LNF Equipment Overview

NNIN Etch Workshop 2013

Kevin Owen

Lurie Nanofabrication Facility

STS Pegasus

- Powerful ICP etcher for Bosch process DRIE
- Two tools, one 4” one 6”
  - Smaller samples can be mounted to a carrier
  - Electrostatic chuck
  - Temperature range -15-50C
- Designed for high aspect ratio Si etching
  - Can also etch dielectrics and organics for preparing masks

STS Pegasus

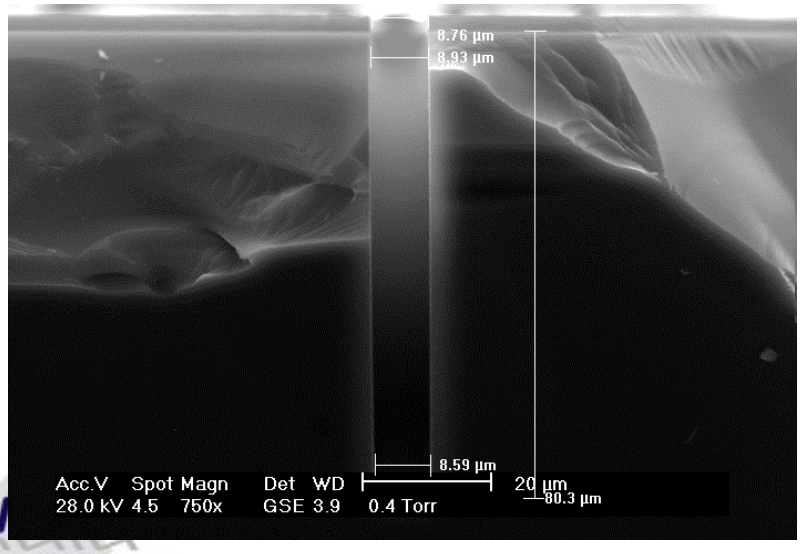
- Gases
  - SF_6
  - C_4F_8
  - O_2
  - Ar
- Masking materials
  - Photoresist
  - Oxide
  - Metals allowed, not recommended
- ICP coil
  - 13.56Mhz
  - Up to 6000W
- Two platen supplies
  - 13.56MHz
  - 380kHz, pulsed
  - Up to 300W
- Pressure range
  - 5mT – 100mT

STS Pegasus

Standard Recipes

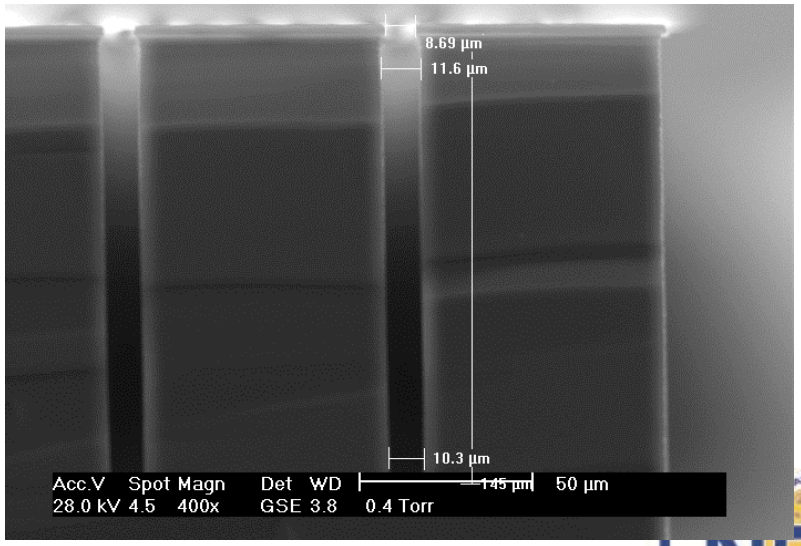
LNF Recipe 1

- **General recipe, minimal undercut**
- 2µm etch rate: 2.76µm/min
- 10µm etch rate: 4.02µm/min
- 100µm etch rate: 5.6µm/min
- PR etch rate: 84nm/min
- Scalloping width/depth: 86/321nm
- Undercut: 75nm



LNF Recipe 2

- **Faster recipe, worse sidewalls**
- 2µm etch rate: 4.69µm/min
- 10µm etch rate: 7.25µm/min
- 100µm etch rate: 12.1µm/min
- PR etch rate: 61nm/min
- Scalloping width/depth: 0.5/2.3µm
- Undercut: 1.06µm

