Defect Mitigation and Reduction in EUVL Mask Blanks

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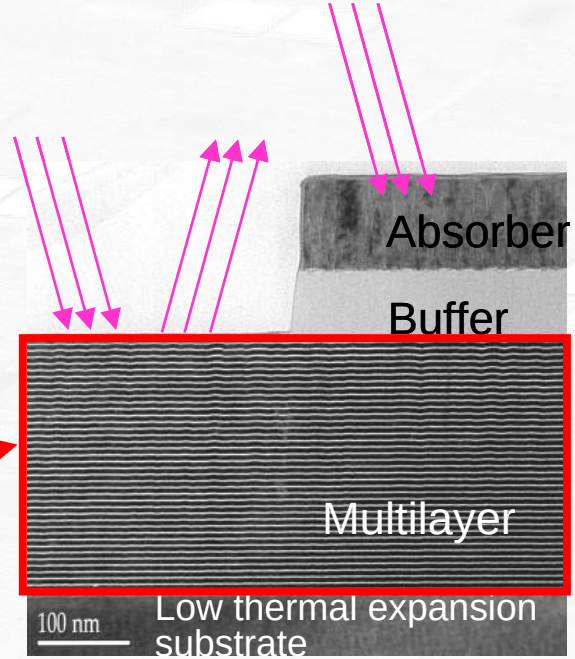
2006 EUV Symposium, Barcelona

EUV Mask Technology

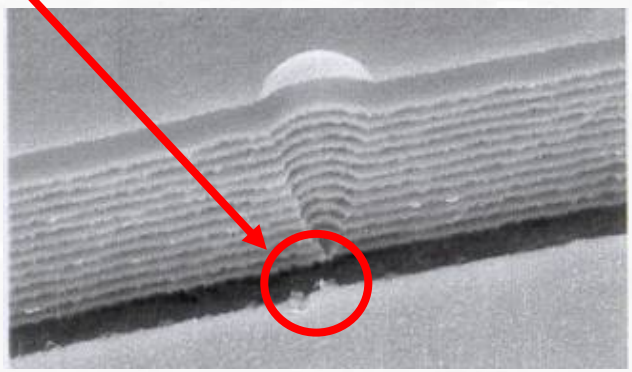
- Masks must be extremely flat and defect free
- Major development effort on EUV mask blanks at SEMATECH North

EUV mask

MBDC Focus



EUV mask construction



Defect in multilayer

TEM courtesy of AMD

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SEMATECH Mask Blank Development Center (MBDC) Strategy

- Joint development agreement with a supplier (Veeco) to develop a low defectivity deposition tool and process for EUVL blank production at the SEMATECH (Albany, NY) facility.
  - Perform defect and root cause analysis, and improve the tools and processes to meet the final specification
- Work with substrate and blank suppliers to drive the technology to produce low defect substrates and ML coated blanks.

Industry Defect Goals (total mask blank defects)

- Pilot Line defect goal: >**0.01 defect/cm^2 @ 40 nm** (2007).
- Long term (HVM) goal: **0.003 defect/cm^2 @ 25 nm** (2009).

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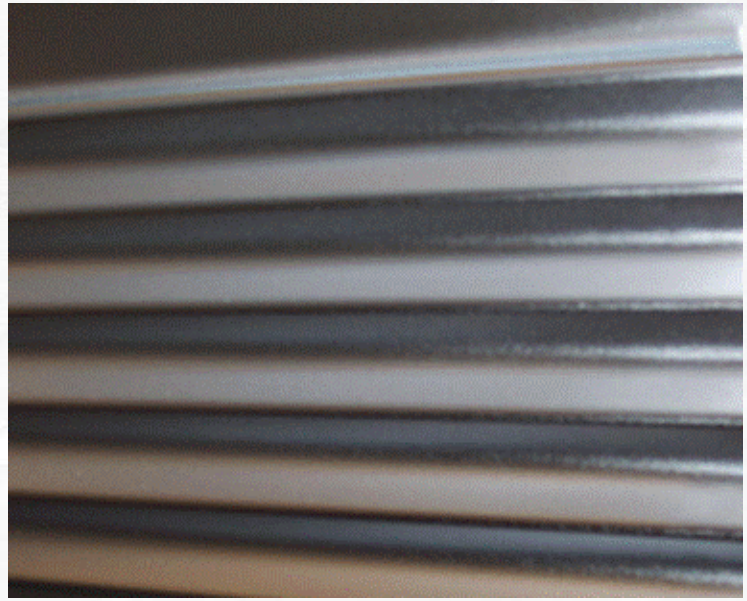
Several upgrades were implemented

