.56 kHz, gap: 1.35 cm, parallel-plate configuration
    - Fast etch rate → for thick nitride film etch

Fluorine-Atom-Plasma Nitride Etches (3)

- Etch conditions
  - SF_6 (25 sccm), 125 W, 200 mTorr, 13.56 MHz, gap: 3.8 cm, parallel-plate configuration
    - This slower etch rate is intended for thinner, stoichiometric silicon nitride films.
  - CF_4+CHF_3+He (45:15:60 sccm), 100 W, 300 mTorr, 13.56 MHz, gap: 3.8 cm, parallel-plate configuration
    - This etch is intended for thicker, silicon rich nitride film.

Plasma Metal Etches (1)

- Cl_2+BCl_3+$CHCl_3$+N_2 (30:50:20:50 sccm), 250 W, 250 mTorr, 60 ^oC, 13.56 MHz, gap: 2.5 cm, parallel-plate ground chuck configuration
  - This is an anisotropic Al plasma etch due to the sidewall inhibit formed from $CHCl_3$.
  - Due to poor selectivity, for thick layer of Al, thicker PR must be used.
  - Overall reaction

$$2Al + 3Cl_2 \rightarrow Al_2Cl_6$$

  - Cl_2 rather than Cl appears to be the main etchant.
  - The etch product becomes $AlCl_3$ at higher temperatures.

Plasma Metal Etches (2)

- SF_6 (80 sccm), 200 W, 150 mTorr, 40 °C, 13.56 MHz, gap: 3.8 cm, parallel-plate configuration
  - This W plasma etch is fairly isotropic.
  - CF_4 added to the feed gas increases anisotropy as sidewall polymer form, but decreases etch rate.
  - The chuck is heated to enhanced the etch rate.
  - Overall reaction

$$W + 6F \rightarrow WF_6$$

Oxygen Plasma PR Etches (1)

- Reaction
  - Oxygen atoms “burn” or “ash” the organic PR, forming mostly H_2O, CO_2, and CO
  - Activation energies for O-atom etching of PR have been measured in the range 0.22 eV to 0.65 eV.

- Etch conditions
  - O_2 (51 sccm), 50 W, 300 mTorr, 50 kHz sq. wave, gap: 2.6 cm, parallel-plate configuration
    - This plasma processing step is used for descumming of freshly developed PR, typically for one minute.
    - Unbaked OCG 820 PR was removed 6 % faster than hardbaked PR during a descum test.

Oxygen Plasma PR Etches (2)

- Etch conditions
  - O_2 (51 sccm), 400 W, 300 mTorr, 50 kHz sq. wave, gap: 2.6 cm, parallel-plate configuration
    - This oxygen plasma is used to ash (strip) PR for 5-10 min.
    - A power of 300 W is also often used.
    - The etch rate decreases when there is more PR surface area.

Plasmaless HF Vapor SiO_2 Etches

- HF vapor etches silicon dioxide.
- It has been used to remove native oxide from silicon before the growth of epitaxial silicon and other processed such as the XeF_2 etching of silicon.
- The nonuniform etching can be reduced by etching in "pulses," removing the wafer from the vapor before droplets form and allowing it to evaporate.
- HF vapor may also be suitable for vapor phase removal of a sacrificial oxide layer for micromechanical fabrication.

- Overall reaction

$$SiO_2 + 4HF \rightarrow SiF_4 + H_2O$$

GaAs Dry Etches (1)

- Unique Advantages of GaAs over Si
  - High resistivity
  - High electron mobility
  - High saturated drift velocity
  - Wide direct bandgap
  - Operability over a wide temperature range

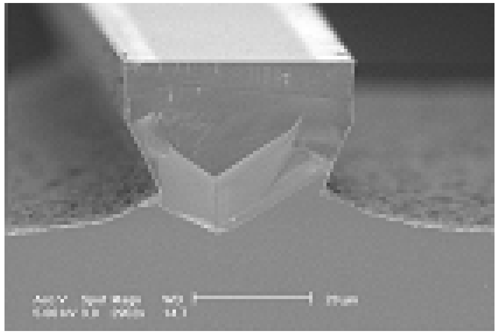
- GaAs dry etch conditions

	1	2	3
Pressure (mTorr)	40	70	100
RF power (W)	200	250	300
Ar flow (sccm)	5	10	15
Cl_2 flow (sccm)	5	10	15

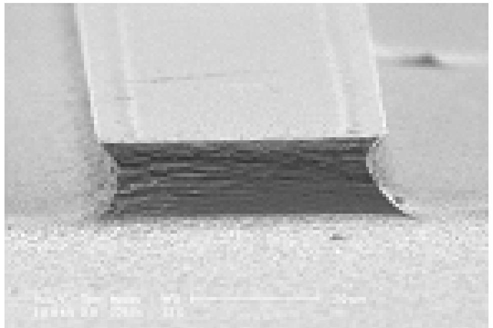
GaAs Dry Etches (2)