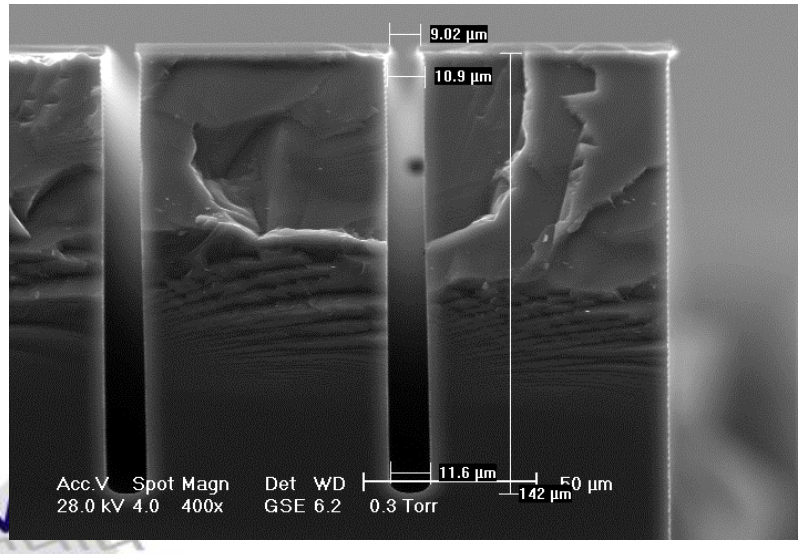


STS Pegasus

Standard Recipes

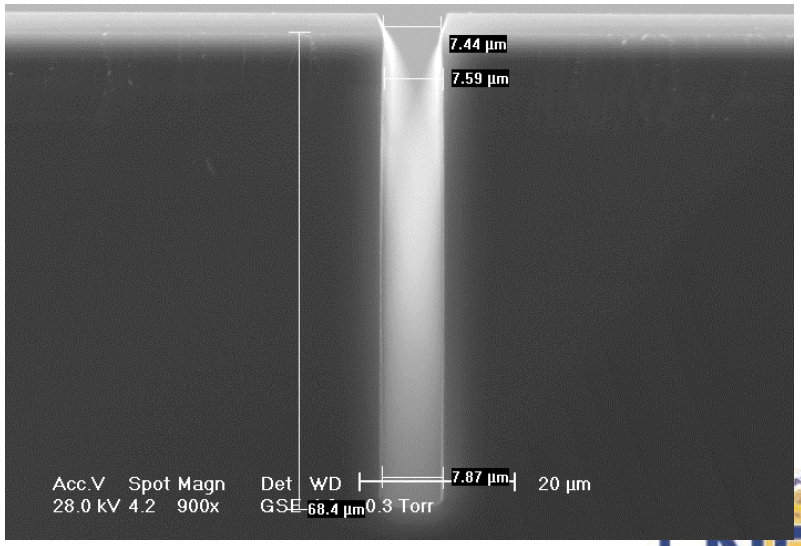
LNF Recipe 3

- **Like Recipe 2, for bigger open area**
- 2µm etch rate: 4.63µm/min
- 10µm etch rate: 7.1µm/min
- 100µm etch rate: 12.5µm/min
- PR etch rate: 77nm/min
- Scalloping width/depth: 0.5/2.2µm
- Undercut: 483nm



LNF Recipe 4

- **High aspect ratio, small areas**
- 2µm etch rate: 2.3µm/min
- 10µm etch rate: 3.4µm/min
- 100µm etch rate: 5.25µm/min
- PR etch rate: 60nm/min
- Scalloping width/depth: 80/300nm
- Undercut: 225nm



STS Pegasus

Other Recipes

- Polysilicon etch (3000-5000Å/min)
- Oxynitride etch (900-1400Å/min)
- Si thinning etch (3-5µm/min)
- Descum recipes
  - O_2 descum
  - Ar descum

STS Pegasus

Capabilities and Features

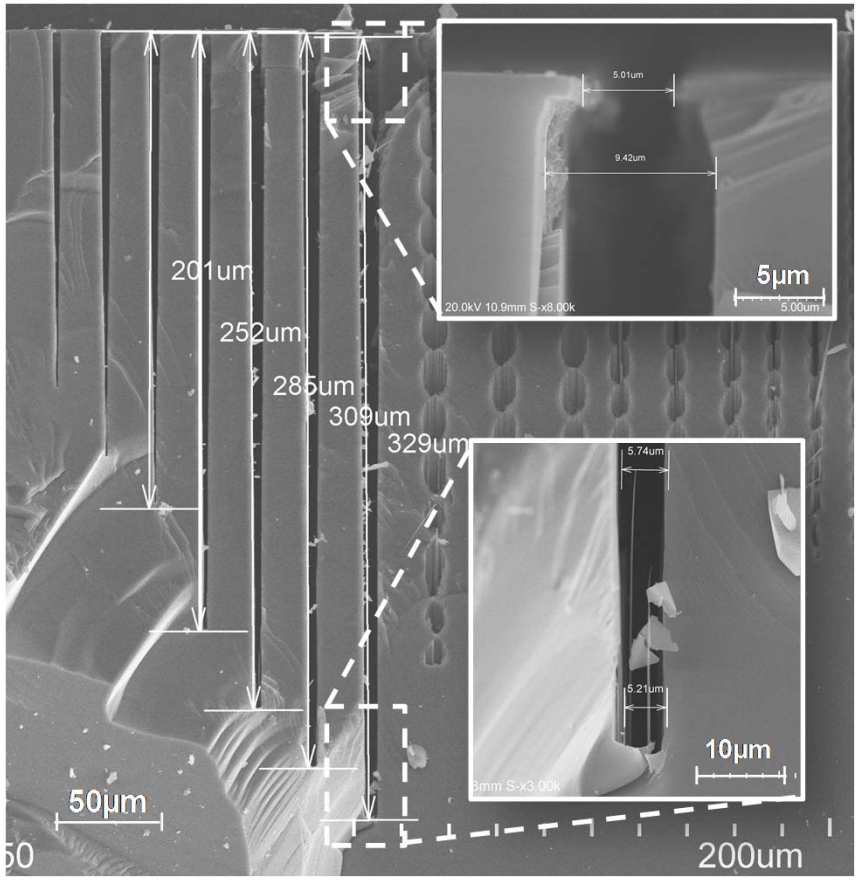
- Fast switching capabilities
  - Match unit, MFCs, throttle valve
  - Short path from MFCs to gas inlet
- Pulsed bias power supply
  - Discharges sidewalls, mask, etc
  - Reduces notching and pinch-off
- Parameter ramping
  - Compensate for ARDE
- Multiple “sub-steps”
  - Within passivation and etch step
  - Most useful for passivation breakthrough