1. Advanced shielding
2. Rotating target
3. Low profile fixture
4. New electrostatic chuck
5. Added smoothing chamber
6. Defect inspection capability increased

Advanced shielding reduces flaking in high deposition areas

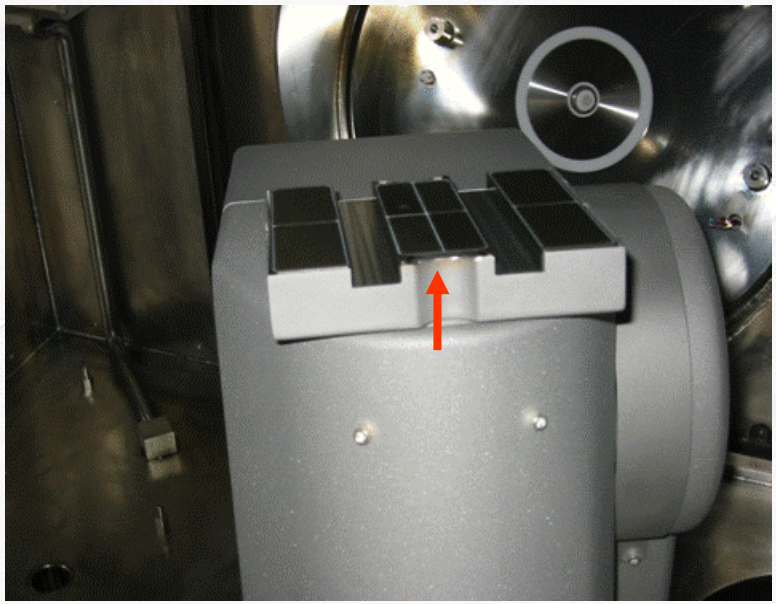
- Tailoring shield design to address problem areas.
  - Target areas with thick deposition
  - Shields designed to reduce flaking
- More production between PMs.

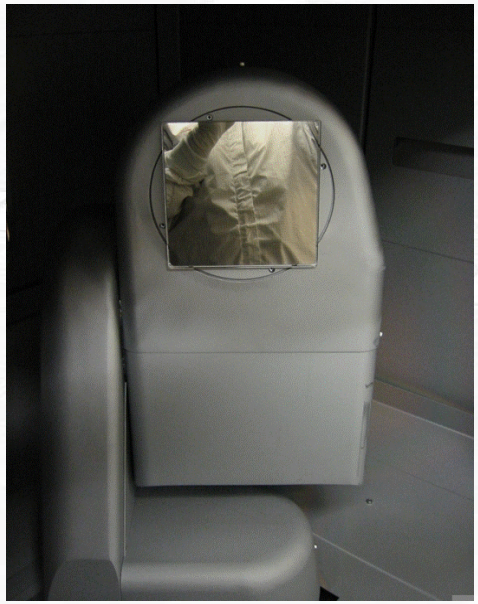


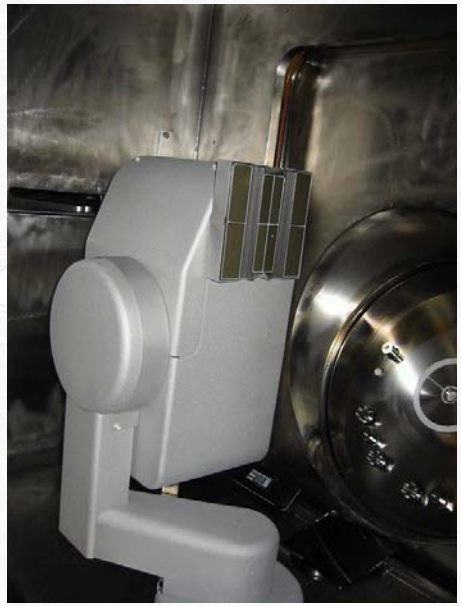
New target design for lower defects

- Target rotation:
  - More uniform target erosion
  - Less redeposition
- Better shielding of targets:
  - No deposition on unused targets
  - No flaking from target edge and fixture.

