ASU NanoFab - Etch Capabilities

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List of Etch Tools

- ICP
  - STS Advanced Silicon Etch, STS All General Etch, Plasma-Therm Apex SLR
- RIE
  - Oxford Instruments Plasmalab 80+ (2), Plasma-Therm 790
- Ashers
  - Tegal Plasmaline 411 and 412
- Vapor Etch
  - XeF2 Xactix e1

ICP - STS Advanced Silicon Etch

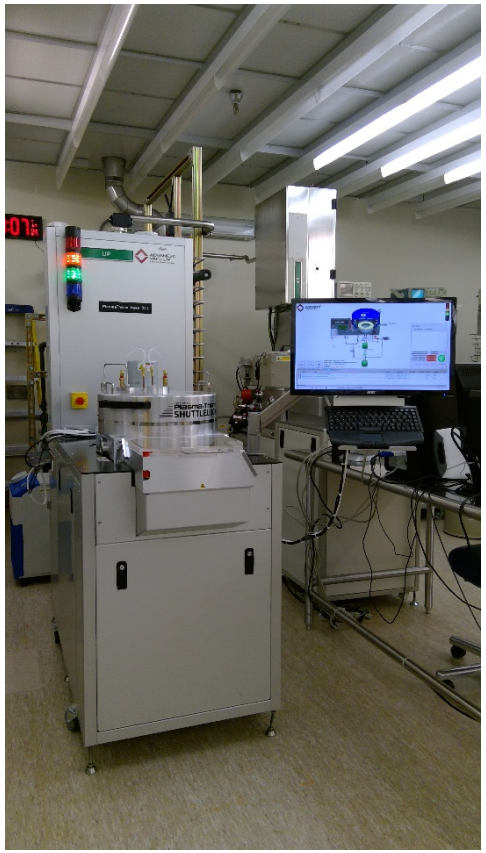
- Installed 2002
- Deep silicon etching using the Bosch process
- SF_6, C_4F_8, Ar, O_2
- 100 mm tool
- Backside helium cooling
- 10:1 easily repeated aspect ratio
- 20:1 maximum aspect ratio
- Selectivity to photoresist is ~50:1
- Selectivity to thermal SiO_2 is ~100:1
- Super-user tool
- No exposed metal

ICP - STS All General Etch

- Installed 2002
- STS ICP dedicated to chlorine etching
- BCl_3, Cl_2, CH_4, H_2, O_2, Ar
- 100 mm tool
- Backside helium cooling
- Used for etching of III-V compounds and dielectrics such as Al_2O_3

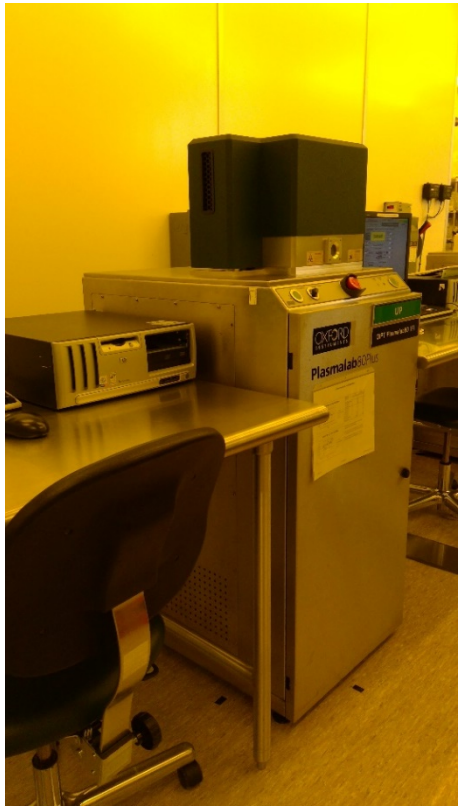
ICP - Plasma-Therm Apex SLR

- Installed 2016
- Tool dedicated to chlorine etching.
- 150 mm tool
- Backside helium cooling
- Used primarily for etching of III-V compounds
- BCl_3, Cl_2, O_2, Ar, N_2



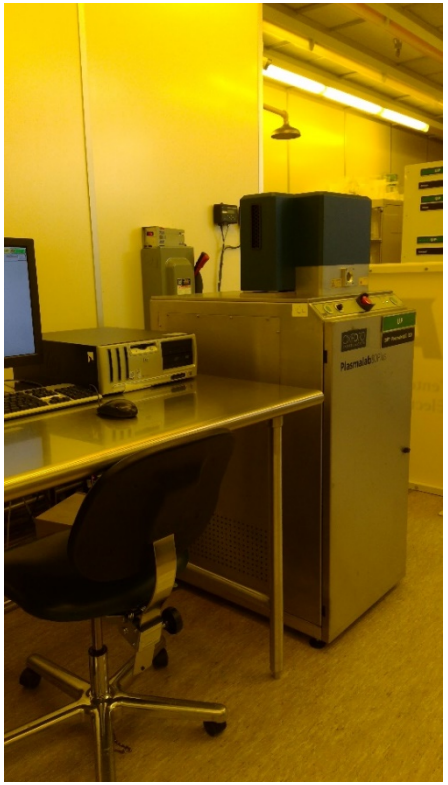
RIE - Oxford Plasmalab M80+ (F)

