UCSB Vapor HF System Process Notes

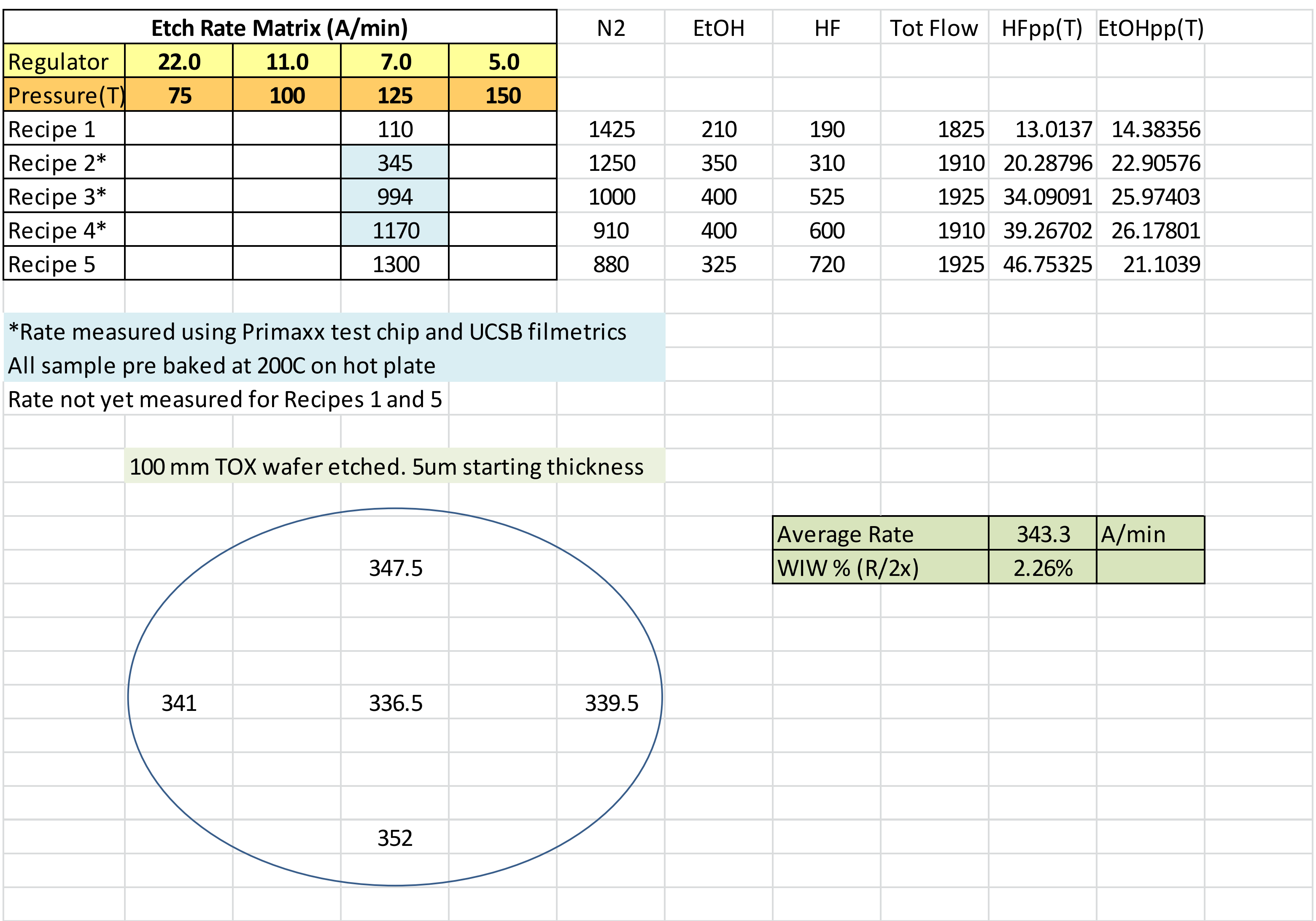
This guide will serve as a process guide for the SPTS Vapor Etch System.

Standard recipes and process details are reported on the following pages.
If processes outside the standard range of operation are required, users can discuss this with staff.

Some Basic Notes:

1. Under no circumstances shall any doped (P or B) glass, pyrex, or glass slides be used in the system. You may only use pure quartz or pure fused silica glass substrates in the system.
2. Users must use Nitrile gloves at all times while using the system, no other glove type allowed.
3. Samples should be baked at 200C for 2 minutes or exposed to an oxygen plasma prior to loading in the system. This is to prevent inhibition of etching due to outgassing of fluoroware or other plastic sample storage containers
4. Photoresist is not a good etch mask, the HF vapor will travel through the material and attack the SiO2 through the resist
5. Any organic residues left on the surface will remain after etching and may accumulate in "piles" on the surface.
6. Please see the materials compatibility chart in this presentation to determine proper masking materials for your process.
7. SiN and PECVD SiO2 (that uses N_2O) require a 250C, 1 minute, hot plate post bake (in a fume hood!) to remove non-volatile residues caused by the presence of nitrogen in the films.