- Dry etch results

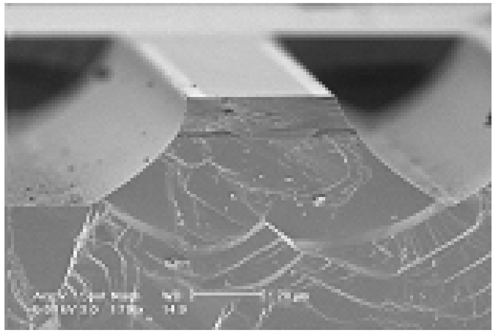
Pressure 100 mTorr, RF 250 W, Ar 5 sccm, Cl_2 15 sccm



<110> direction beam

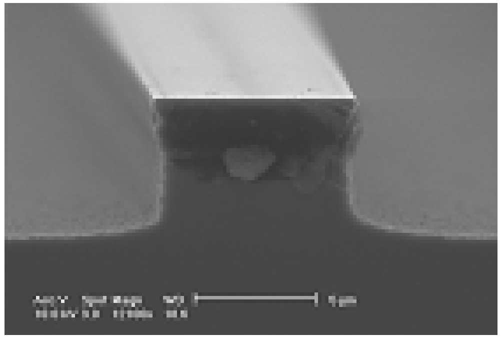


<100> direction beam

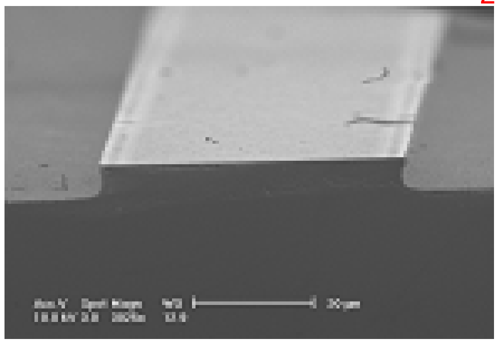


<1-10> direction beam

Pressure 70 mTorr, RF 250 W, Ar 15 sccm, Cl_2 5 sccm



<110> direction beam



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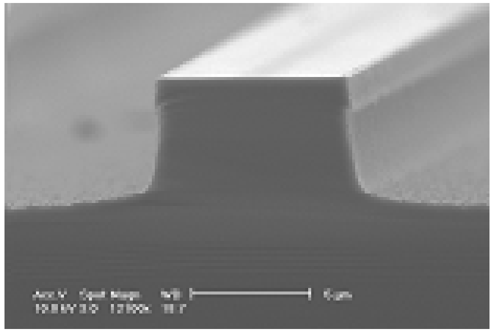


<1-10> direction beam

Etch Rate Table (1)

Etch Rates for Micromachining and IC Processing (Å/min) v. 4.4 29 July 1996

U.C. Berkeley Microfabrication Laboratory / Berkeley Sensor & Actuator Center / Kirt R. Williams

The top etch rate was measured by the author with fresh solutions, clean chambers, etc.
The center and bottom values are the low and high etch rates observed by the author and others in the UCB Microlab using fresh and used solutions, clean and "dirty" chambers, etc.