- Installed 2004
- Tool dedicated to fluorine etching
- SF_6, CHF_3, CF_4, O_2 Ar
- Can handle up to 200 mm wafers
- Used for etching of silicon, SiO_2, Si_3N_4, quartz and diamond



RIE - Oxford Plasmalab M80+ (Cl)

- Installed 2004
- Tool dedicated to chlorine etching.
- BCl_3, Cl_2, N_2, CF_4, O_2, Ar.
- Can handle up to 200 mm wafers.
- Used primarily for etching of III-V's, dielectrics and metals



RIE - Plasma-Therm PT790

- Installed 2015
- RIE tool dedicated to fluorine etching
- Up to 200 mm wafers
- Used primarily for etching of silicon, dielectrics, metals and organics
- SF_6, CHF_3, CF_4, O_2 Ar

Vapor Etch - Xactix e1

- Installed 2008
- Dry vapor phase etch system
- Etch gas is XeF_2
- Can handle up to 100 mm wafers
- Used for deep isotropic etching of silicon

Future Wish List

- Short term – general purpose F-based ICP to replace Oxford Plasmalab 80+
- Longer term – DRIE with 150 mm capability

Recent Project Highlights

- ICP isotropic etch of silicon microwells
- RIE etching of diamond to fabricate PIN and BJT
- RIE etching multilayers – Stellar Coronagraph
- SPC efforts

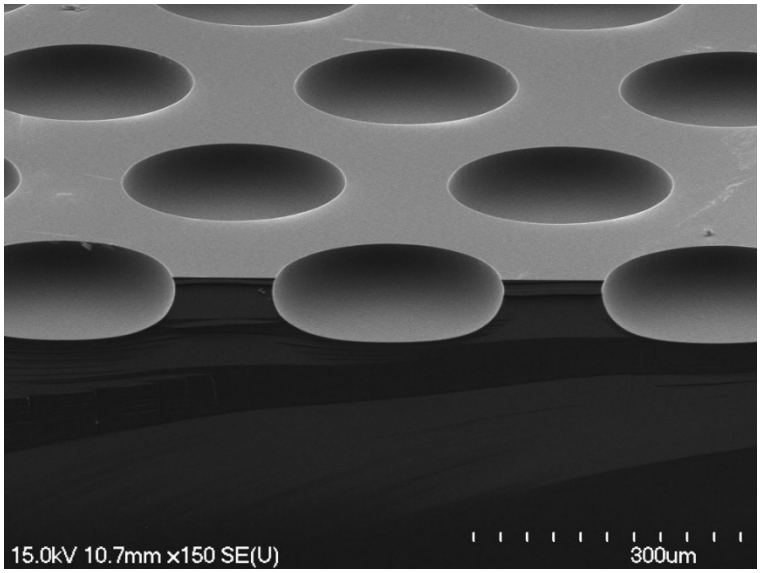
ICP - Isotropic Deep Silicon Etching

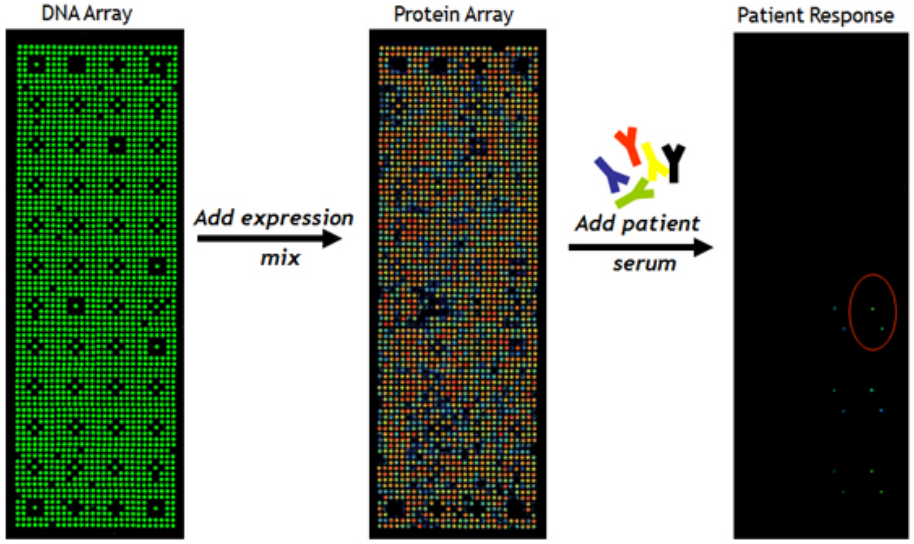
- Isotropic etching performed with multiplexing turned off
- SF_6 with high process pressure.
- Microwells are etched in silicon - used for Nucleic Acid Programmable Protein Arrays (NAPPA) by researchers at ASU BioDesign Institute
- NAPPA is used to identify/characterize proteins in medical diagnostics
- http://cpdlab.biodesign.asu.edu/research/HighDensityNAPPA.html
- Fabricate two 1 inch x 3 inch 'microscope' slides per 4-inch silicon wafer
- The slides are re-useable after wet chemical cleans
- Plasma etched microwells have better overall performance (fluorescence response) than the previously used wet chemistry approach