E-Chuck and low profile substrate Fixture







Upgraded E chuck

- Improved electrostatic chuck
- Upgraded substrate lift mechanism
- Improved substrate presence sensor

Standard Substrate Fixture → **Low profile Substrate Fixture**

- Reduces deposition capture in vicinity of substrate
- Reduced flaking in area of substrate

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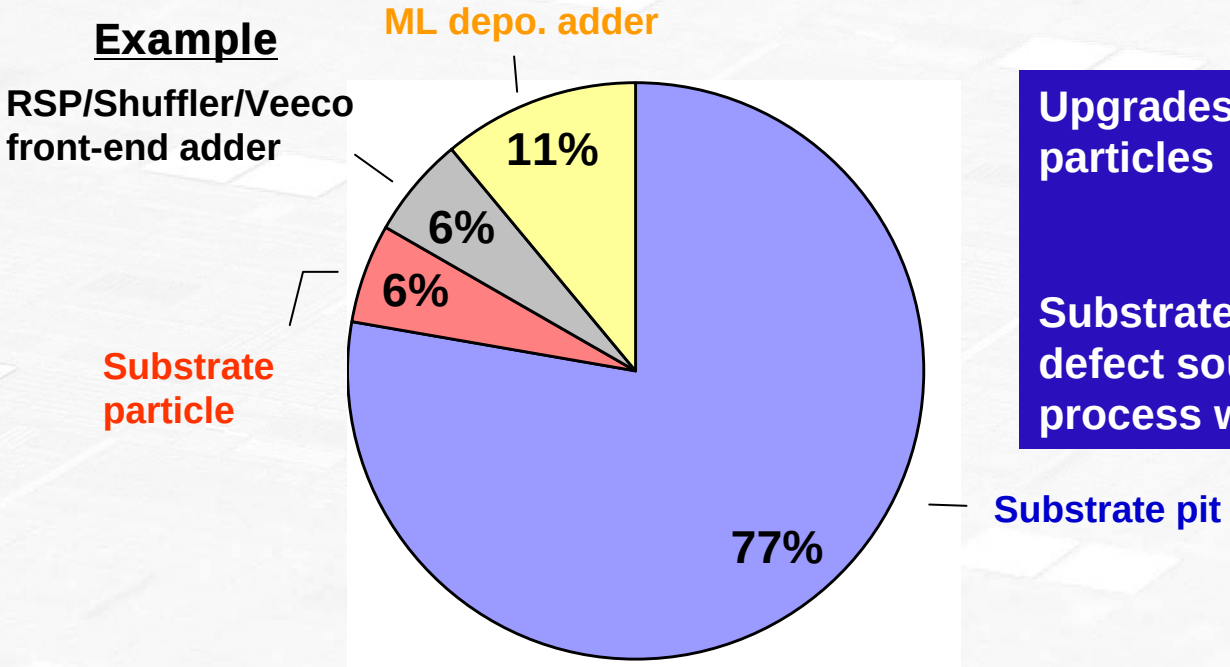
Smoothing motivation: State of the art blanks have too many pits

Example



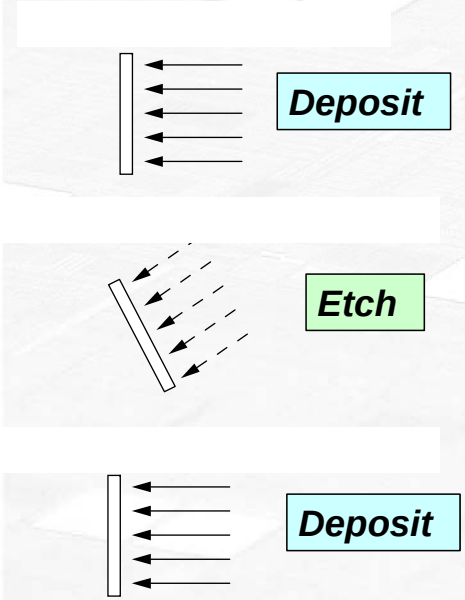
Upgrades 1-4 focused on added particles

Substrate pits remain the primary defect source, so the smoothing process was implemented.

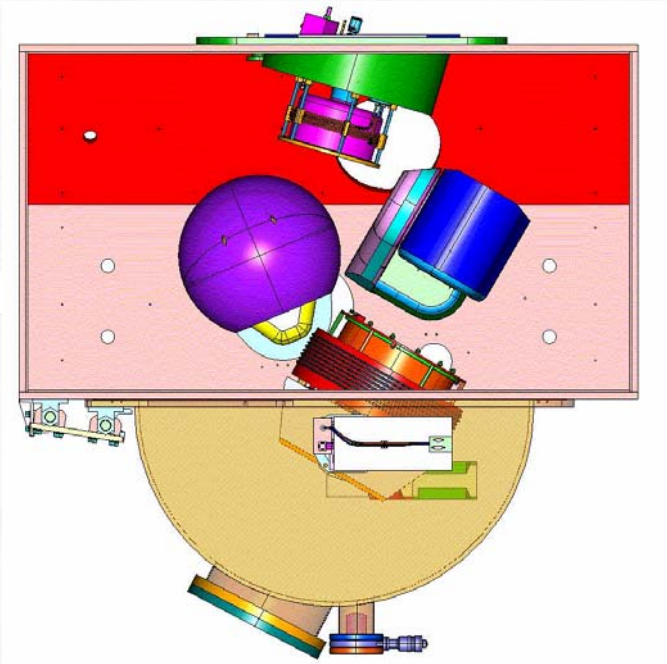
- Cannot clean substrate pits (unlike substrate particles).
- Needed to implement pit smoothing.
- Needed to design, fabricate, and install a module designed for substrate defect smoothing. New development work needed to make process clean enough for manufacturing.