CF_4+CHF_3+He (90:30:120 sccm) Lam 590 Plasma 450W, 2.8T, gap=0.38cm, 13.56MHz	Silicon oxides	W	1900 1400 1900	2100 1500 2100	4700 2400 4800	W	4500	7300 3000 7300	6200 2500 7200	1800	1900	-	W	W	W	2200	2000
CF_4+CHF_3+He (90:30:120 sccm) Lam 590 Plasma 850W, 2.8T, gap=0.38cm, 13.56MHz	Silicon oxides	W	2200 2200 2700	1700 1700 2100	6000 2500 7600	W	6400 6000 6400	7400 5500 7400	6700 5000 6700	4200 4000 6800	3800	-	W	W	W	2600 2600 6700	2900 2900 7200
SF_6+He (13:21 sccm) Technics PE II-A Plasma 100W, 250mT, gap≈2.6cm, 50kHz sq. wave	Silicon nitrides	300 300 1000	730 730 800	670 670 760	310	350	370	610	480 230 480	820	620 550 800	-	W	W	W	690 690 830	630
CF_4+CHF_3+He (10:5:10 sccm) Technics PE II-A Plasma 200W, 250mT, gap≈2.6cm, 50kHz sq. wave	Silicon nitrides	1100	1900	W	730	710	730	W	900	1300	1100	-	W	W	W	690	600
SF_6+He (175:50 sccm) Lam 480 Plasma 150W, 375mT, gap=1.35cm, 13.56MHz	Thin silicon nitrides	W	6400	7000 2000 7000	300 220 400	W	280	530	540	1300 830 2300	870	-	W	W	W	1500 1300 1500	1400
SF_6+He (175:50 sccm) Lam 480 Plasma 250W, 375mT, gap=1.35cm, 13.56MHz	Thick silicon nitrides	W	8400	9200	800	W	770	1500	1200	2800 2100 4200	2100	-	W	W	W	3400 3100 3400	3100
SF_6 (25 sccm) Tegal Inline Plasma 701 125W, 200mT, 40°C	Thin silicon nitrides	W	1700	2800	1100 1100 1600	W	1100	1400	1400	2800 2800 2800	2300	-	W	W	W	3400 2900 3400	3100
CF_4+CHF_3+He (45:15:60 sccm) Tegal Inline Plasma 701 100W, 300mT, 13.56MHz	Si-rich silicon nitrides	W	350	360	320	W	320	530	450	760	600	-	W	W	W	400	360
Cl_2+He (180:400 sccm) Lam Rainbow 4420 Plasma 275W, 425mT, 40°C, gap=0.80cm, 13.56MHz	Silicon	W 5000 5000	5700 3400 6300	3200 3200 3700	8 8 380	-	60	230	140	560	530	W	W	-	-	3000 2400 3000	2700
HBr+Cl_2 (70:70 sccm) Lam Rainbow 4420 Plasma 200W, 300mT, 40°C, gap=0.80cm, 13.56MHz	Silicon	W	450 450 740	460	4 4 10	-	0	0	0	870	26	W	W	-	-	350 350 500	300
Cl_2+BCl_3+$CHCl_3$+N_2 (30:50:20:50 sccm) Lam 690 RIE 250W, 250mT, 60°C, 13.56MHz	Aluminum	W	4500	W	680	670	750	W	740	930	860	6000 1900 6400	W	-	-	6300 3700 6300	6300 3300 6100
SF_6 (80 sccm) Tegal Inline Plasma 701 200W, 150mT, 40°C, 13.56MHz	Tungsten	W	5800	5400	1200 2000 2000	W	1200	1800	1500	2600	2300 1900 2300	-	2800 2800 4000	W	W	2400 2400 4000	2400
O_2 (51 sccm) Technics PE II-A Plasma 50W, 300mT, gap≈2.6cm, 50kHz sq. wave	Descumming photoresist	-	0	0	0	0	0	0	0	0	0	0	0	0	-	350	300
O_2 (51 sccm) Technics PE II-A Plasma 400W, 300mT, gap≈2.6cm, 50kHz sq. wave	Ashing Photoresist	-	0	0	0	0	0	0	0	0	0	0	0	0	-	3400	3600
HF Vapor 1 cm over plastic dish Room temperature and pressure	Silicon oxides	-	0	0	660	W	780	2100	1500	10	19	A	0	A	-	P 0	P 0

Ref.) K. R. Williams, and R. S. Muller, JMEMS, Vol. 5, No. 4, pp. 256-269, 1996

Etch Rate Table (2)

Material	Gas	Reactor Type	Pressure (torr)	Etch Rate (μm/min)	Etch Selectivity	Comments
Si_3N_4	SiF_4/O_2	Barrel	.3	.1	Si_3N_4 : Si :Poly Si :SiO_2 25:5:2.5:1	Anisotropic
	SiF_4/O_2(2%)	Barrel	.75	.08 ~ 1	Si_3N_4 : Poly Si 7.5:1	-
	CF_4/O_2	Barrel	1.1	.02	Si_3N_4 :SiO_2 5:1	Isotropic
SiO_2	C_2F_4	Planar	.4	.043	SiO_2 : Si 15:1	Anisotropic
	CF_4(70%)/H_2(30%)	Planar	.03	.004	SiO_2 : Si 5:1	-
	CHF_3(90%)/ CO_2(10%)	Vertical Barrel	.06~.08	.05 .075 .10 .14	Thermal SiO_2 :Si 17:1 4 wt% Phos. doped CVD SiO_2 : Si 25:1 8 wt% Phos. doped CVD SiO_2 : Si 33:1 (densified) 8 wt% Phos. doped CVD SiO_2 : Si 47:1	Reactive Ion Etch Anisotropic
	C_2F_4(12%)/ CHF_3(12%)/ He(76%)	Planar	4.0	.5 .7 1.1 .6	Thermal SiO_2 :Si 15:1 CVD SiO_2 : Si 19:1 8 wt% Phos. doped CVD SiO_2 : Si 30:1 Plasma SiO_2 :Si 16:1	Single Wafer Chamber Anisotropic
Aluminum	CCl_4He	Planar	.3	.18	Al : SiO_2 : Poly Si : Si 100:1:1:1	-
	CCl_4	Planar	.1	.06~.36	Al : Si 100:1	Sensitivity to any H_2O Present Etches alloys containing Si, but must be heated to 200℃ to each copper
	BCl_2	Planar	.1	.06	Al : Si 100:1	Not sensitive H_2O. Etches alloys Containing Si, but must be heated to 200℃ to each copper.