ICP - Isotropic Deep Silicon Etching

"Microwells" Etched Into Silicon Slide

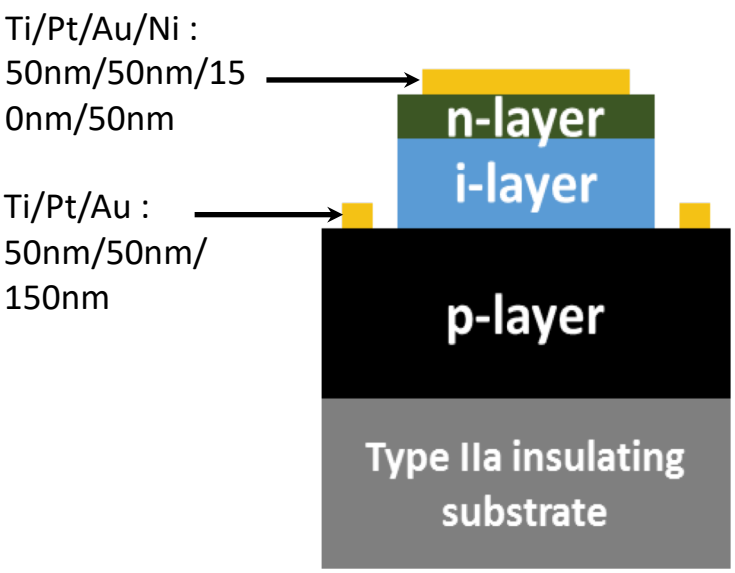
http://nappaproteinarray.org/





Diamond PIN Diode

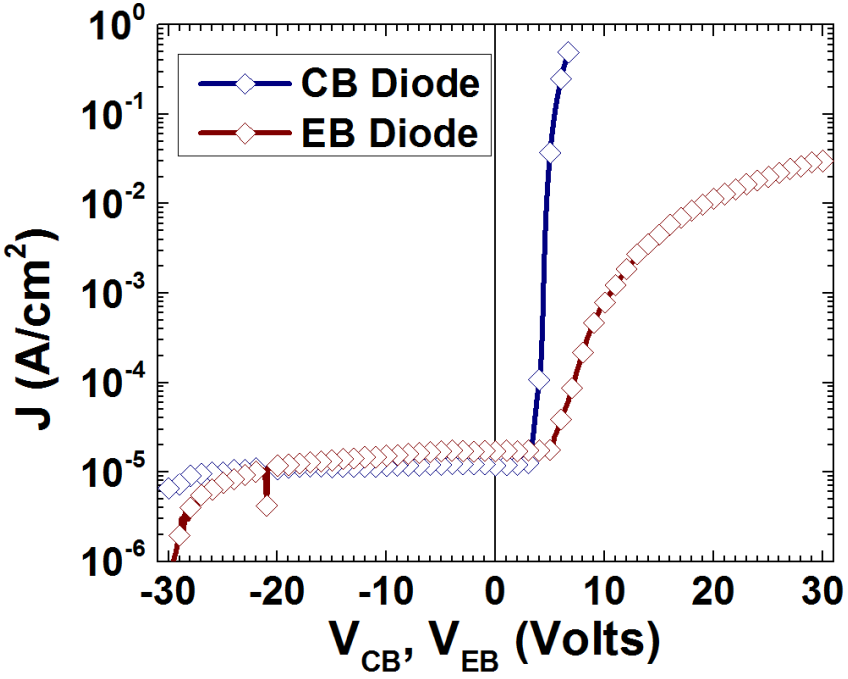
M. Dutta et al, IEEE Electron Device Lett., vol 37, No.9 pp1170-1173 (2017)