UCSB Standard System Recipes



Etch Rate Matrix (A/min)					N2	EtOH	HF	Tot Flow	HFpp(T)	EtOHpp(T)
Regulator	22.0	11.0	7.0	5.0						
Pressure(T)	75	100	125	150						
Recipe 1			110		1425	210	190	1825	13.0137	14.38356
Recipe 2*			345		1250	350	310	1910	20.28796	22.90576
Recipe 3*			994		1000	400	525	1925	34.09091	25.97403
Recipe 4*			1170		910	400	600	1910	39.26702	26.17801
Recipe 5			1300		880	325	720	1925	46.75325	21.1039

*Rate measured using Primaxx test chip and UCSB filmetrics
All sample pre baked at 200C on hot plate
Rate not yet measured for Recipes 1 and 5

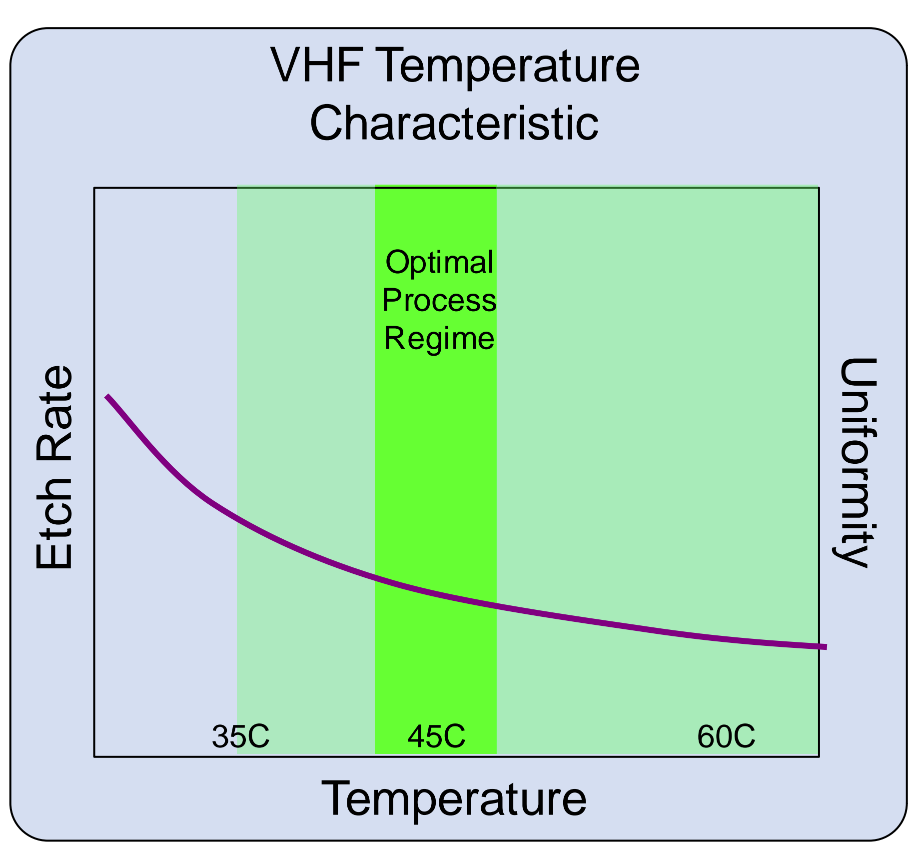
100 mm TOX wafer etched. 5um starting thickness

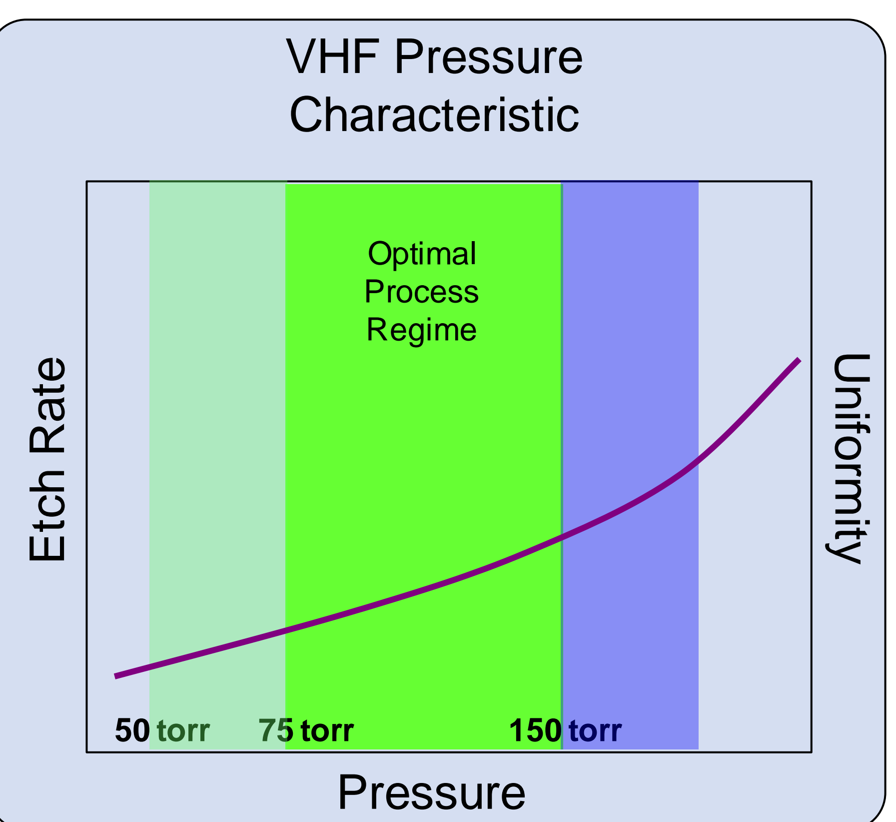
Average Rate	343.3	A/min
WIW % (R/2x)	2.26%	