Ref: J. D. Lee, "Silicon Integrated Circuit microfabrication technology," 2nd edition

Etch Rate Table (3)

Material	Common etch gases	Dominant reactive species	Product	Comment
Aluminum	Chlorine-based	Cl, Cl_2	$AlCl_3$	Toxic gas and corrosive gases
Copper	Chlorine forms low pressure compounds	Cl, Cl_2	$CuCl_2$	Toxic gas and corrosive gases
Molybdenum	Fluorine based	F	MoF_6	
Photoresists	Oxygen	O	H_2O, CO_2, CO	Explosive hazard
SiO_2	CF_4, CHF_3, C_2F_6, C_3F_6	CF_X	SiF_4, CO, CO_2	
Tantalum	Fluorine based	F	TaF_3	
Titanium	Fluorine or chlorine based	F, Cl, Cl_2	TiF_4, TiF_3, $TiCl_4$	
Tungsten	Fluorine containing	F	WF_6	

Ref.) Marc J. Madou, "Fundamentals of MICROFABICATION," 2nd edition

ISRC Non Si Etcher (1)

- P-5000 (MEMS)

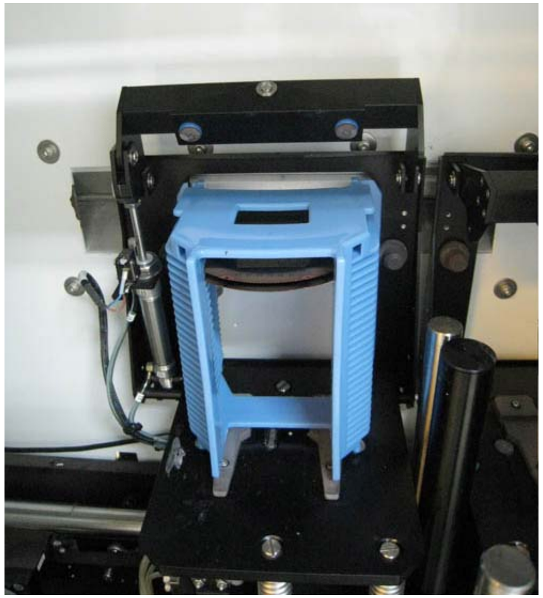
	Oxide	Nitride
Etch rate	>2000 Å/min	>2500 Å/min
Within wafer uniformity	±3 %	±3 %
Wafer to wafer uniformity	±5 %	±5 %
Selectivity to resist	4 : 1	3 : 1
Etch profile	90°±1°	87°±2°

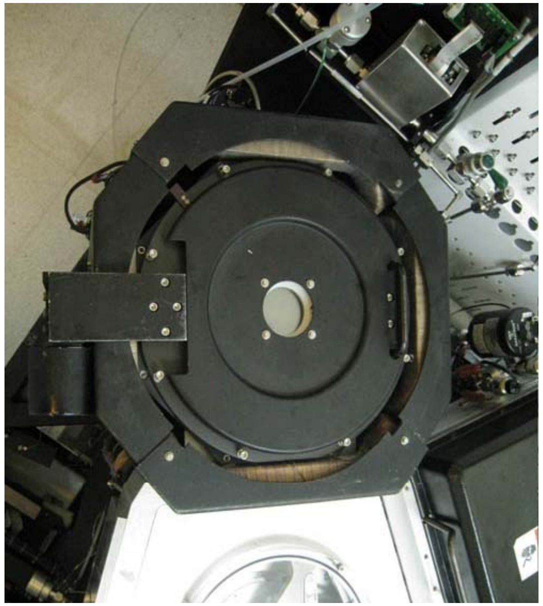
Main-step (oxide etch)							
CHF_3	CF_4	Ar	O_2	RF Power	Pressure	Gauss	He
25 sccm	5 sccm	70 sccm	0 sccm	600 W	130 mTorr	60	20 sccm

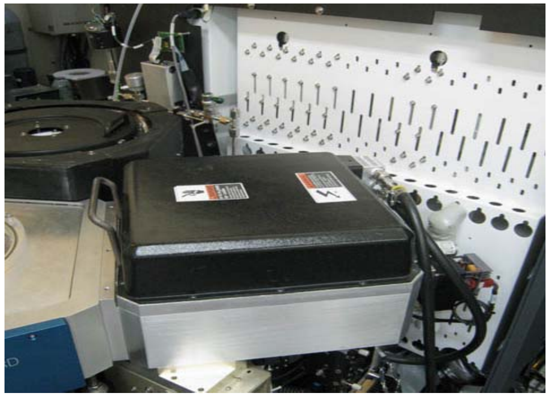
Main-step (nitride etch)							
CHF_3	CF_4	Ar	O_2	RF Power	Pressure	Gauss	He
15 sccm	10 sccm	10 sccm	8 sccm	600 W	100 mTorr	30	20 sccm

ISRC Non Si Etcher (2)

- P-5000 (MEMS)