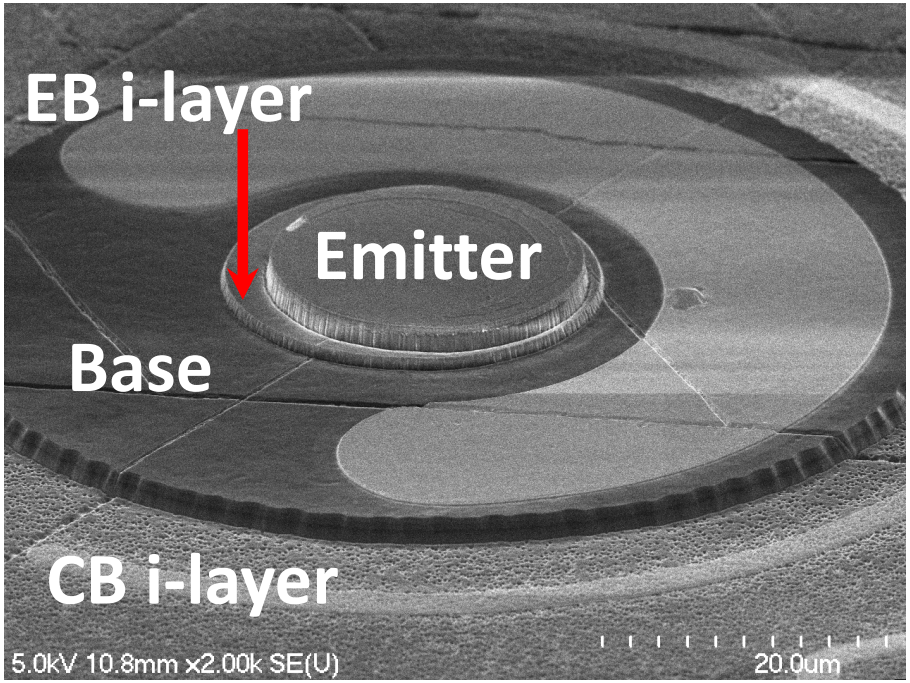


- Homoepitaxial diamond growth (100) and (111) orientated substrates by microwave plasma enhanced CVD
- B and P doping
- Diodes fabricated using conventional mesa etch approach.
- Diamond etched in Oxford Plasmalab M80 (F) using SiO_2 hard mask.
- O2, SF_6
- Best breakdown voltage - 3.9 MV/cm in (111) diamond
- Limited by hopping conduction c/o threading dislocations

Diamond Bipolar Junction Transistor

(Courtesy of Maitreya Dutta, UC Davis)





- Partial mesa etch on both E-B and C-B diodes showed rectification with a on:off ratio of 10^3 at ±30V.
- Low forward current density of E-B diode attributed to current crowding.
- Presence of possible defect states within the bandgap in E-B i-layer increases the ideality factor (>30).
- No modulation or gain is observed in 3-terminal measurements (also because of high series resistance of base).

RIE - Multilevel Shallow Silicon Etching

- Project: Fabrication of a Stellar Coronagraph
- PI: Justin Knight and Oliver Guyon, University of Arizona
- A phase shift mask that leads to destructive interference to suppress starlight to image nearby, faint planetary companions or exoplanets
- Ultimately to be installed on the Subaru Telescope on Mauna Kea, Hawai'i
- A total of 5 photo and etch steps - results in 16 discrete levels
- GCA 8500 stepper used for lithography steps
- Plasma-Therm PT-790 RIE used for shallow etches
- CF_4/Ar with low process power.
- J.M. Knight et al., Proceedings of SPIE, Vol. 10400, pp104000N1-N11, (2017)

RIE - Multilevel Shallow Silicon Etching

Mask Features

~295 µm diameter hexagonal tiling
1237 hexagons
9.10 µm hexagon diameter
16 discrete depths