4 inch wafer 100% SiO2 open area

PRIMAXX® VHF Etching – Rate Control

- Etch Rate dependencies
  - ***Increases*** with lower temperature and higher pressures
  - ***Decreases*** with higher temperature and lower pressures
  - Uniformity degrades as etch rate increases





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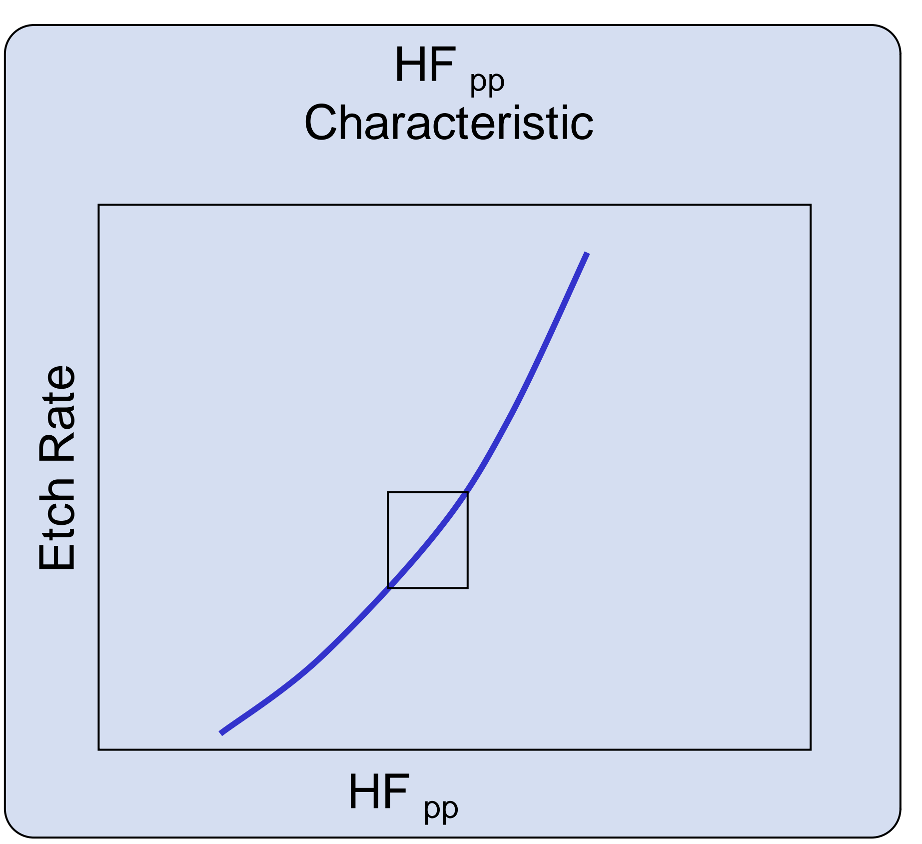
Etch Rate Control – HF_{pp} using HF Flow

- HF_{pp} is the dominant parameter used to control etch rate
- Increasing Total Gas Flow (and Total N_2) without changing HF flow rate reduces etch rate because HF_{pp} is reduced