Etch source is isolated from deposition flux in new module

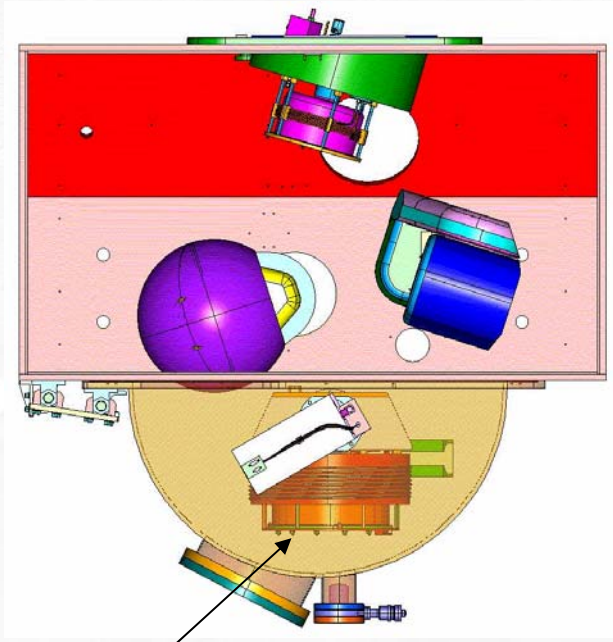
Smoothing process



Etch Position



Deposition Position



Etch source is isolated

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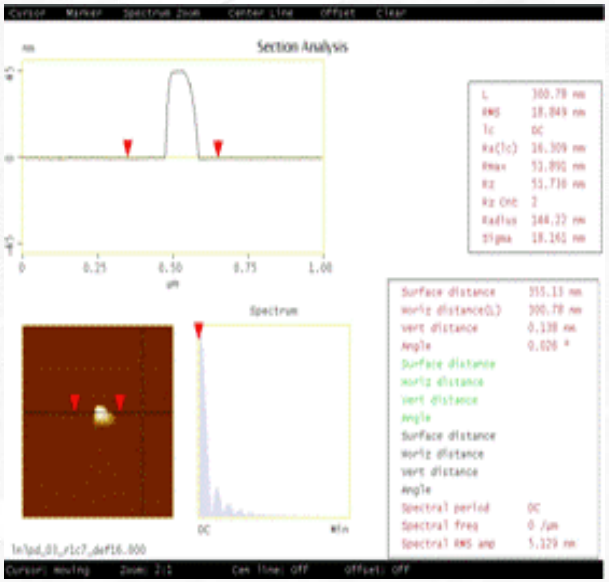
Smoothing renders 50nm particles non-printable

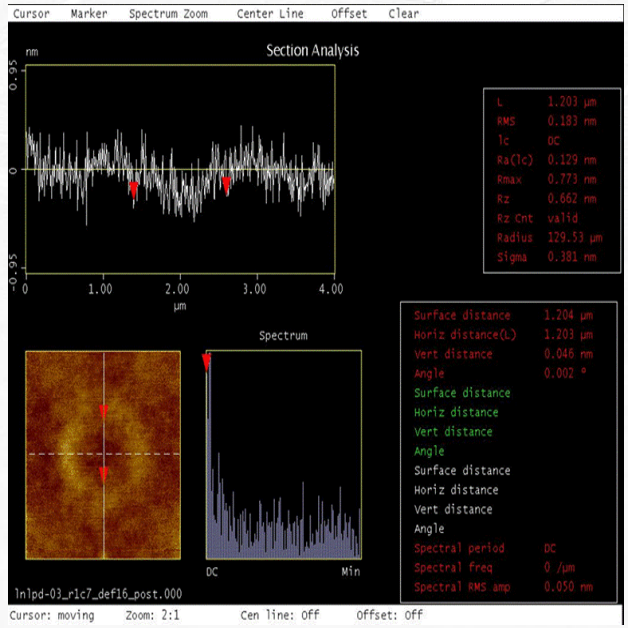
Particle: 49 nm



Particle smoothing
49 nm → ~ 0. 2 nm
Goal: 50 nm → < 1.0 nm

30 cycles

Particle ~ 0.2 nm



Smoothing process developed at Lawrence Livermore National Laboratory for more specifics see the presentation at the EUV symposium 2006 by Mirkarimi et. al.