Etch Depths

1st exposure: 0.4828 µm

2nd exposure: 0.2414 µm

3rd exposure: 0.1207 µm

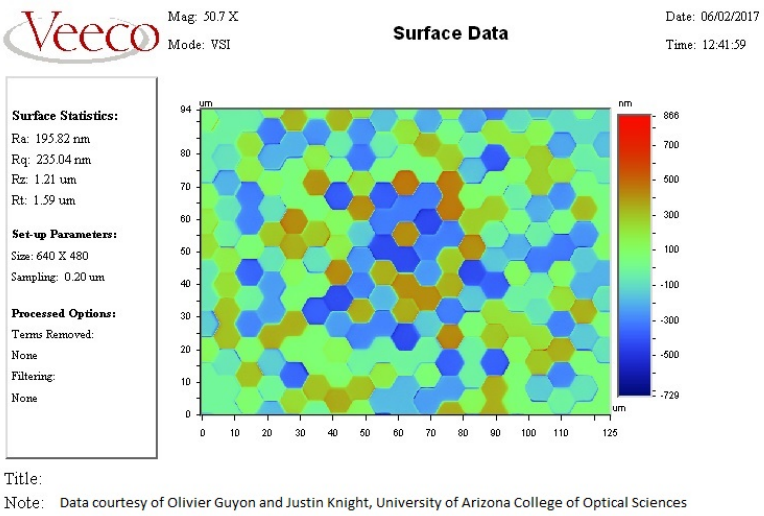
4th exposure: 0.0603 µm

5th exposure (Bipolar*): 0.4504 µm

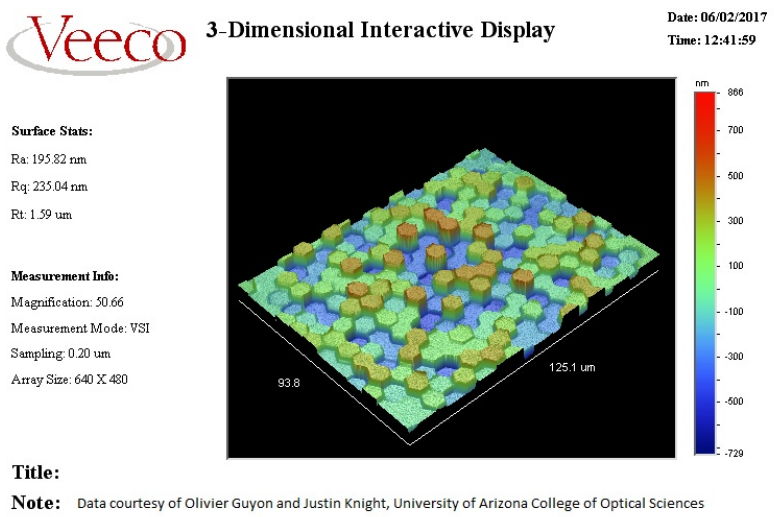
*Bipolar etch changes the mask zero depth reference from the top of the substrate to the midway point of the etch depths.