STS Pegasus

Custom Recipes

K. Owen, et al., *MEMS, 2012 IEEE 25th Intl. Conf.*, 251-254 (2012).

- Reducing effect of ARDE
  - Parameter ramping
  - Mainly etch/dep step times, power, pressure
- Good for 1-10µm features
- Highest AR reported
  - 70:1 for a 5.7 µm trench
  - 97:1 for a 3 µm trench

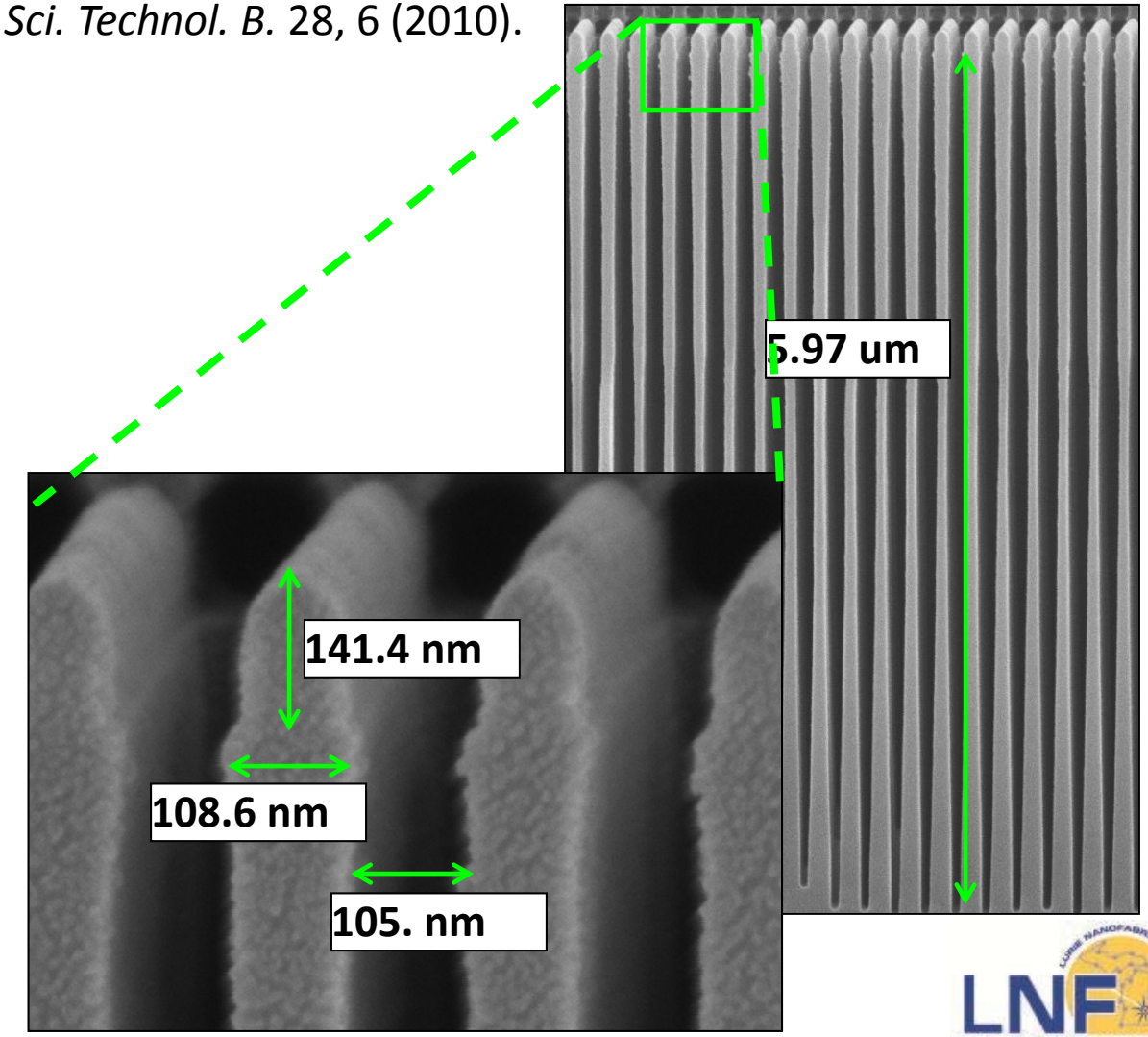


STS Pegasus

Custom Recipes

P. Mukherjee, et al. *J. Vac. Sci. Technol. B.* 28, 6 (2010).

- Nanoscale DRIE
  - <1µm features
- Challenges
  - Scalloping
  - Undercut
  - Bowing
- Final AR
  59.7:1 for 100nm