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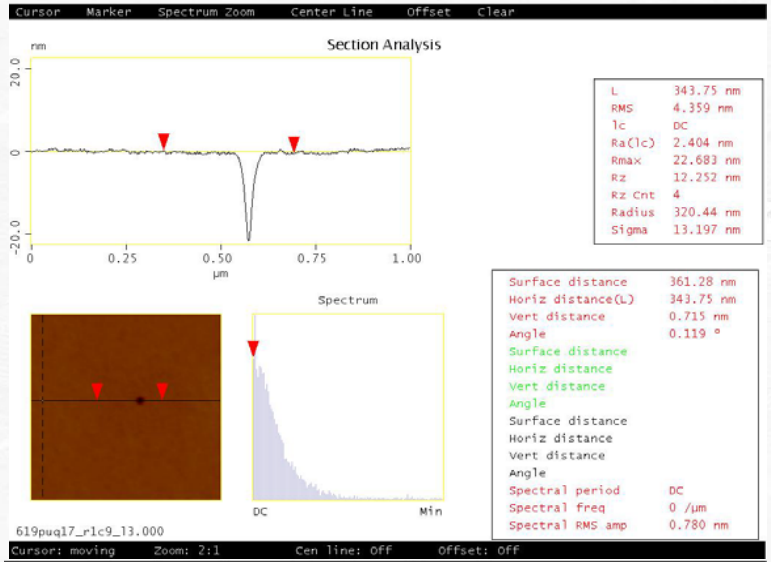
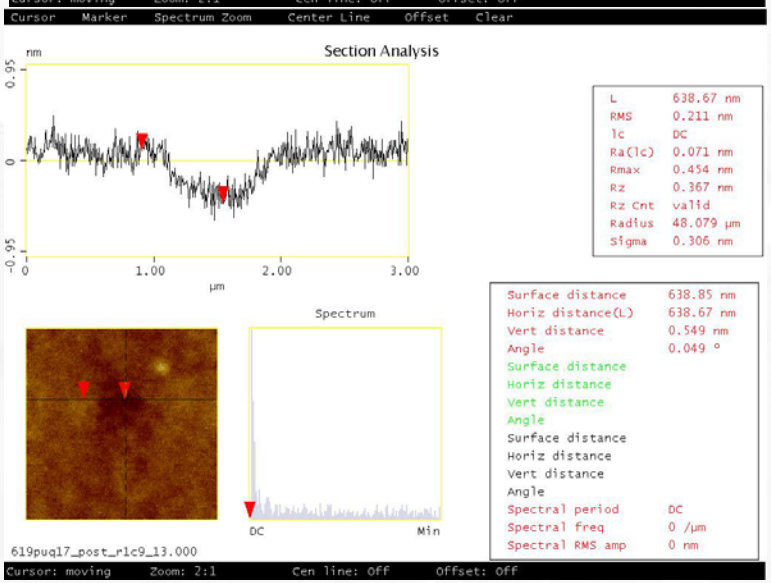
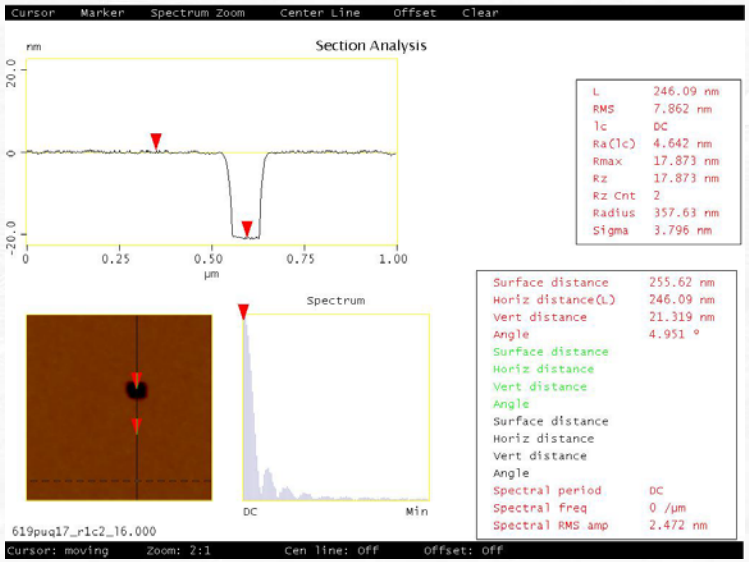
Smoothing renders 21nm pits non-printable

