Accelerating the next technology revolution

Mask Blank Development
IEUVI Mask TWG – 06 Oct 2013

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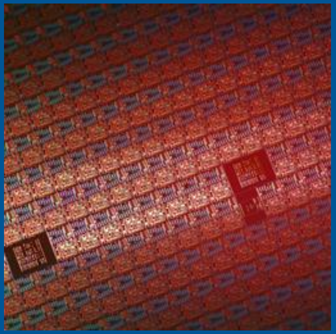
SEMATECH

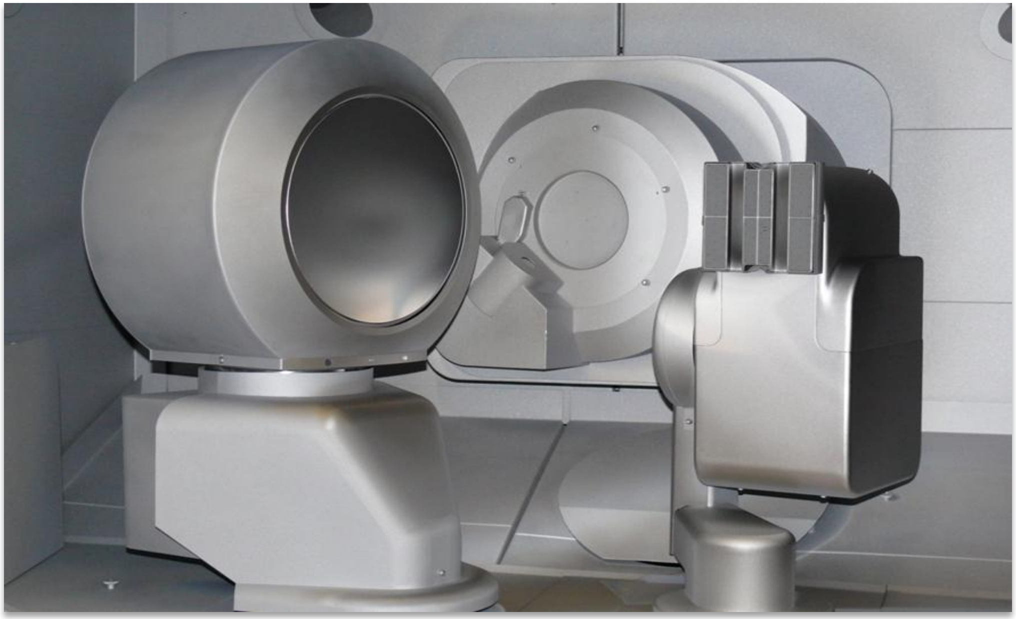


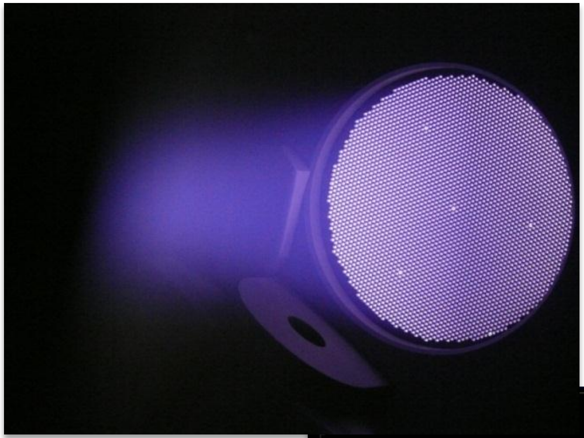
Key Defect Challenges for EUV HVM Mask Blanks

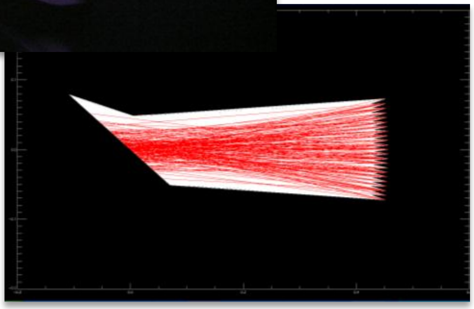
- Mask Defect Density
  - Mask Blank Defects > 100nm*
    - Yield of useable mask blanks and pattern masks
    - Majority are deposition defects
  - Mask Blank Defects < 100nm*
    - Limited counts needed to enable mitigation schemes
    - Decorated substrate defects
  - Mitigation strategies
    - Feature level OPC
    - Pattern shift
    - Defect Repair
    - etc ,,,
  - Adder Defects
    - The entire EUV mask ecosystem need improvements to manage working with pellicle free reticles

*** SiO_2 equivalent**

Mask Blank ML Deposition
Veeco Nexus IBD Tool







- Ion Beam Deposition (IBD)
  - The leading technology for deposition of mask blank Si/Mo multilayers
  - Has demonstrated potential to achieve useable EUV mask blanks
    - But high variability in handling defects and deposition excursions have limited further isolation of deposition defect sources