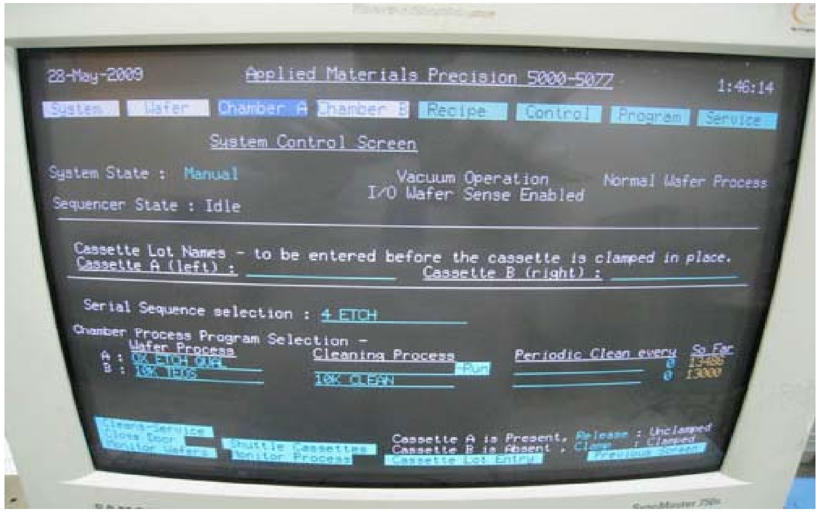


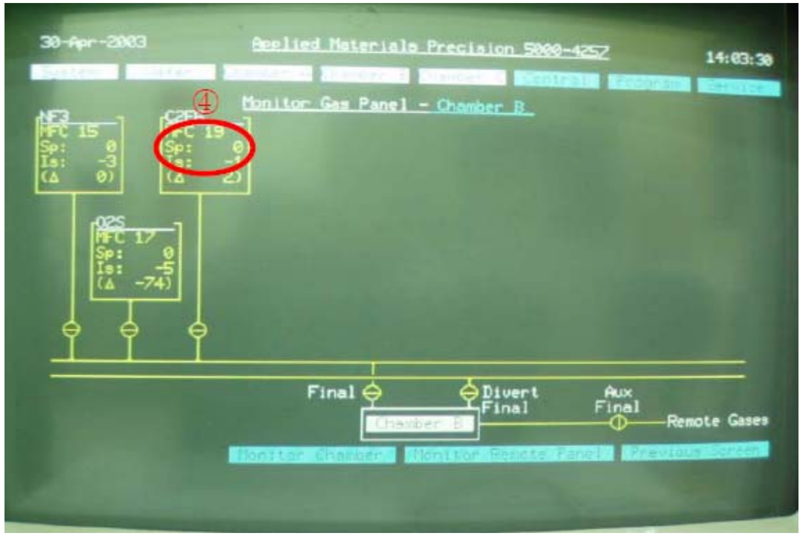


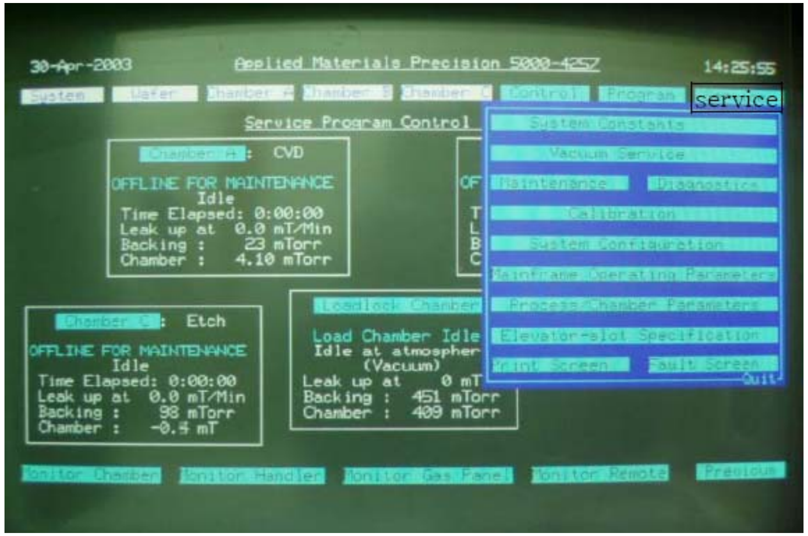


ISRC Non Si Etcher (2)

- P-5000 (MEMS)