STS Pegasus

Maintenance & Qualification

- O_2 clean run between every wafer
- Weekly Maintenance
  - Inspect, clean chamber
  - Chamber leak rate
  - MFC check
  - Wafer centering
  - Recipe backup, maintenance
- Weekly Qualification
  - Recipe 1 etch
  - Break down the Bosch Process
    - Etch test, Passivation test, DC Boost test

STS APS System

- ICP system for deep etching of dielectrics
- Configured for 6” wafers
  - Smaller samples may be mounted to a carrier
  - Electrostatic chuck
  - Temperature control -15-50C
- High aspect ratio etching from nanoscale up to very large features

STS APS System

- Gases
  - SF6
  - C4F8
  - O2
  - Ar
  - He
  - H2
- ICP coil
  - 13.56Mhz
  - Up to 2000W
- Platen supply
  - 13.56MHz
  - Up to 1000W

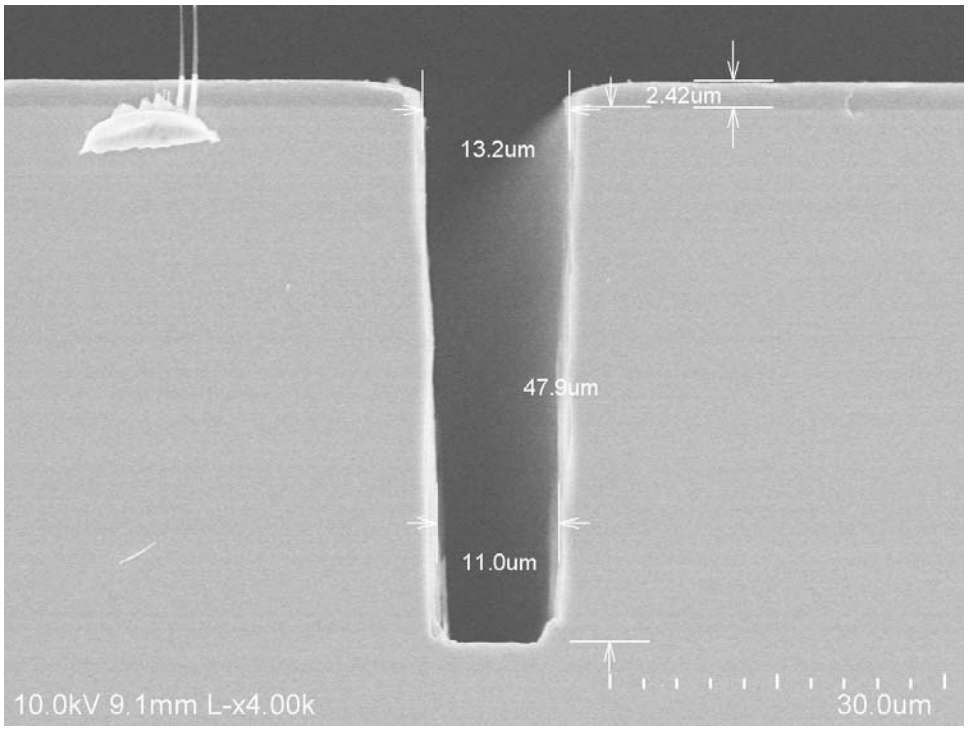
STS APS System

Recipes

- uk_submicron etch
  - **Standard oxide etch**
  - 2200Å/min etch rate
  - 2:1 PR selectivity
  - Vertical sidewalls
- Quartz etch
  - **Faster oxide etch**
  - More fluorocarbon buildup – non-vertical sidewall
- Fused Silica etch
  - **Deep etch**
  - 5000Å/min
  - 5:1 PR selectivity
- Rhenium
- Silicon Carbide
- PZT

STS APS System

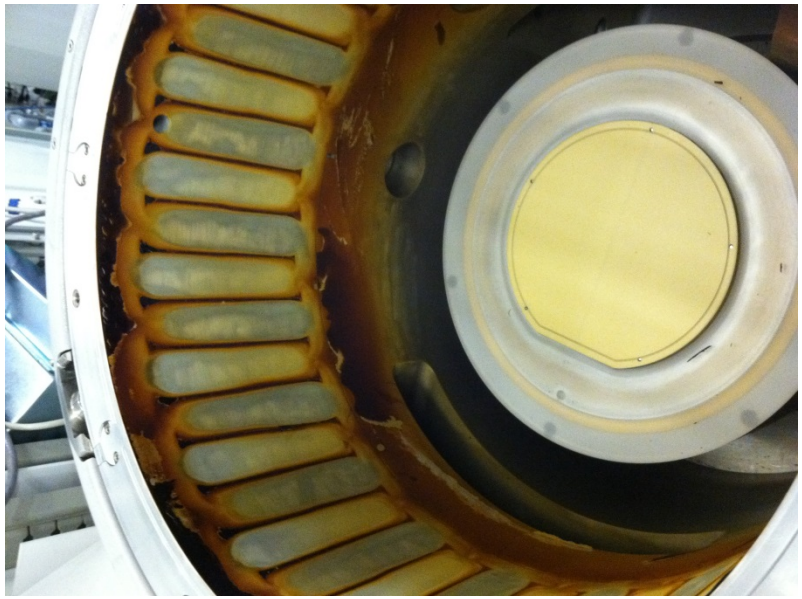
Recipes



STS APS System

Maintenance & Qualification

- O_2/CF_4, SF_6 cleans run between every wafer
- Weekly Maintenance
  - Inspect, clean chamber
  - Chamber leak rate
  - Wafer centering
  - O_2 clean, C_4F_8 condition



