NNCI ETCH WORKSHOP - STANFORD NNCI PLASMA ETCH OVERVIEW

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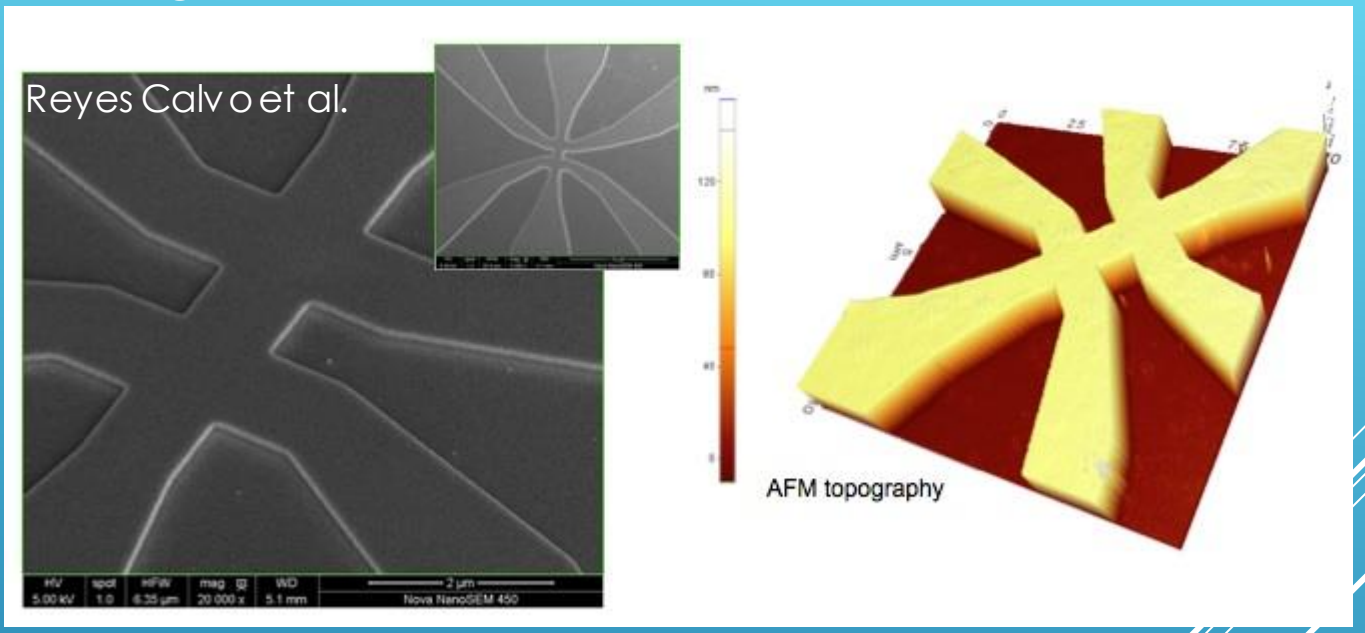
NNCI AT STANFORD

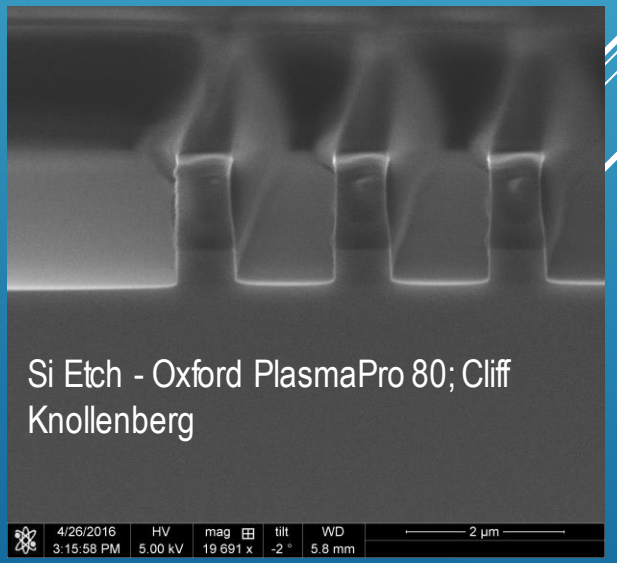
- Four labs under NNCI Umbrella at Stanford –
  - SNSF – Stanford Nano Shared Facilities (Nano characterization lab, Nano patterning lab, Ginzton Microfab, Soft and Hybrid Materials Facility)
    - Limited etch capability in the Nano patterning cleanroom – Oxford PlasmaPro 80 and Intlvac Ion Mill
  - SNF – Stanford Nanofabrication Facility (main clean room + two satellite sites – MOCVD & Experimental Fabrication Labs) – Plasma Etch Equipment in the main cleanroom
  - MAF – Mineral Analysis Facility
  - EMF – Environmental Measurement Facility
- Devices developed –
  - Semiconductors, Memory, Solar cells, Optoelectronics, MEMS, bio-MEMS, Microfluidics and more