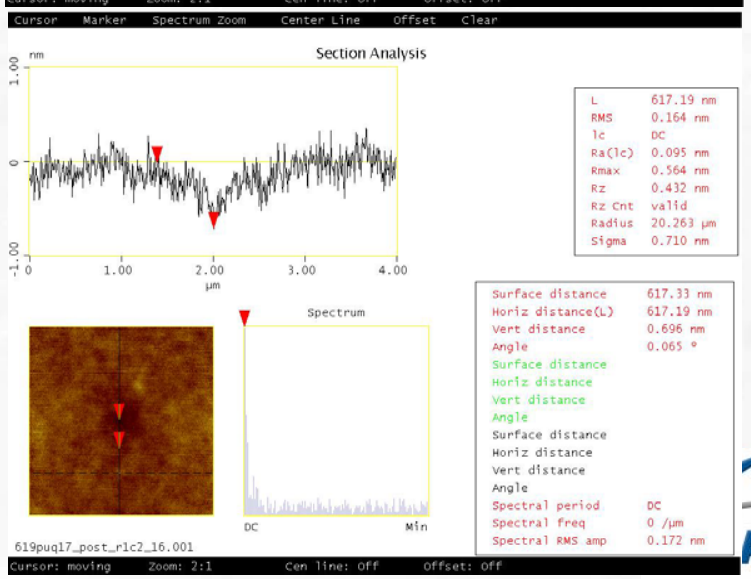
Depth: 21 nm → 0.55 nm (FWHM ~ 50 nm)





Depth: 21 nm → 0.6 nm (FWHM ~ 100 nm)

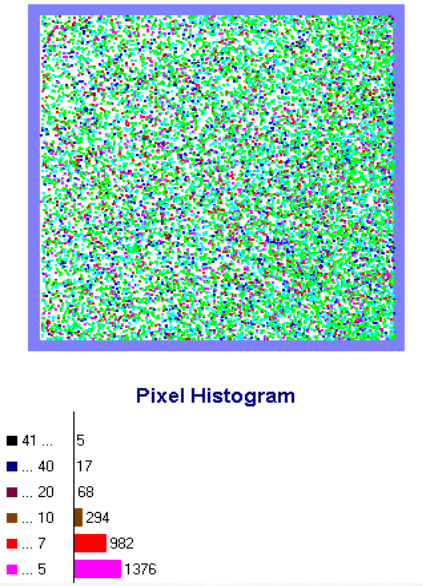




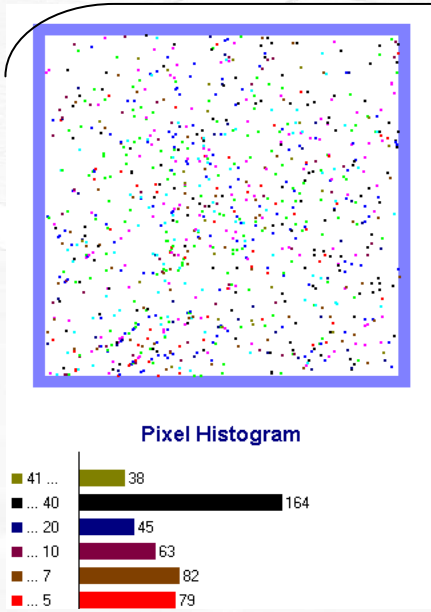
Smoothing chamber cleanliness is greatly improved