LAM 9400

- ICP system for dielectric, semiconductor, and polymer etching
- Configured for 6” wafers
  - Smaller samples may be mounted to a carrier
  - Electrostatic chuck
  - Chuck temperature range: -40C to 80C

LAM 9400

- Gases
  - Cl_2
  - BCl_3
  - HBr
  - C_4F_8
  - SF_6
  - O_2
  - Ar
  - He
- ICP coil
  - 13.56Mhz
  - Up to 1000W
- Platen supply
  - 13.56MHz
  - Up to 1000W
- Pressure range
  - 5mT to 300mT

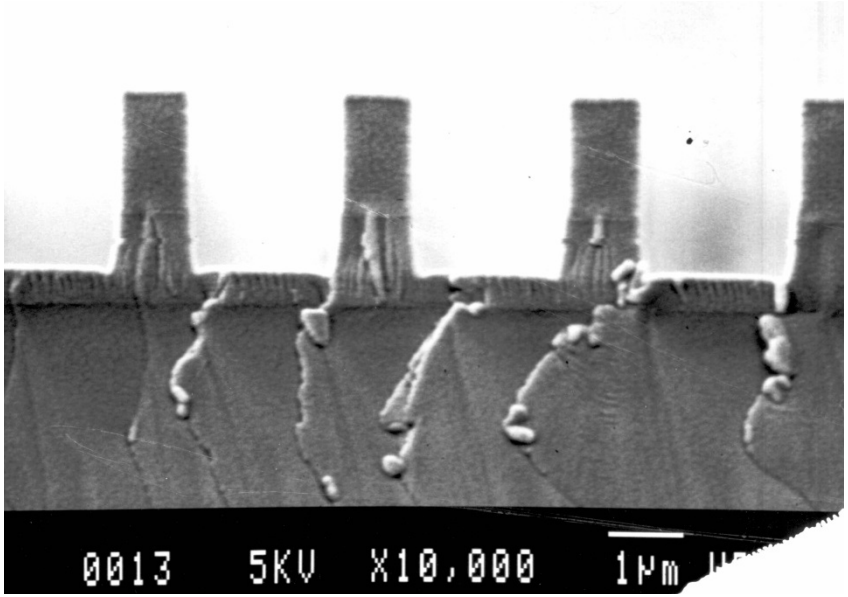
LAM 9400

Capabilities

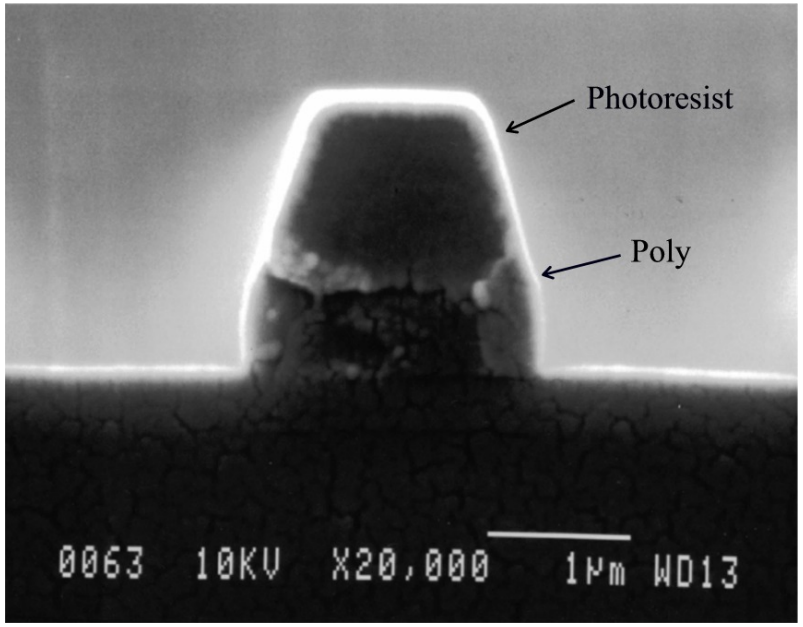
- LNF Supported Recipes
  - Polysilicon (1500Å/min)
  - Oxide (1500Å/min)
  - Nitride
  - Oxynitride (1600Å/min)
  - Parylene (750Å/min)
- Other Recipes
  - GaAs
  - AlN
  - PDMS
  - Polymers
  - InP, GaN, etc
  - Reactive metals (W, Cr, Mo, Al, Ti)