DRY ETCH EQUIPMENT AT SNSF

- Intlvac Nanoquest Research Ion Beam Milling System
  - 4” water cooled rotating stage; 4” wafers to pieces
  - Ar milling of any material
  - https://snsf.stanford.edu/equipment/fab/ionmill.html
- Oxford PlasmaPro 80 RIE Etcher -
  - Pieces to 8” wafers; no load lock; flexible group
  - SiO2, SiN, Si, etches - CHF3, CF4, SF6, Ar and O2
  - https://snsf.stanford.edu/equipment/fab/etcher.html

HgTe Quantum Well Structures – Ion Mill Etch





DRY ETCH EQUIPMENT AT SNF

- List of equipment: https://snf.stanford.edu/SNF/equipment/dry-etching
- Over 15 dry etch equipment at SNF and they can be grouped in many different ways
  - Clean/ semi-clean Vs flexible
    - Clean / Semi clean - Restricted to CMOS compatible materials
    - Flexible – Not restricted; however, some restrictions apply based on chemistry, material compatibility, or memory effect.
  - Chemistry / etched materials dependent -
    - Chlorine chemistry Vs fluorine chemistry
    - Si etchers, silicon dioxide etchers, metal etchers, III-V etchers, deep Si etchers, plasma strip tools etc..
  - Based on plasma type
    - CCP, ICP, ECR or remote plasma
  - With or without load lock
  - Ability to handle varying substrate sizes

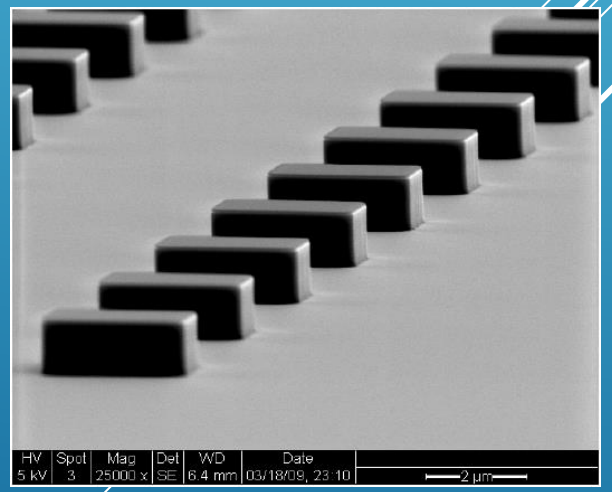
ETCHER SELECTION FOR PROCESSING

- Managing the demand for new materials and chemistries Vs preserving process reproducibility is always challenging
- Impact of chamber memory effect on subsequent processing can be minimized by –
  - Plasma clean and condition
  - Chamber wet clean
  - Replacing some critical parts
- PROM committee (Process or Materials Review) reviews requests for processing new materials and proposes the guidelines
- Etched materials leave behind contaminants in the tool which can be transferred to subsequent wafers processed
  - This is especially a serious issue if the wafers processed through contaminated tools go through further high temp processing
  - However, during etching the contaminants are present mainly at the surface of the substrate and can be removed by subsequent cleans.
  - PROM committee also reviews these type of requests and comes up with a protocol to avoid potential cross contamination.