Old chamber Designed for ML deposition

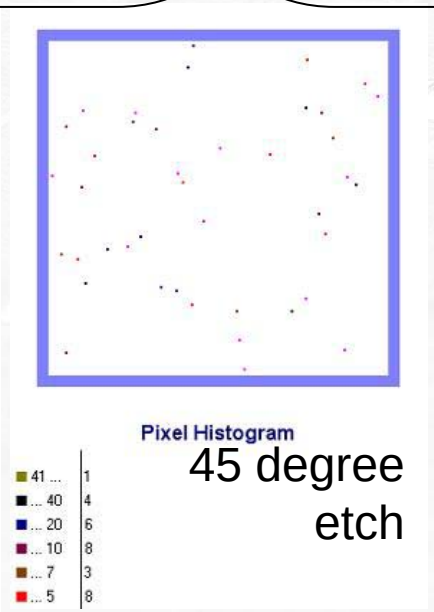
New chamber Designed for Etch



2742 total defects

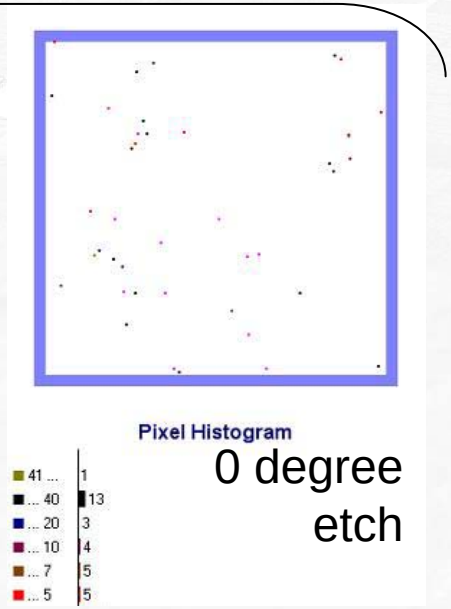


471 total defects



45 degree etch

30 total defects



0 degree etch

31 total defects

Initial testing Dep + etch

Trying for cleanliness Etch only

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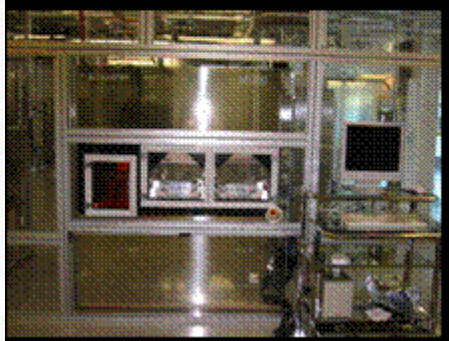
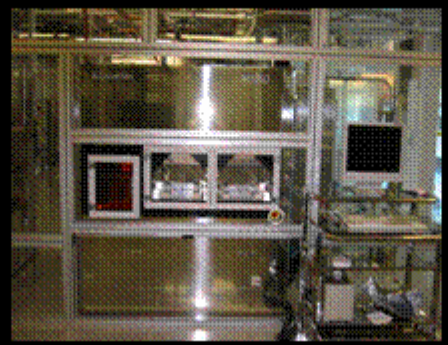
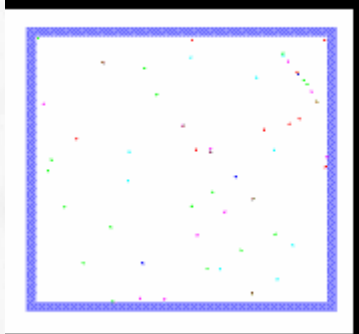
Characterizing the Defect Composition

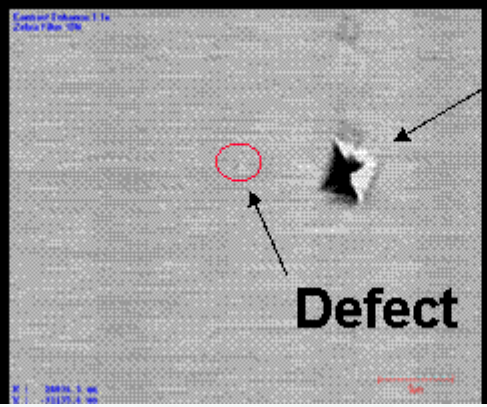
Defect inspection & Map the defect (Lasertec M1350) → Marking the defect Location (Lasertec M1350) → Characterize defect Composition (SEM/EDX/FIB)