HF Partial Pressure =

$$\frac{\text{HF Vapor Flow * Pressure}}{\text{Total Gas Flow}}$$

20% increase in HF_{pp} = 40% increase in etch rate when in a controlled regime

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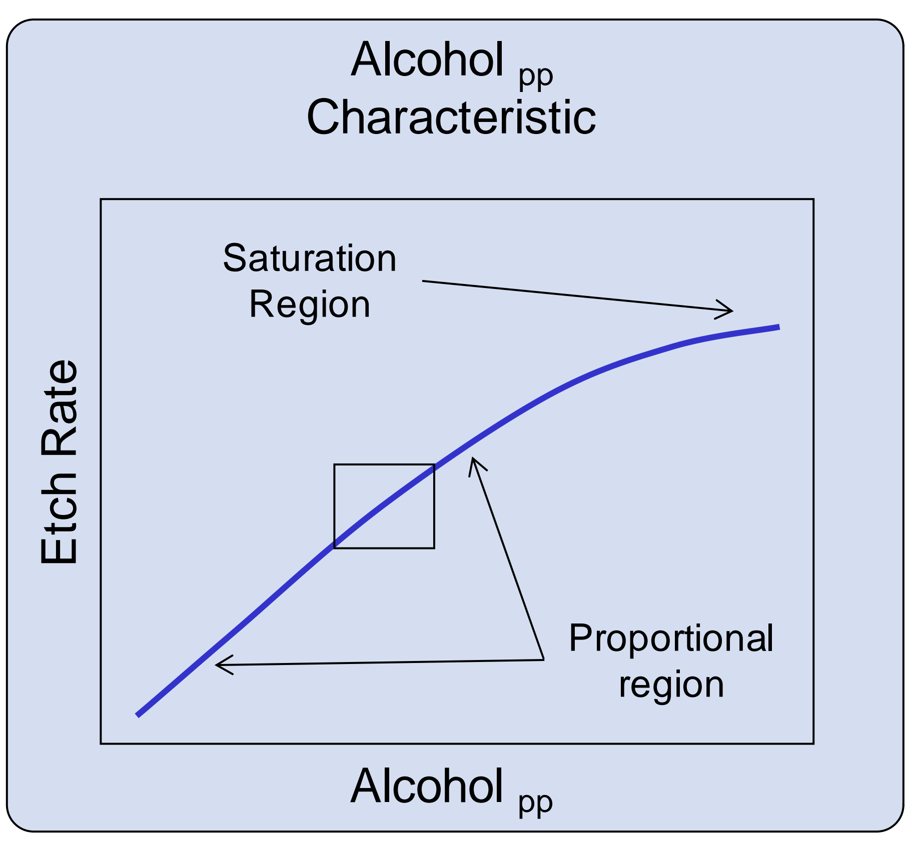
Alcohol in the PRIMAXX® VHF Process

- Alcohol is **required** to ionize the HF and activate etching
- Alcohol influences within wafer etch uniformity
- Ethanol vapor pressure most compatible with VHF



Alcohol Partial Pressure =

$$\frac{\text{Alcohol Vapor Flow * Pressure}}{\text{Total Gas Flow}}$$

+ 1% Alc_{pp} ~ + 1% etch rate (up to saturation)

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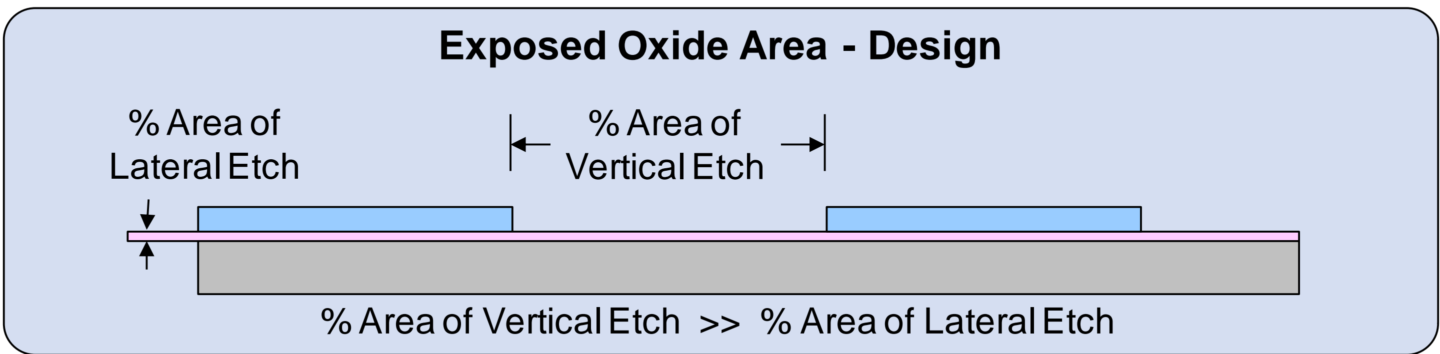
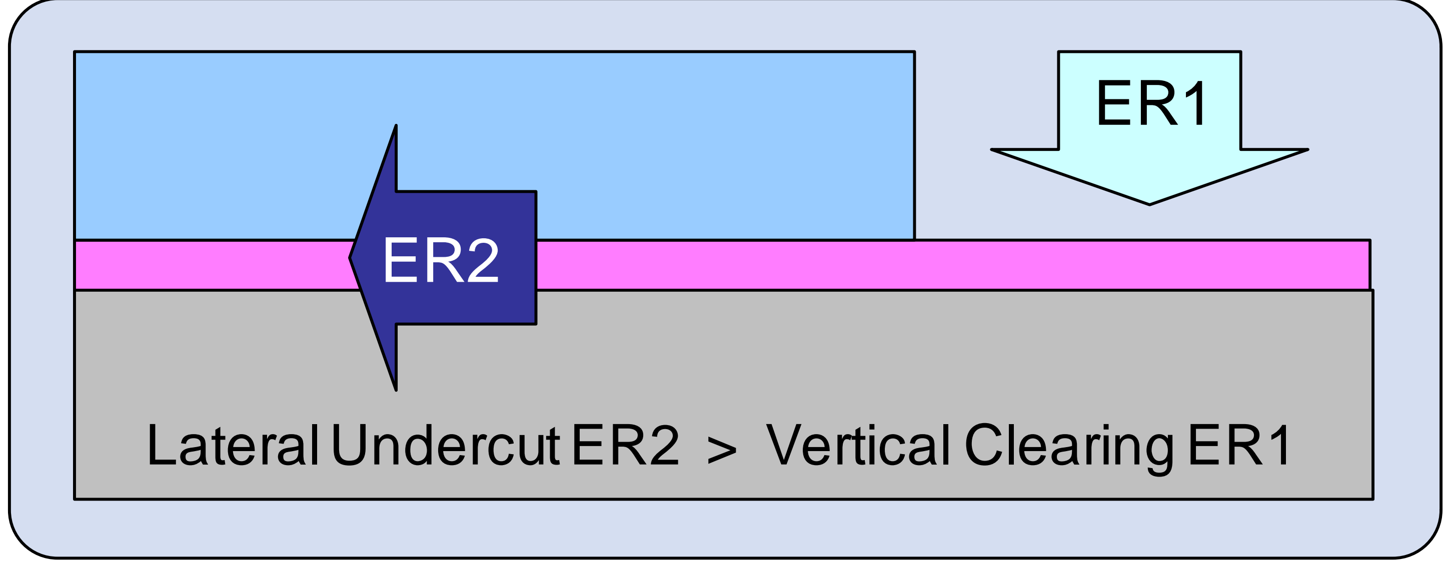
Typical Two Step Etch Approach