LAM 9400
Capabilities

mnf_oxide_1



mnf_poly_2

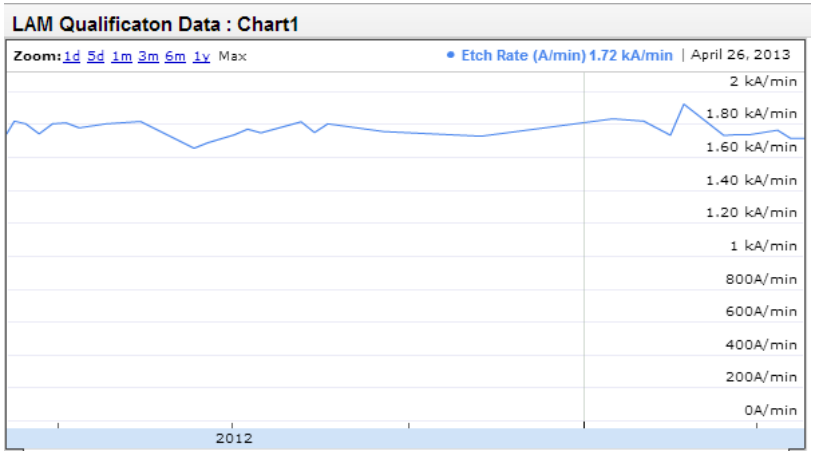


LAM 9400

Maintenance & Qualification

- Series of O_2, SF_6, Cl_2 cleans before each wafer
  - Depends on gas chemistry
- Weekly Maintenance
  - Clean load cassettes, shuttle arm
  - Chamber leak rate
- Monthly Maintenance
  - Chamber inspection/clean
  - Gas flow calibration
- Yearly pump maintenance

- Weekly Qualification
  - Blanket oxide etch



Plasmatherm 790

- Parallel plate system
- Configured with both etch and PECVD chambers
- Can handle any sample size up to 4”
  - Unclamped
- Mainly for etching silicon based dielectrics and organics

Plasmatherm 790

- Gases
  - SF_6
  - CF_4
  - CHF_3
  - O_2
  - Ar
  - H_2
  - He
- RF generator
  - 13.56MHz
  - Up to 500W
- Pressure Range
  - 5mT to 300mT

Plasmatherm 790

Capabilities

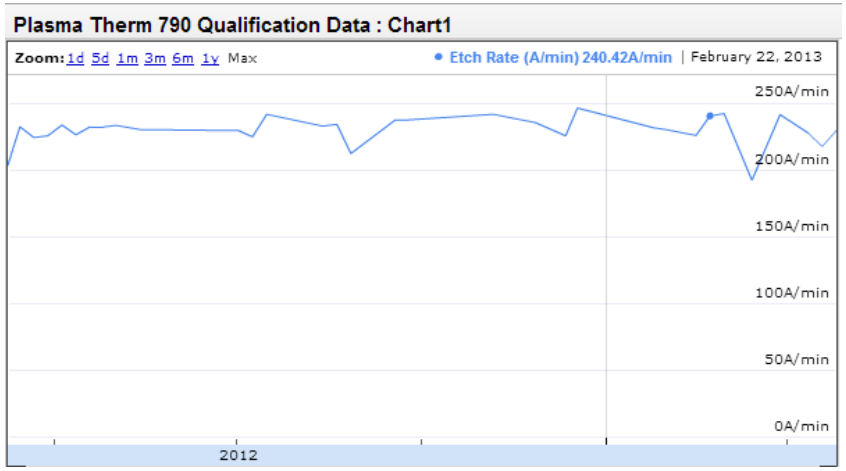
- LNF Supported Recipes
  - Oxide (250A/min)
  - Nitride (250A/min)
- Other processes
  - Polymer etching (parylene, polyimide, photoresist descum)
  - Polysilicon

Plasmatherm 790

Maintenance & Qualification

- O_2 clean run after each process
- Weekly maintenance
  - Chamber clean
  - Chamber leak rate
- Monthly maintenance
  - Gauge calibration
- Every 2-3 months
  - Chamber bead blasting

- Weekly qualification
  - Blanket oxide etch



Oxford Plasmalab 100

- ICP etcher designed for III-V materials
- Mechanical clamping of 4” wafer
  - Etch uniformity only 1 ½ inch diameter
  - Samples can be mounted to a carrier
- Cryogenic chuck
  - -150 – 350C

Oxford Plasmalab 100

- Gases
  - Cl_2
  - CH_4
  - H_2
  - O_2
  - Ar
  - BCl_3
- ICP coil
  - 600W
- Platen supply
  - 600W
- Pressure range
  - 2mT – 60mT