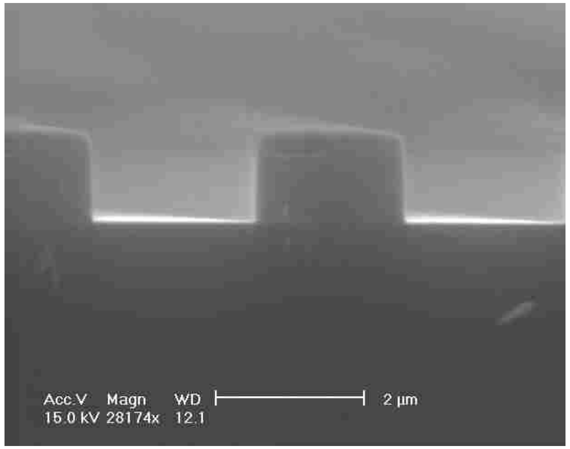


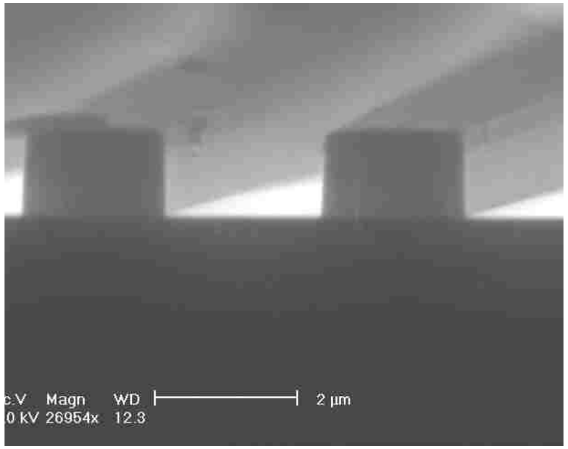




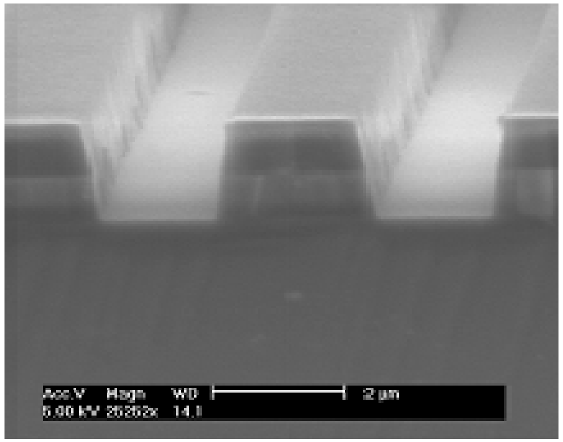
ISRC Non Si Etcher (3)

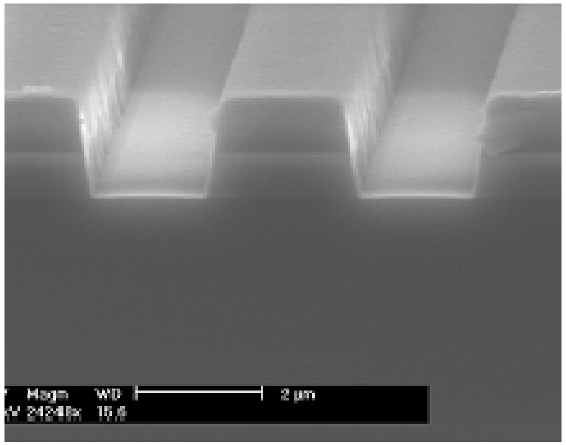
- MEMS P-5000 etch results





- PR etch Rate: ~650 Å/min
- Selectivity over PR: 5 : 1
- Etch Profile: 90°±1°





- PR Etch Rate: ~930 Å/min
- Selectivity over PR: 3.12:1
- Etch Profile : PR slop: 82.5°
  Nitride slop: 83.5°

Dong-il "Dan" Cho **Nano/Micro Systems & Controls Lab.**

ISRC Non Si Etcher (4)

- P-5000 (CMOS)

	Oxide	Nitride
Etch rate	3519 Å/min	3620 Å/min
Within wafer uniformity	1.23 %	< 4.1 %
Selectivity to resist	3 : 1	2.5 : 1
Etch profile	85° ± 1°	85° ± 2°

Main-step (oxide etch)							
CHF_3	CF_4	Ar	O_2	RF Power	Pressure	Gauss	He
25 sccm	5 sccm	70 sccm	0 sccm	600 W	130 mTorr	60	20 sccm

Main-step (nitride etch)							
CHF_3	CF_4	Ar	O_2	RF Power	Pressure	Gauss	He
15 sccm	10 sccm	10 sccm	8 sccm	600 W	100 mTorr	30	20 sccm

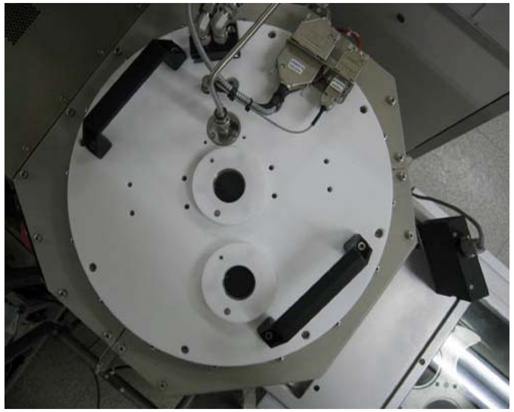
Non Si Etcher in ISRC (5)

- STS poly/metal etcher (MEMS)
- Plasma source type : ICP
- Main feed gas: HBr, Cl_2, Ar, SF_6, O_2, He
- Main power: 13.56 MHz – 1000 W
- Operating pressure: tens mTorr
- Bias power: 13.56 MHz 30/300 W

Non Si Etcher in ISRC (6)