- Initial oxide loading often high (field oxide, exposed BOX)
- Once etched to handle wafer (ER1), exposed area small





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Process Regimes for Two Step Etching

	Clearing Step – ER 1	Undercut Step – ER 2	
Slow / High oxide %	< 350 A/min	< 0.12 um/min	High Stiction Probability
Fast / Low oxide %	300 - 750 A/min	0.15 - 0.25 um/min	Low Stiction Probability

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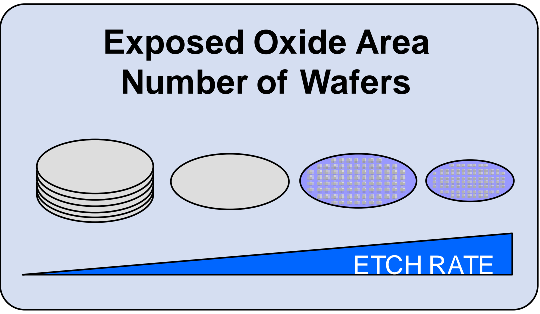
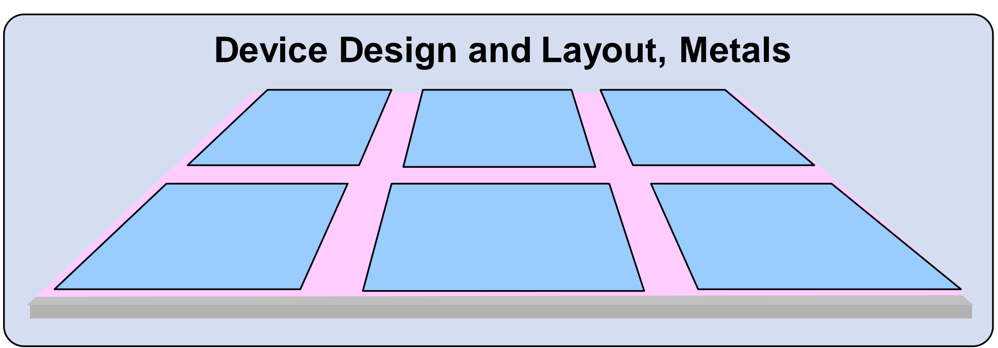
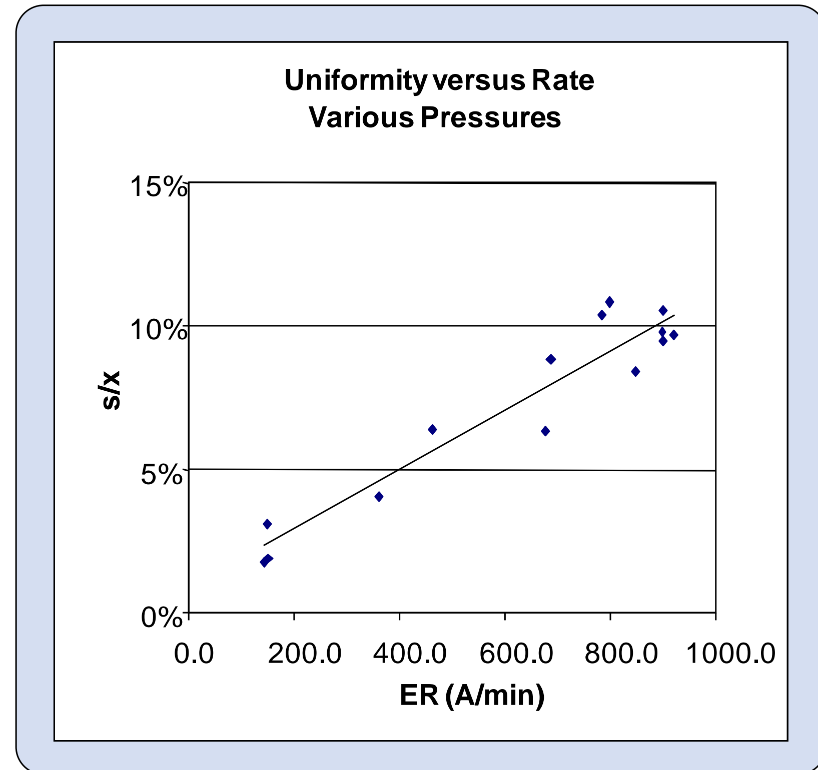
Process Loading Effects