Oxford

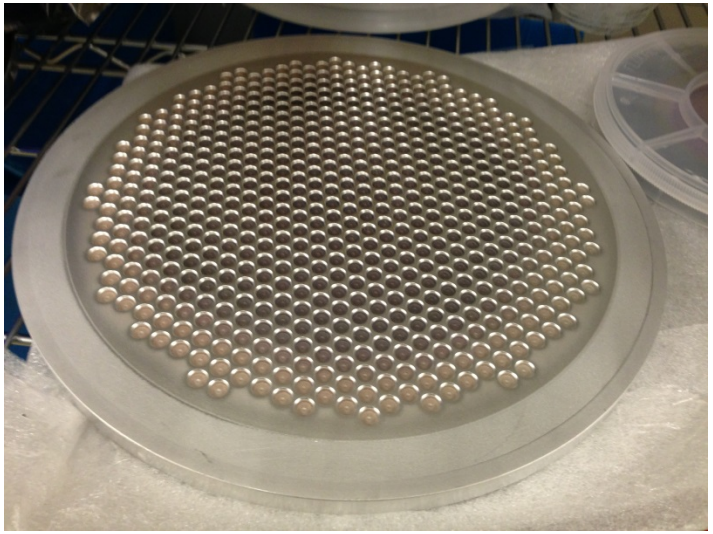
- Processes
  - Few lab supported recipes
  - Some recipes from Oxford
- Other capabilities
  - Anisotropic polymer etch (nanoimprint residual layer removal)
- Weekly maintenance
  - Chamber leak rate
- Monthly maintenance
  - Chamber inspect, clean
  - Gauge calibration

YES CV200RFS

- Downstream plasma system for organics etching
- Handles samples up to 8” diameter
- Sample thickness limited to ~2mm
- Can etch from 100s of A/min to over 1um/min

YES CV200RFS

- Gases
  - O_2
  - Ar
  - N_2
  - NF_3
- Heated chuck
  - Up to 250C
- Variable frequency RF generator
  - 35-45kHz
  - Up to 1000W



Upper electrode

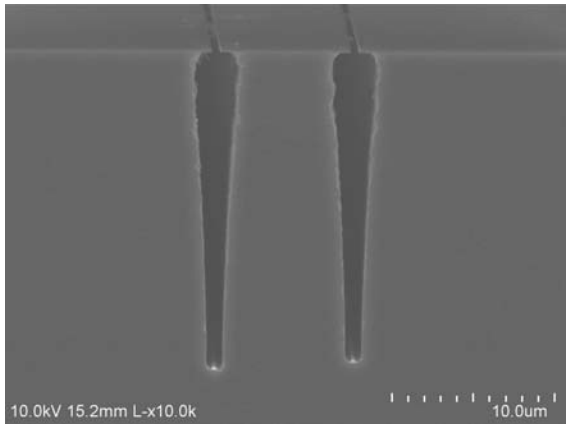
YES CV200RFS

Capabilities

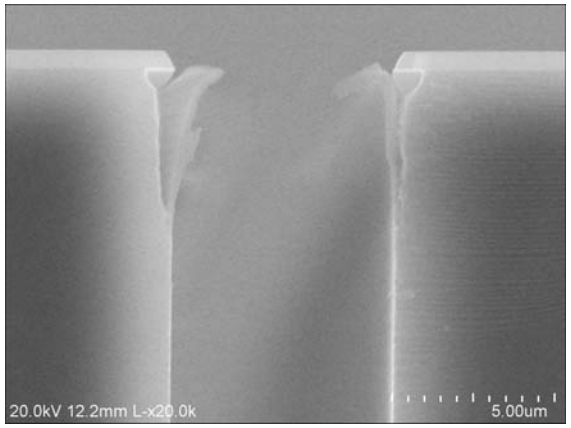
- Fast polymer stripping
  - 6000Å/min
  - 800W
  - 150°C
- Slow photoresist descum
  - 600Å/min
  - 100W
  - 60°C
- KMPR stripping
  - Several µm/min
  - 10% NF_3
  - Will etch oxide slowly
- Fluorocarbon removal
  - High temperature necessary

Fluorocarbon Removal

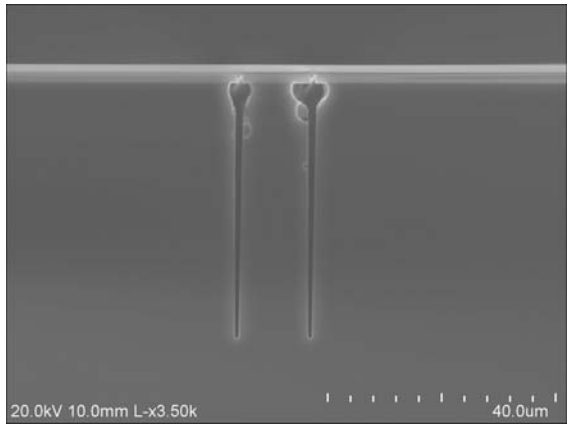
- Significant testing done to remove FC after RIE etching (particularly Bosch process DRIE)
- YES is the best way to do it
  - Likely due to the heated chuck
- Tested using XeF_2 etch