SEMATECH Champion Data

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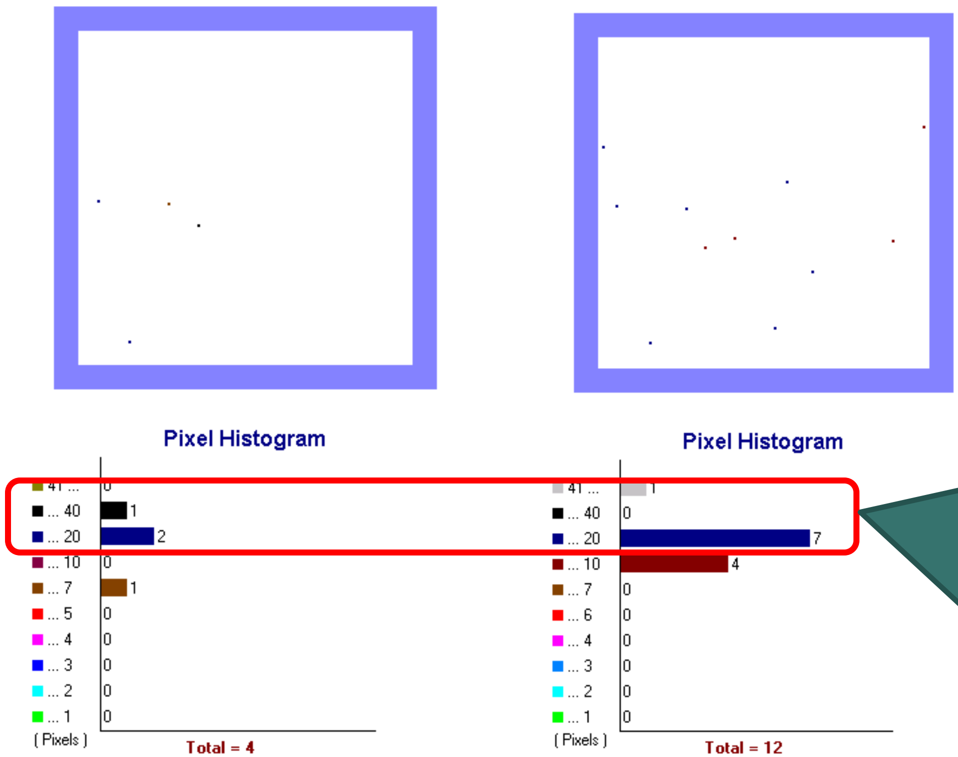
M1350 | M7360 Dense Scan