- Amount of exposed oxide is the biggest loading factor
  - Device/wafer layout, # of wafers, presence of back side oxide
- Uniformity degrades with increasing etch rate
- Presence of exposed metals limits maximum etch rates







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Materials Compatibility with VHF

Material	Sacrificial Oxide	Protective Layer	Metal/Electrode /Adhesion
Thermal Oxide, TEOS	🟢		
SOI bonded oxide	🟢		
Quartz	🟢		
PECVD oxide	🟡		
Spin on oxide	🟡		
Doped oxides BPSG, PSG	🔴		
Doped glass, Pyrex	🔴		
Low temperature spin on glass	🔴		
PECVD oxide (SiH_4 +N_2O)	🔴		
Silicon (poly, amorphous, single crystal)		🟢	
Alumina (thick)		🟢	
ALD alumina (1000A)		🟢	
Aluminum		🟢	🟢
Silicon Carbide		🟢	
Si-Rich LPCVD silicon nitride (low stress)		🟡	
Stoichiometric PECVD nitride		🔴	
Photoresist		🔴	
Gold			🟢
Copper			🟡
Ti			🔴
TiO2			🔴
TiW			🟢
Nickel			🟢

PECVD Oxide has worked well for us.
Other substrates than listed can be used. Confirm with staff.
Other metals may also be OK. Confirm with staff.
NEVER use doped glass (P or B) or pyrex or glass slides in the system.
Thinner ALD Al2O3 films may work fine as well. This needs testing.

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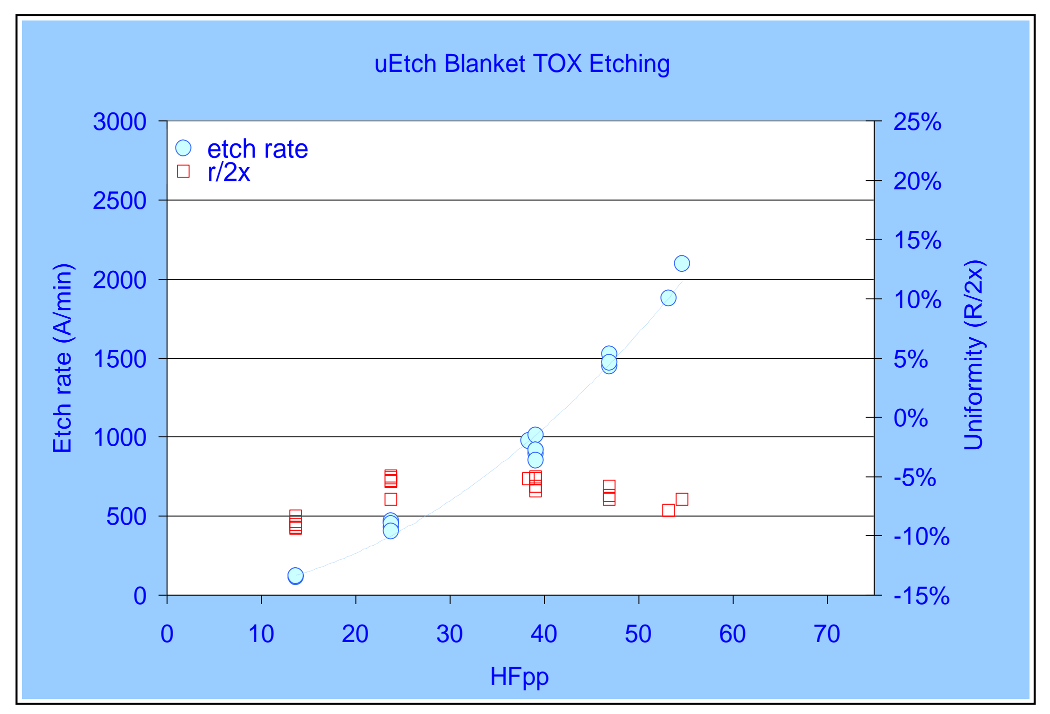
uEtch Performance Specifications

- Processes up to 1 x 200mm wafer per run
  - Or silicon wafer carrier/optional “pocket” carrier for die level
- Etch Specifications (200 mm blanket TOX etching)
  - Etch rate range : 100 A/min - 1000 A/min
  - WIW ≤ 12%, R2R ≤ 15% (r/2x at 100 A/min, ER dependent); device wafer uniformities are typically better