RIE - Multilevel Shallow Silicon Etching

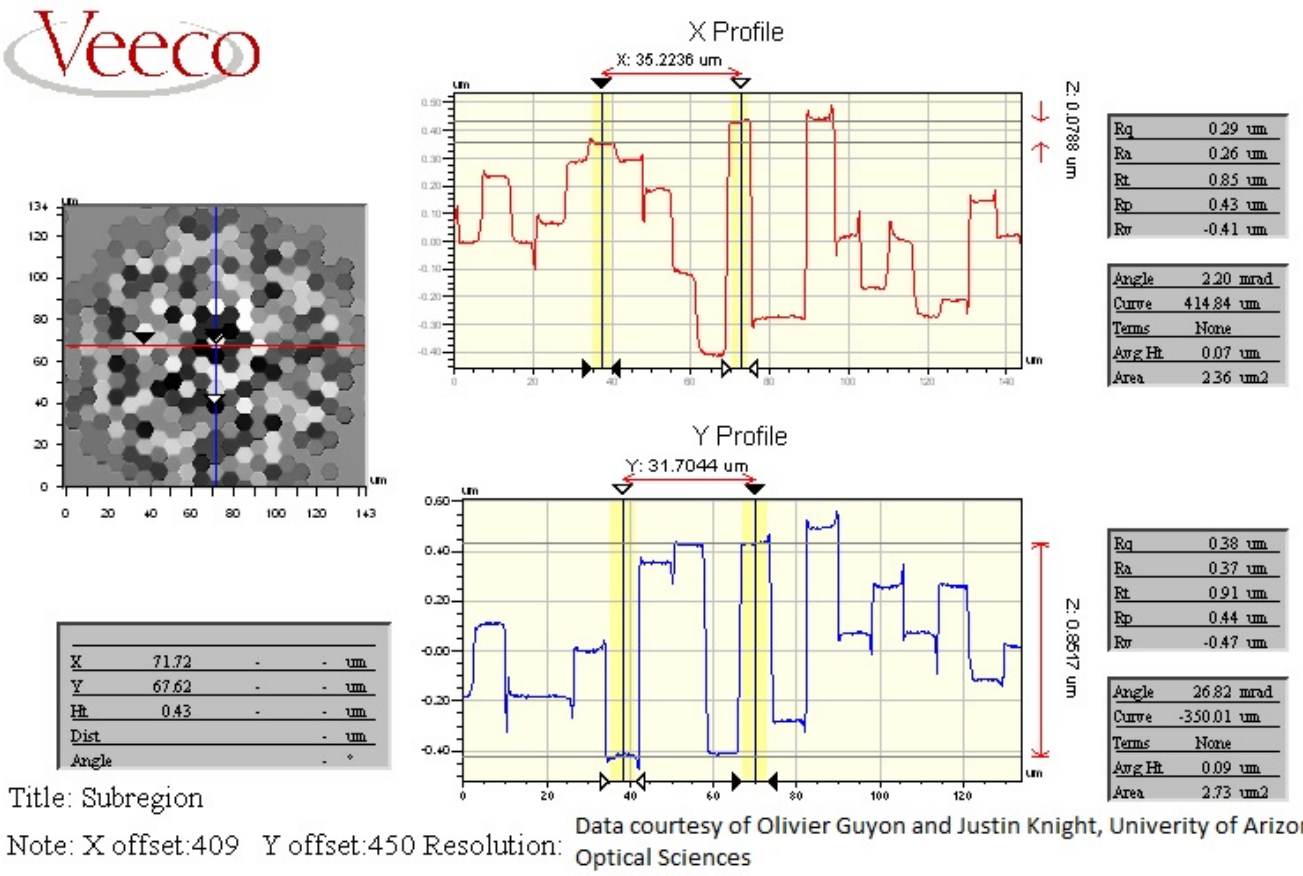
2D Surface Profile of Coronagraph



3D Surface Profile of Coronagraph

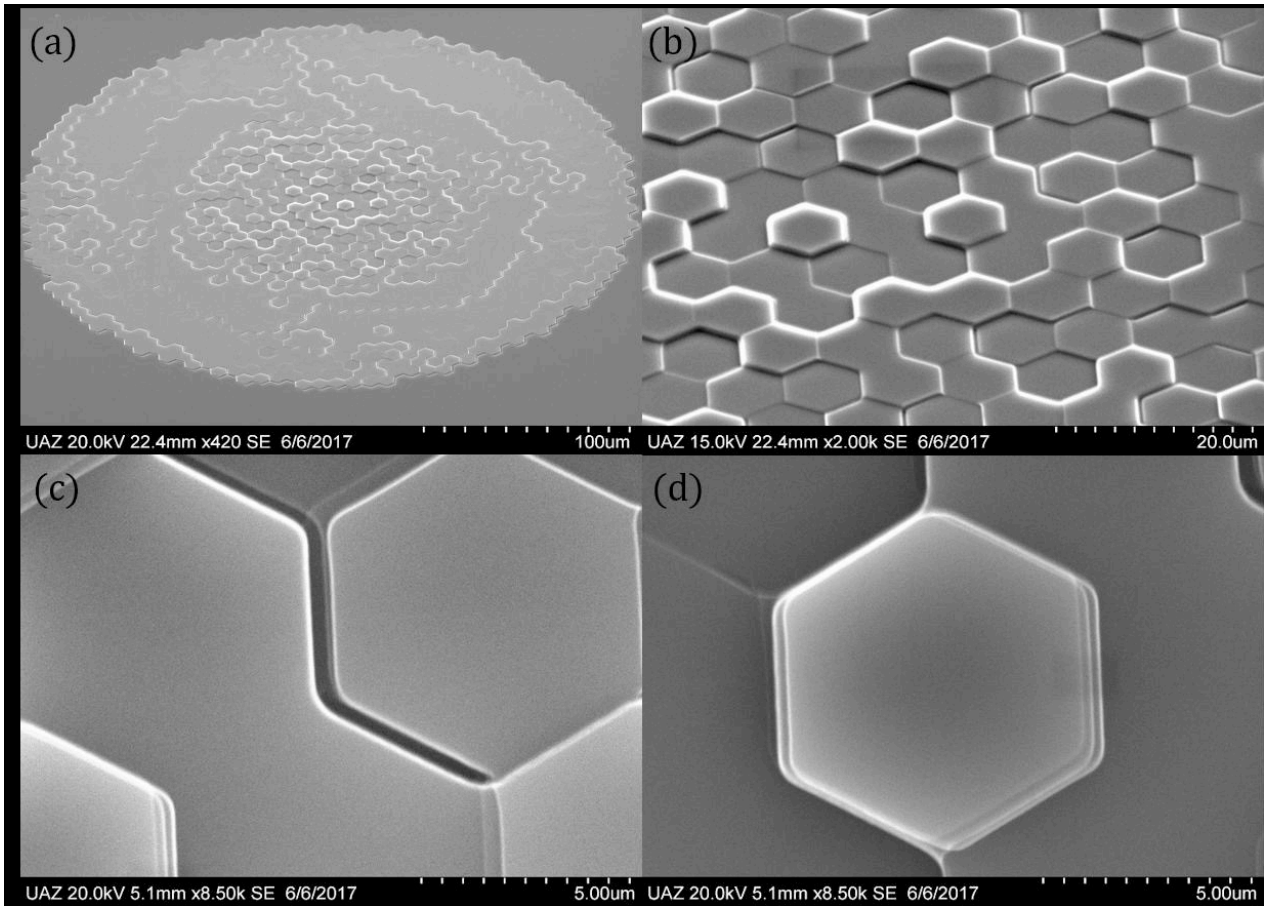


RIE - Multilevel Shallow Silicon Etching



Data courtesy of Olivier Guyon and Justin Knight, Univerity of Arizona College of Optical Sciences