DRY ETCH EQUIPMENT AT SNF - CLEAN/ SEMI CLEAN

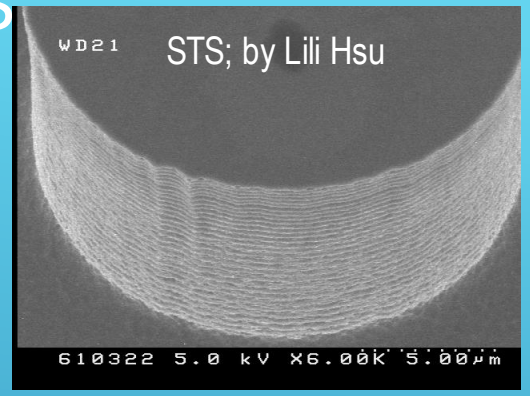
- Lam 9400 –
  - ICP etcher; 4” wafers only
  - Poly Si gate, Si trench, isotropic Si etch etc..
- AMAT P5000 –
  - Three chamber cluster tool; ccp etcher; all chambers semi-clean; 4” wafes only
  - One chamber is for SiN, SiO2 etching (fluorocarbon etches); one for poly Si / gate etching (Cl2/HBr); third chamber for Al etching (Cl2/ BCl3)
- AMT8100 –
  - Hexode etcher; CCP ether; up to 24 wafers can be processed in a batch
  - Used typically for etching shallow contact/ via, alignment marks, anisotropic Si etch etc..
  - 4” wafers only – pieces need to be attached to the 4” wafers
  - Planning to fit a 6” wafer hexode (18 wafers) with a couple of trays modified for 4” wafers.
- Drytek 100 –
  - CCP; 6 wafers (trays per batch); four of which are dedicated for clean/ semi-clean wafers
  - Can process up to 6” wafers; available gases SF6, CF4, O2, CHClF2
  - Processes – Poly Si, Si, resist, descum, W, Ti, SiN and SiO2 etches
- Gasonics Aura 1000 Asher

Lam 9400 – Isotropic and Anisotropic Etches



DRY ETCH EQUIPMENT AT SNF – DEEP SI ETCHERS

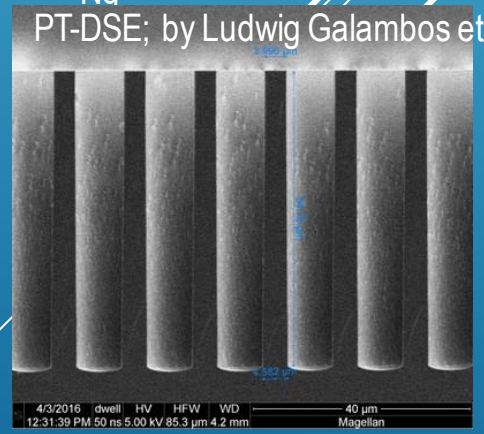
- Deep Si Etch –Bosch process
  - STS Etcher – ICP Etch
    - Older generation process; semi-clean
    - 4” wafers
    - Si Etch rate up to 5um/min
    - ~60:1 selectivity to resist and 100:1 selectivity to SiO2/ SiN
  - STS Multiplex Pro ASE HRM – ICP Etch
    - Next generation tool; Semi-clean (down; device-net issues)
    - Faster etch (~17um/min); better selectivity to resist >200:1
    - Scallop width ~0.2um; Better for SOI process
  - PlasmaTherm –DSE – ICP Etcher
    - 4” or 6” wafers; flexible group
    - Fast etch ~10um/min; >100:1 sel to resist & 200:1 selectivity to oxide
    - Scallops can be reduced to less than 30nm
    - SOI process available



STS; by Lili Hsu

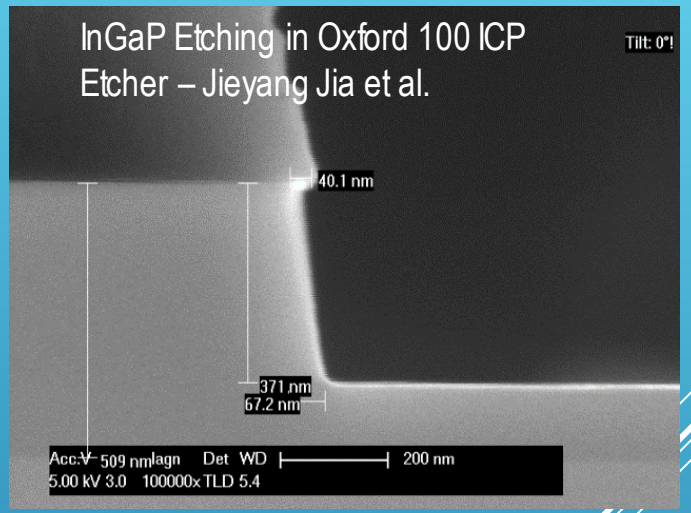
STS HRM; Courtesy Edwin Ng

PT-DSE; by Ludwig Galambos et al



DRY ETCH EQUIPMENT AT SNF – III-V ETCHERS

- Oxford Plasma Pro 100 ICP Etcher
  - ICP Etcher for III-V Etches
  - 4” configuration; load locked
  - Available gases – Cl2, BCl3, HBr, Ar, CH4, H2, O2, N2, SF6
- PQuest ECR Plasma Etcher
  - 4” substrate; load-locked
  - Available gases – Cl2, BCl3, O2, N2, Ar, SF6
  - Flexible group; III-V etches and other metal etches.
  - Can go up to 200C (with no coolant circulation)