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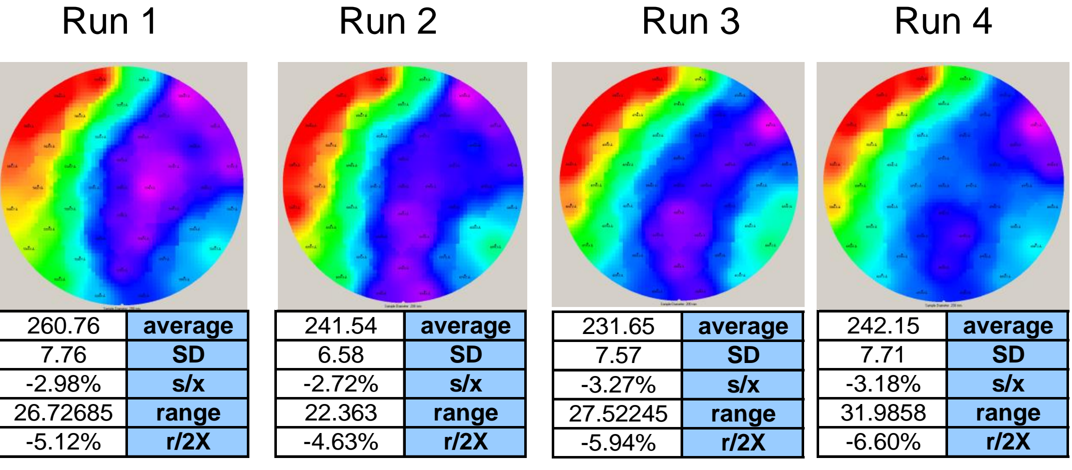
uEtch Results – TOX Wafers



Run 1

260.76	average
7.76	SD
-2.98%	s/x
26.72685	range
-5.12%	r/2X

Run 2

241.54	average
6.58	SD
-2.72%	s/x
22.363	range
-4.63%	r/2X

Run 3

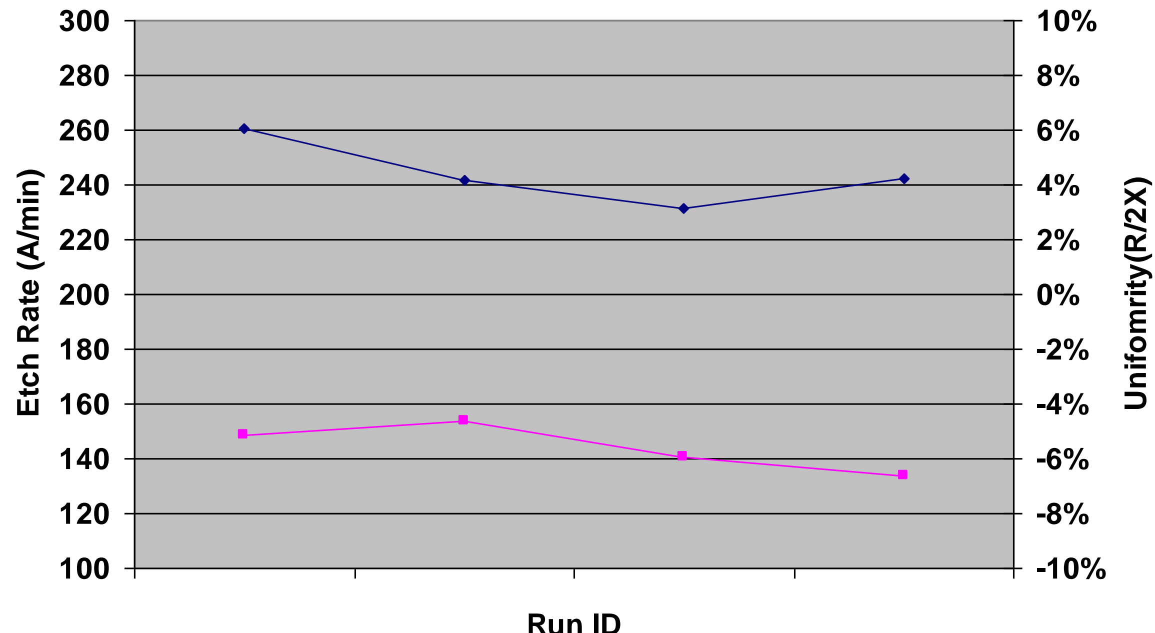
231.65	average
7.57	SD
-3.27%	s/x
27.52245	range
-5.94%	r/2X

Run 4

242.15	average
7.71	SD
-3.18%	s/x
31.9858	range
-6.60%	r/2X

R2R statistics

average	244.03
sd	12.152039
s/x	4.98%
r/2x	5.97%



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uEtch Patterned Wafers – Methodology

- Use TWO "patterned" test wafers to establish WIW% and R2R repeatability
- Use standard etch methodology:
  - Clearing Step – remove exposed oxide using a slow to moderate etch rate to control uniformity under high loading conditions
  - Undercutting Step – use a higher etch rate since the exposed oxide percentage has been reduced by an order of magnitude
- Etch test on each wafer (FOUR tests total)
  - Etch ~ 50% of exposed vertical thickness of BOX layer ($ER_{CL}1$)
  - Etch remaining exposed oxide, confirm clearing rate ($ER_{CL}2$)
  - Etch laterally (undercut) using higher etch rate ($ER_{UC}1$)
  - Repeat for a second lateral etch ($ER_{UC}2$)

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uEtch Patterned Wafers – Etch Runs

VHF Run 1

VHF Run 2

VHF Run 3

VHF Run 4

Pre-measure 69 oxide pads with thickness mapping tool

Etch 50% exposed pads and calculate $ER_{CL}1$ with thickness mapping tool

Etch to substrate and calculate $ER_{CL}2$ with thickness mapping tool **(NOTE THAT SOME UNDERCUT OCCURS - ISOTROPIC ETCH)**