RIE - Multilevel Shallow Silicon Etching

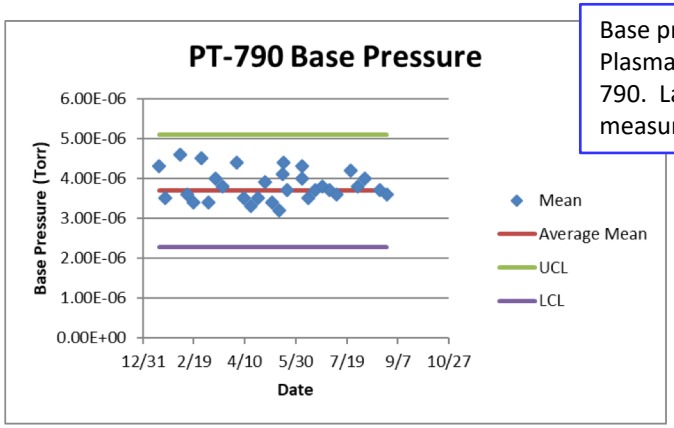


Statistical Process Control

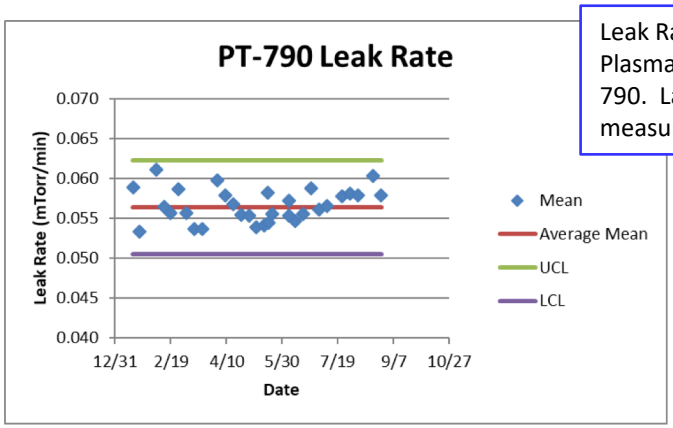
- Statistical process control is now being implemented on the etch tools.
- Typically, both machine and process parameters are monitored.

- Machine Parameters
  - Base pressure
  - Leak rate
  - MFC flow rates
  - Pumping speeds
- Process parameters
  - Etch rates
  - Process pressure
  - Process power
  - MFC flow rates

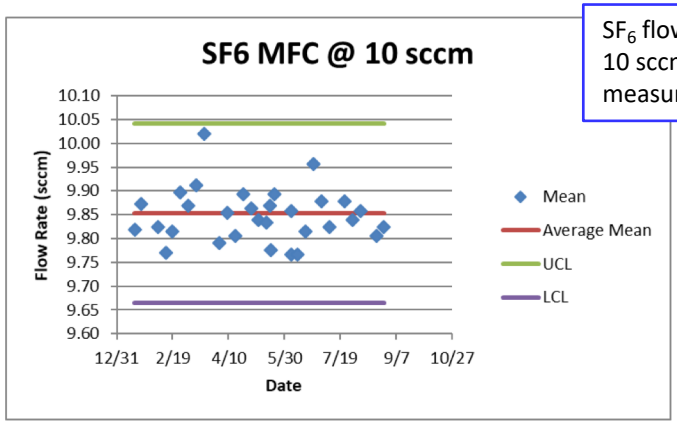
Typical Machine Parameters



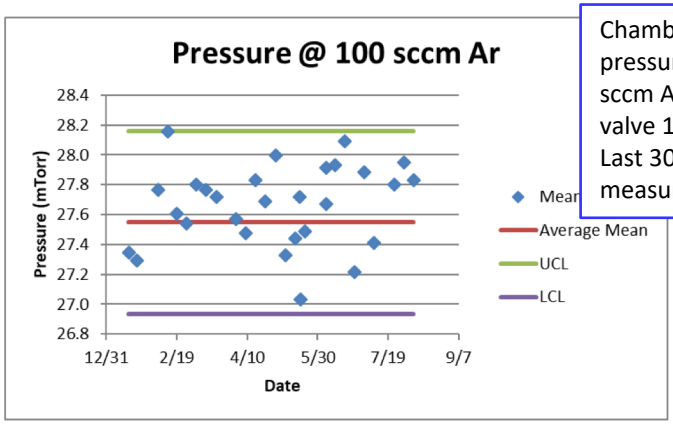
Base pressure for Plasma Therm 790. Last 30 measurements.