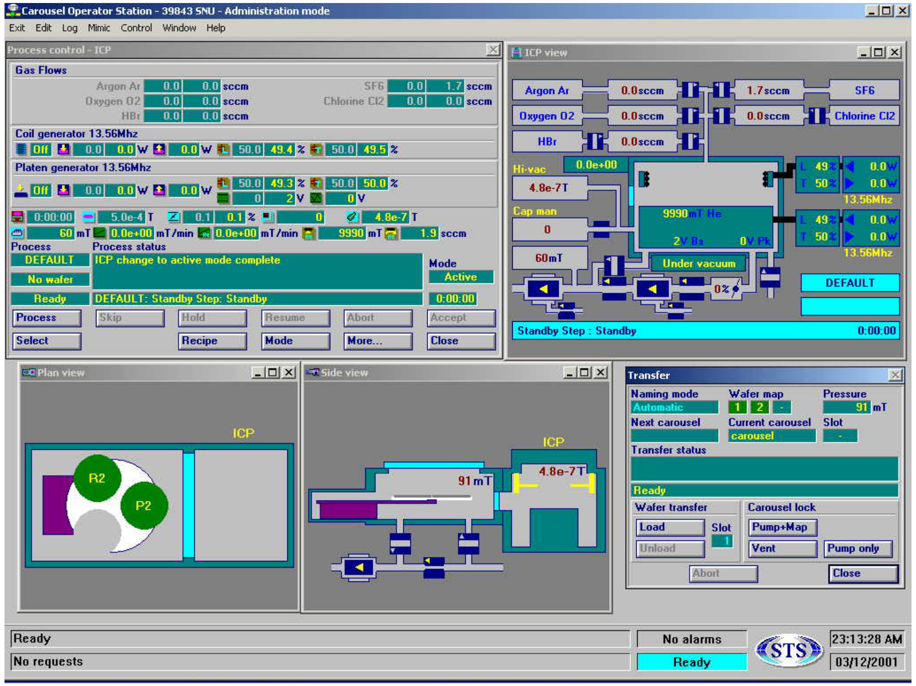
- STS poly/metal etcher (MEMS)

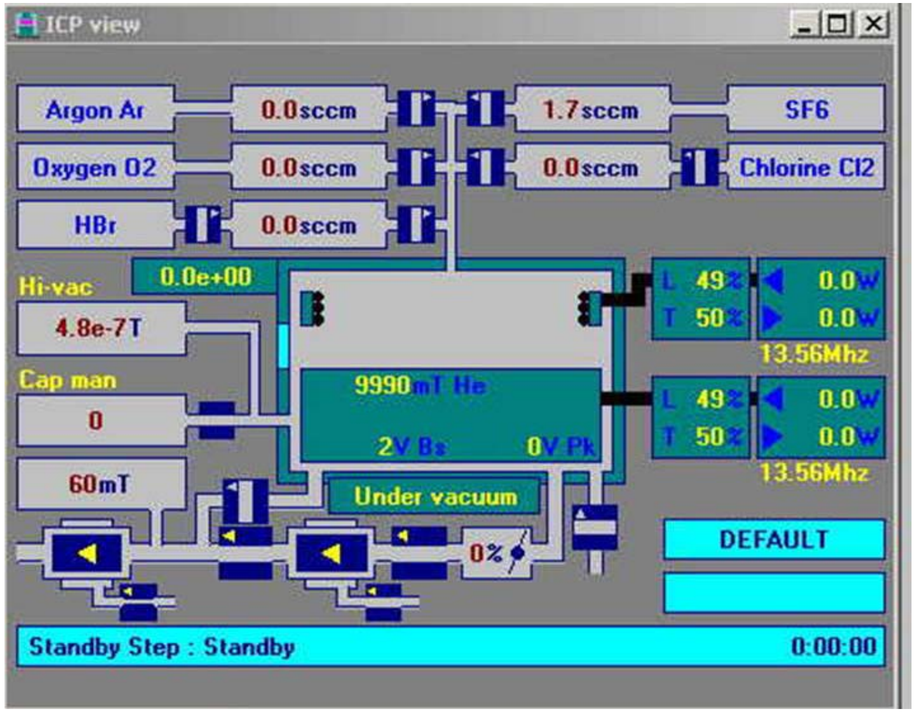




Non Si Etcher in ISRC (6)

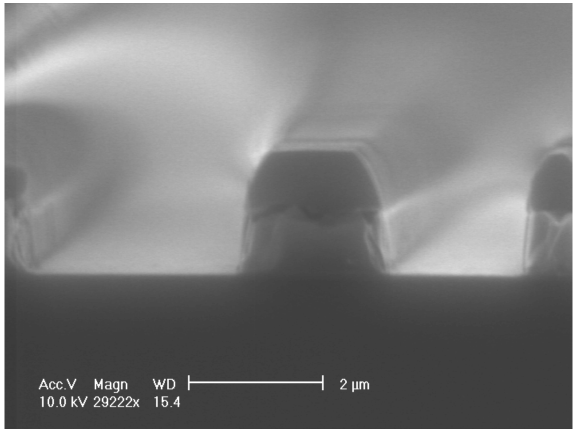
- STS poly/metal etcher (MEMS)