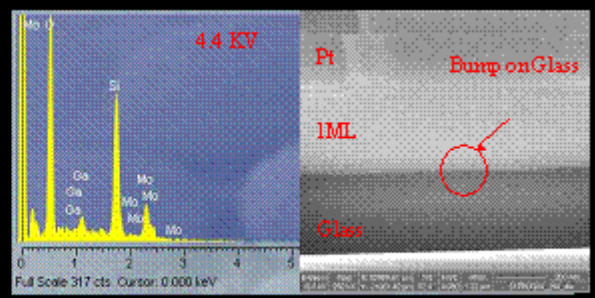




Altura 835 Dual beam

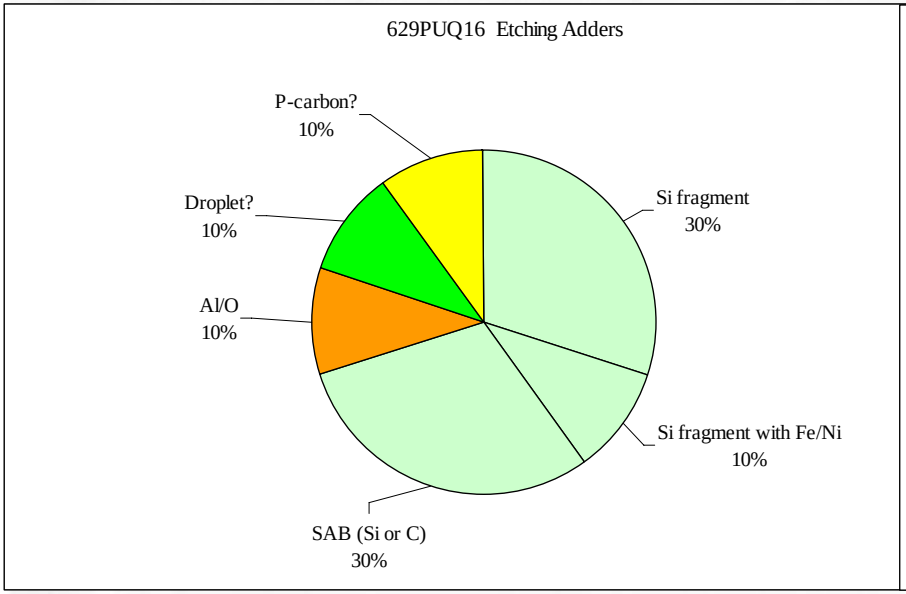




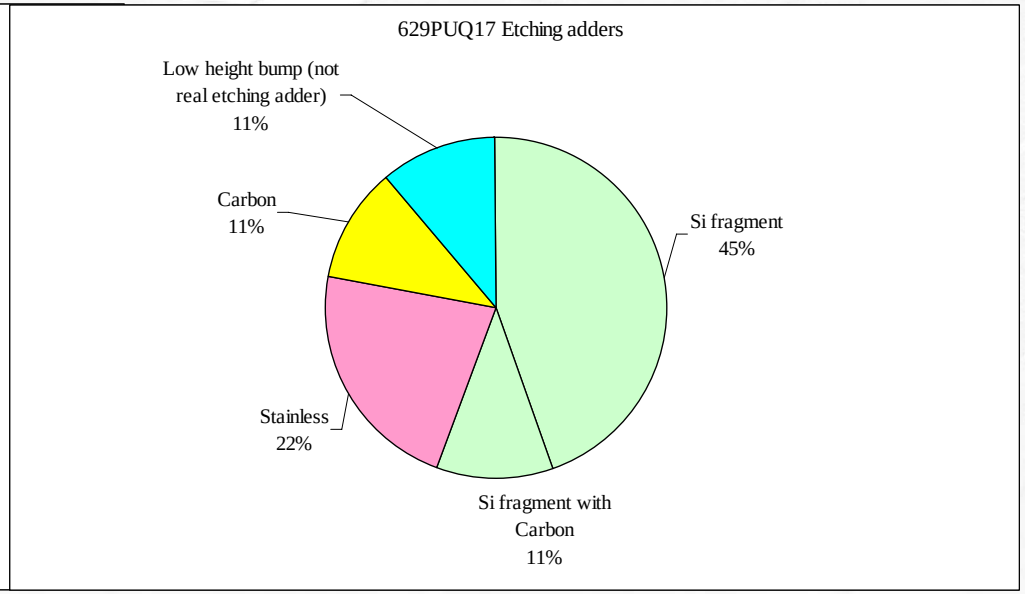


Etch defect pareto dominated by Si

Pareto of added defects at a 45° etch



Pareto of added defects at a 0° etch



- Si particles dominate. Since ion source is shielded from Si depo flux now, most likely mechanism for particles is flaking from walls and subsequent entrainment in beam.
- Stainless steel is the next most common defect material. This is consistent with a flaking/entrainment mechanism, but this material is also present in ion source.
- No Mo was observed. This indicates that the erosion of Mo from the grids is not creating observable particles. No proof that gridded ion sources are inherently dirty!

Conclusions

- A new smoothing process module has been designed, installed and made operational.
- We have successfully implemented the smoothing process in this new module.
  - ~ 50 nm diameter particles smoothed to 0.2 nm in height (non-printable)
  - ~20 nm deep by 100nm wide pits smoothed to ~0.6 nm in depth (non-printable)
- No Mo defects result from etching, hinting that the (Mo) grids in gridded ion sources may not be an inherent source of particles.
- No fundamental limits to defect reduction have been identified.

Acknowledgement:

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