Leak Rate for Plasma Therm 790. Last 30 measurements.

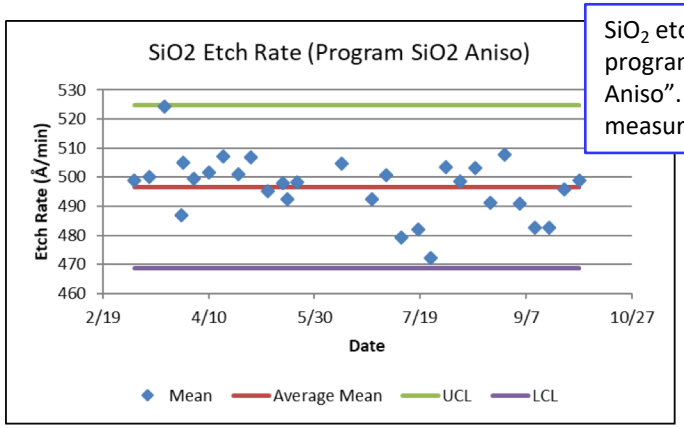


SF_6 flow rate @ 10 sccm. Last 30 measurements.

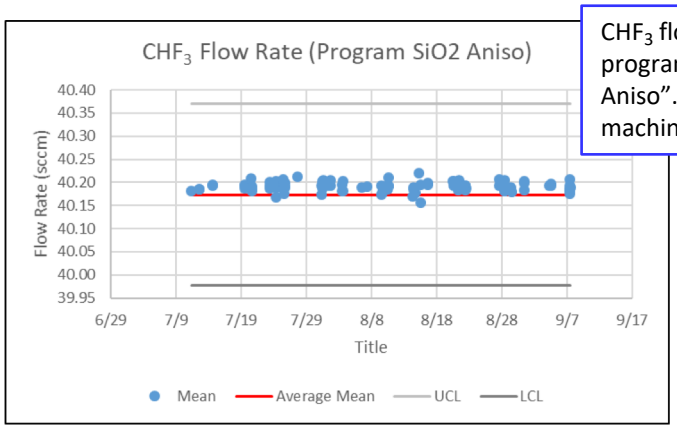


Chamber pressure at 100 sccm Ar. Throttle valve 100% open. Last 30 measurements.

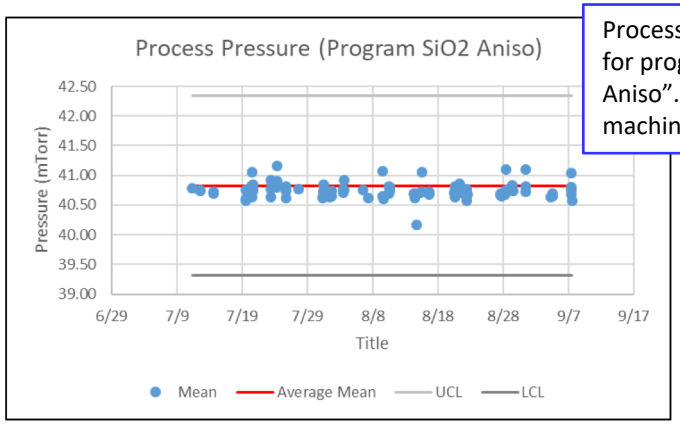
Typical Process Parameters



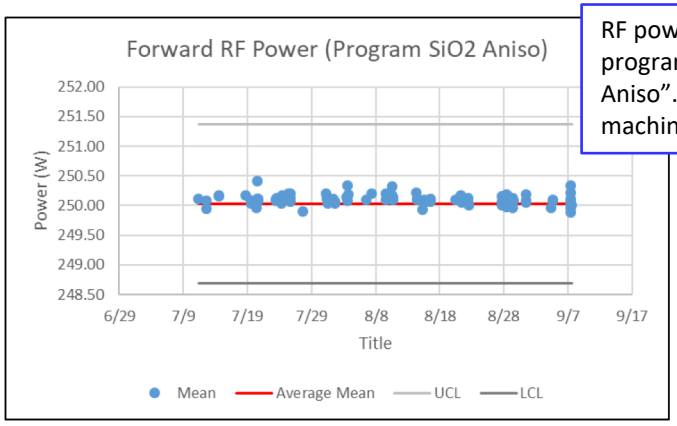
SiO_2 etch rate for program "SiO2 Aniso". Last 30 measurements.



CHF_3 flow rate for program "SiO2 Aniso". Last 100 machine runs.



Process pressure for program "SiO2 Aniso". Last 100 machine runs.



RF power for program "SiO2 Aniso". Last 100 machine runs.