YES CV200RFS



STS Pegasus

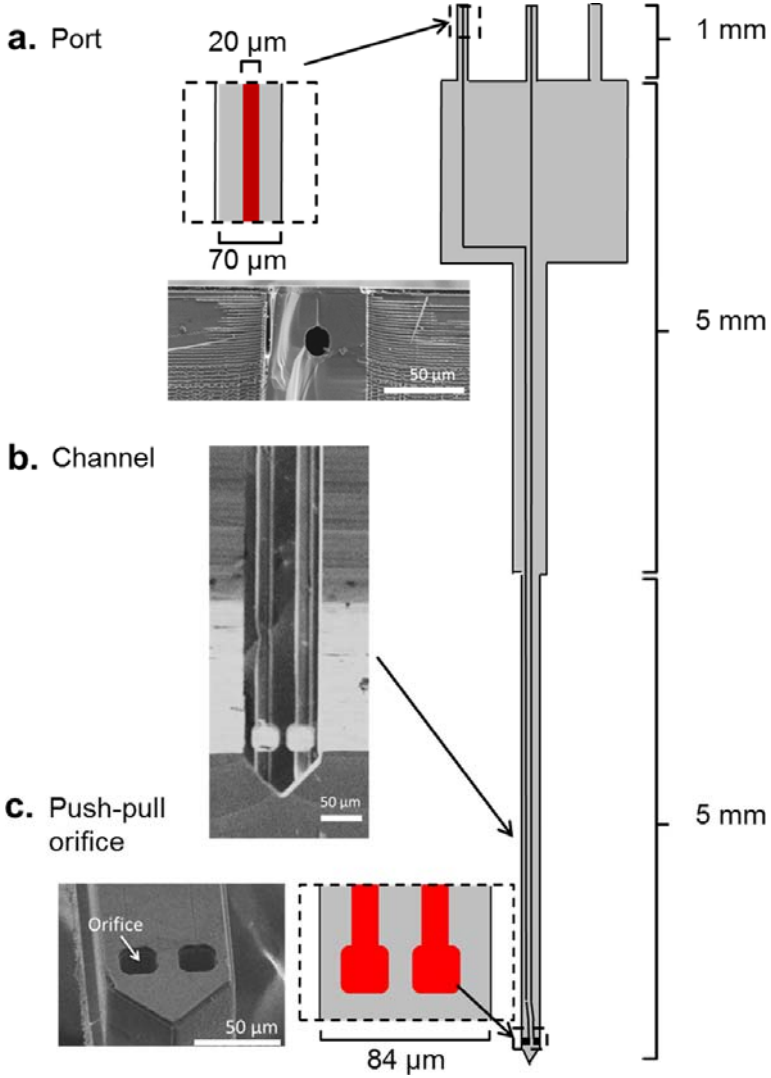


LAM 9400

Xactix Xetch

- XeF2 etch system
- Very high selectivity etching of Si, Mo, Ge
- Gases
  - XeF_2
  - N_2
- Up to 6” wafers
- Pressure range 1-5T
- Can be used for device release
  - Can undercut layers as thin as 20nm
  - Can undercut mm’s deep
- Very nonuniform

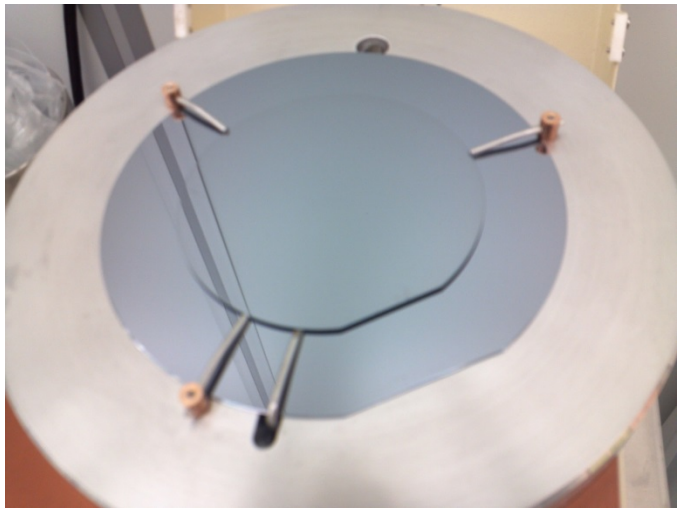
Xactix Xetch



W. H. Lee, et al. *Analytical Chemistry*. 85, 2013.

Wafer mounting

Mounting Material	Temperature Range	Removal	Thermal Conductance	Material Compatibility
Crystalbond 555	< 50°C	DI, PRS2000	OK	Reacts with PR
Crystalbond 509	< 120°C	Acetone	OK	Reacts with PR
Santovac 5		Acetone	Good	Reacts with PR
PFPE		IPA (nonsoluble)	Poor	
Photoresist		PRS2000, Acetone	Poor	
KMPR	< 300°C	Remover PG	Good	
WaferBond CR200		Xylenes, Acetone, IPA	OK	



Future Tools/Projects

- P5000 RIE system
- Etch process characterization
- Glass etcher redesign
  - Deep, also nanoscale FS, oxide
- Better nanoscale etch support
  - Nanoimprint lithography

P5000 RIE System

- Three chambers
  - One for polysilicon
  - Two for dielectrics
    - One configured for DLC deposition
- Configured for 6” wafers
  - Electrostatic chuck, normally at 40°C
- Fast etch rates seen

Etch Process Characterization

- We currently lack extensive process data for many of etch recipes used
- It is vital that we improve in this area
  - Improve user experience
  - Increase our own knowledge
- How can we achieve this?

Etch Process Characterization

Etched Material

- …Needed
  - Etch rate
  - Sidewall profile
  - CD loss
  - Uniformity
  - Repeatability
- There are a lot of materials
  - And a lot of “duplicates”
  - But they may behave differently

Masking Material

- We need
  - Bulk material etch rate
  - “Effective” etch rate
- Again, there are a lot of masks to choose from