Etch laterally by time and calculate $ER_{UC}1$ with optical inspection of vernier deflection

Etch laterally by time and calculate $ER_{UC}2$ with optical inspection of vernier deflection

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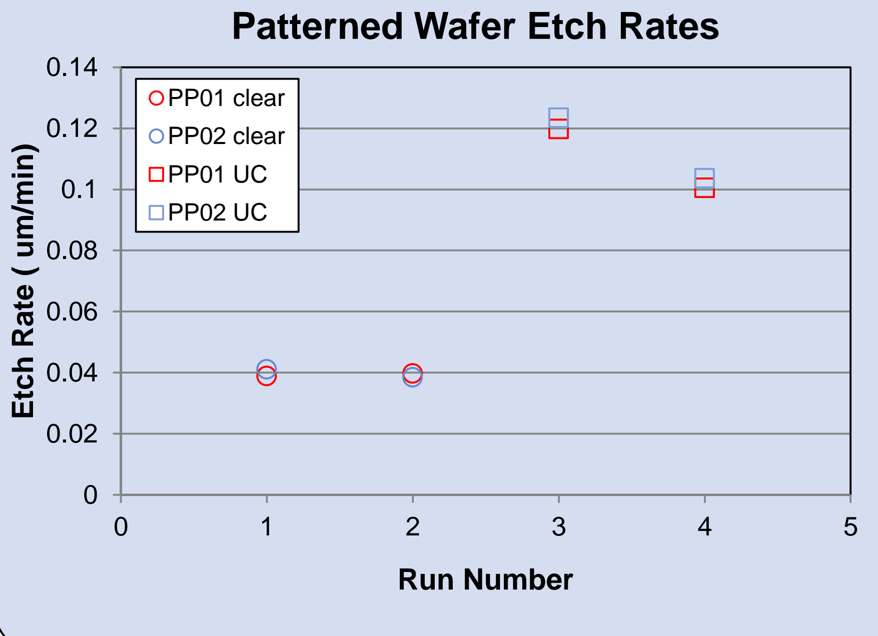
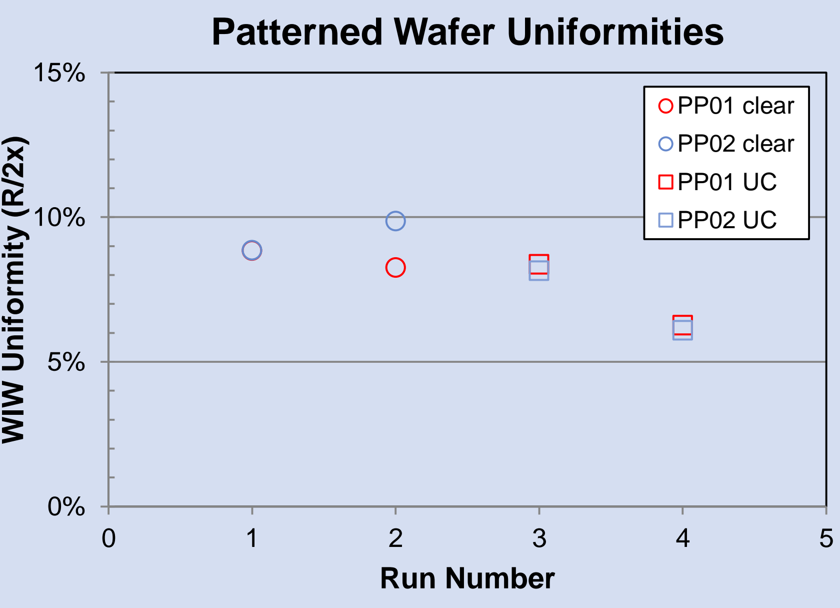
uEtch Patterned Wafers – Data Summary

SPTS

Sequential chart of Etch Rate and R/2x U % for each step (TWO patterned wafers)





- Total Etch Time = 90 minutes (excludes overhead time)
- Average Total Etch Length = 8.1 um
- Average Etch Rate = 0.090 um/min

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Etch Stability – Very Long Undercuts

- SOI based sample, full removal of BOX layer with mm length undercuts

Undercut Length versus Etch Time

Etch Length (um): 0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

Elapsed Etch Time (minutes): 0, 500, 1000, 1500, 2000, 2500

IR Scope Image at 240 um undercut

Etch Uniformity

POSITION	UNDERCUT (um)
Top	244
Center	240.1
Bottom	241.2
Left	242.1
Right	241.2
AVERAGE	241.7
WIW% (SD)	0.6%

Devices are cleared at 1080 minutes. Only the frame remains bound.

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Etch Stability at Ultra Low Etch Rates

- Controlled, repeatable etching on 150 mm blanket TOX wafers at ultra low etch rates from 60 A/min to 3 A/min

Low Etch Rate Repeatability - 150 mm TOX Etching

average	58.67
s/x	3.27%
R/2x	3.76%

average	22.71
s/x	1.95%
R/2x	1.72%

average	12.56
s/x	7.73%
R/2x	8.66%

average	3.75
s/x	7.94%
R/2x	8.41%

Etch Rate (A/min)
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Run ID

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