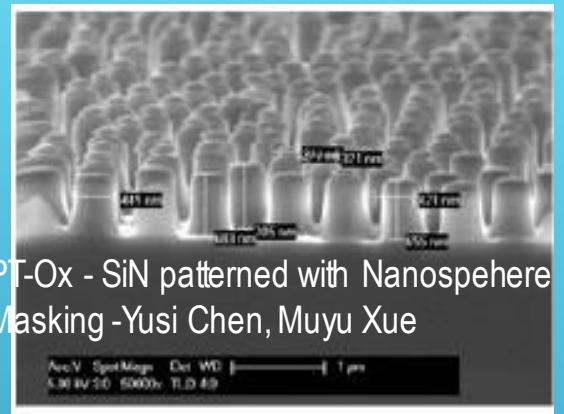


DRY ETCH EQUIPMENT AT SNF – FLEXIBLE GROUP METAL AND DIELECTRIC ETCHERS

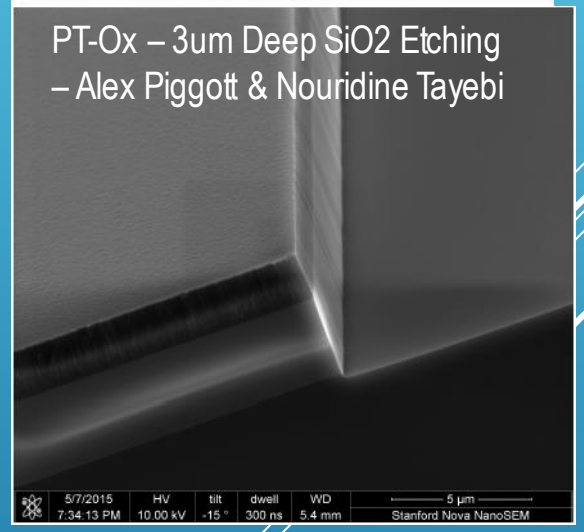
- PlasmaTherm Versaline Metal Etcher
  - ICP etcher, load locked
  - 4” or 6” substrates; flexible group
  - Available gases – Cl2, BCl3, CF4, Ar, CH4, O2, N2, SF6
  - Metals, metal oxides, Si etc.

- Plasma Therm Versaline ICP Oxide Etcher
  - ICP etcher; load locked;
  - 4” or 6” substrates; flexible group
  - High aspect ratio SiO2 etching, contact, via etches, SiN, SiC, poly imide etc.
  - Available gases – CHF3, CF4, C4F8, H2,O2, N2, Ar, He

- Oxford Plasma Pro 100 CCP Etcher
  - CCP Etcher; load locked
  - 4” configuration; load locked
  - SiO2, SiN, Si, resist, SiC etches
  - Available gases – CF4, CHF3, O2, SF6, Ar, N2
  - Plan to include 6” and 8” capability and processing without clamp.



PT-Ox - SiN patterned with Nanospehere Masking -Yusi Chen, Muyu Xue



PT-Ox – 3um Deep SiO2 Etching – Alex Piggott & Nouridine Tayebi

DRY ETCH EQUIPMENT AT SNF – OTHER ETCHERS

- MRC Model 55 RIE Etchers
  - Flexible group, direct load
  - Pieces to 6” substrate
  - O2, Ar / SF6, CHClF2 (Freon 22) / CHF3
  - Diffusion pump; process pressure can get to <10mT
  - Used for etching as well as sputtering
- Drytek 100, modified
  - Modified Drytek 100 system for single 4” wafer
  - Flexible group
  - Available gases – CHF3, O2, Ar, C2F6, SF6
- Matrix Plasma Strip
  - Down stream plasma
  - 4” wafers; flexible group
- Xactix – XeF2 etch
  - Pieces - 6” wafers
  - Isotropic Si etching

SUMMARY

- Variety of equipment serving the needs of researchers from various departments at Stanford, other academic institutions, government funded labs and industry.
- Stanford, under NNCI umbrella satisfies the unique need of researchers and startups for process expertise as well as equipment to enable successful evaluation of new technologies.
- Devices include Semiconductors, Memory, Solar, Optoelctronics, MEMs, Bio devices, Microfluidics and others.
- Lab is also used for teaching courses at Stanford.
- Students as well as other lab members share some of their characterization data to enrich the wiki library.
- Student helpers are utilized to run equipment qualifications.
- Continuous improvement efforts are ongoing to better utilize equipment and push their limits to meet the changing needs of researchers.
- Contamination protocols are evaluated whenever needed to accommodate new materials and interdisciplinary research.