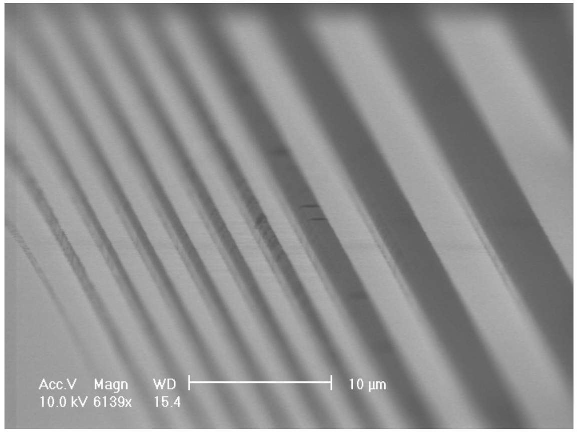


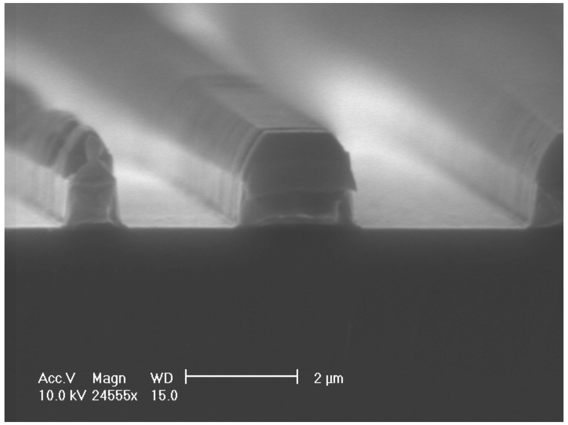


ISRC Non Si Etcher (7)

- Al etch process
  - Main step
    - Gas: Cl_2 – 33 sccm
    - RF Power: 125/1000 W
    - Pressure: 2 mTorr
  - Over etch step
    - Gas: HBr – 20 sccm
    - RF Power: 125/600 W
    - Pressure: 5 mTorr
  - Etch properties
    - Oxide : Poly - 1 : 10
    - PR : Al - 1 : 3
    - Etch rate: 3000 Å/min







ISRC Non Si Etcher (8)

- STS metal etcher (CMOS)
  - STS Multiplex ICP
  - Plasma source type: ICP (inductively coupled plasma)
  - Main feed gas: O_2, Cl_2
  - Main power: 13.56 MHz-1250 W
  - Bias power: 13.56 MHz-300 W
  - Operating pressure: tens mTorr

  - Stand Process Parameter (Main etch step)
    - Main etch step: 1 step
    - Main feed gas: Cl_2 (30 sccm)
    - Main power: 13.56 MHz, 1000 W
    - Bias power: 13.56 MHz, 125 W
    - Operating pressure: 2 mTorr

ISRC Non Si Etcher (9)

- Oxford etcher
  - Oxford RIE 80 plus
  - Pump (Alcatel)
    - Rotary: 2033CP+, 575 ℓ/m
    - Turbo: ATC400C, 400 ℓ/s
  - MFC
    - O_2 – 1000 sccm
    - Cl_2 – 100 sccm
    - SF_6 – 500 sccm
    - CF_4 – 200 sccm
    - CH_4 – 200 sccm
    - CHF_3 – 200 sccm
    - Ar – 50 sccm
    - BCl_3 – 200 sccm
    - N_2 – 200 sccm
    - H_2 – 200 sccm
  - RF Generator: ENI, ACG-10B, 200 W, 13.56 MHz

ISRC Non Si Etcher (10)

- Oxford etcher recipes
  - SiO_2
    - O_2 - 5sccm
    - CF_4 - 50sccm
    - 55 mTorr
    - 150 W
    - 700 Å/m
  - Si_3N_4
    - O_2 – 5 sccm
    - CF_4 – 50 sccm
    - 55 mTorr
    - 150 W
    - 700 Å/m

ISRC Non Si Etcher (11)

- Asher I (MEMS)
  - Plasma finish V15-G
  - Lab master V15-G
  - Plasma: micro wave
  - Frequency: 2.45 GHz
  - Plasma power : 600 W
  - Gas: O_2 500sccm (2chanel)
  - Substrate: Si, glass, Pyrex

  - AZ1512 ashing recipe
    - Plasma power : 300 W
    - Gas flow: O_2 200 sccm
    - Time: 10~60 min

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ISRC Non Si Etcher (12)

- Asher II (MEMS)
  - Lab master V15-G
  - Plasma: micro wave
  - Frequency: 2.45 GHz
  - Plasma power : 600 W
  - Gas: O_2 500sccm (2chanel)
  - Substrate: Si, glass, Pyrex

  - AZ1512 ashing recipe
    - Plasma power : 300 W
    - Gas flow: O_2 200 sccm
    - Time: 10~60 min

ISRC Non Si Etcher (13)

- Asher (CMOS)
  - Tepla AG. 200 semi-auto
  - Pump: Leybold, Rotary, D65BCS
  - MFC: Brooks, O2, 2000 sccm
  - RF Generator:

    Microwave, 2.45GHz, 1000Wss

  - PR ashing recipe
    - O_2 – 700 sccm
    - RF – 700 W

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