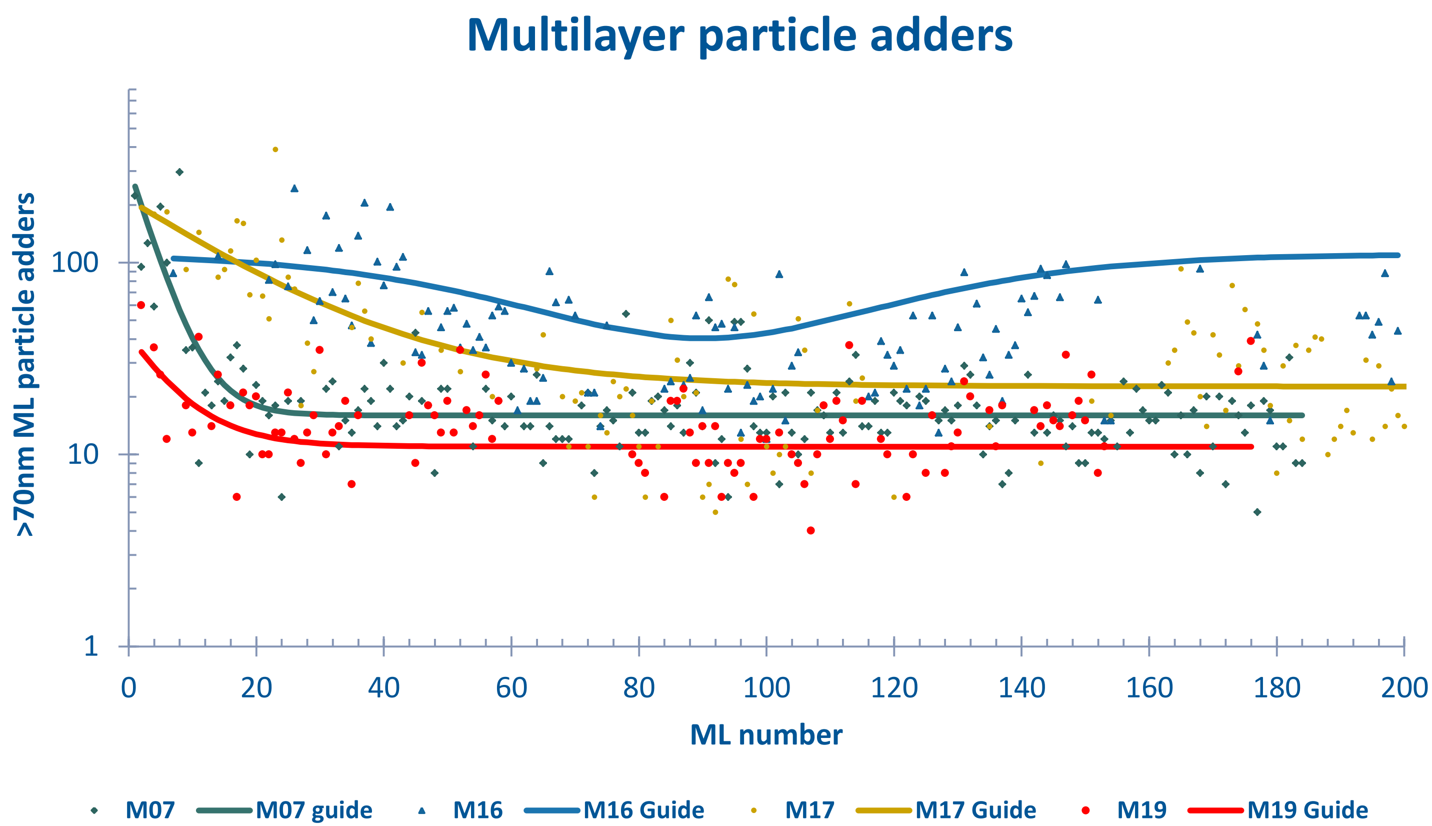


- Large defects – would not be considered a useable HVM mask blank
- Key limiter to yield of useable mask blanks
- Currently the primary focus of SEMATECH's mask program

- Achieved 12 defects @ >45nm* or 8 defects @ >50nm* from M7360 inspection
  - 10 pits (from substrate), 1 handling defect, 1 defect from deposition

* SiO_2 equivalent

SEMATECH Marathon Comparison

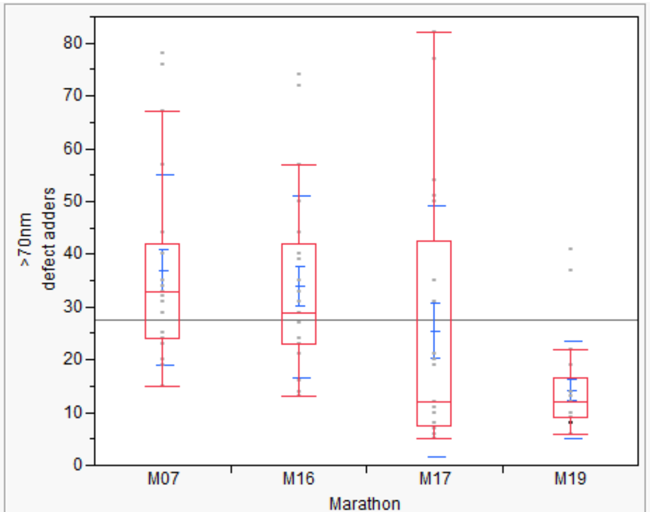


- Results of recent process changes introduced by SEMATECH
- Reduction in deposition defect adders (@70nm*) to improved single digit performance

* SiO_2 equivalent

Variability of Defect Counts

>70nm* adders

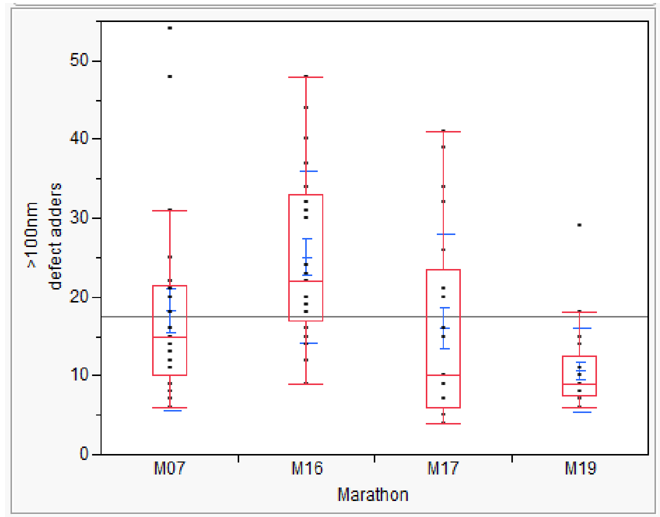


Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
M07	21	36.9048	18.0303	3.9345	28.697	45.112
M16	21	33.8571	17.3098	3.7773	25.978	41.736
M17	21	25.4286	23.8172	5.1973	14.587	36.270
M19	21	14.2381	9.2785	2.0247	10.015	18.462

Best run of 21 multilayer blanks from each marathon

>100nm* adders



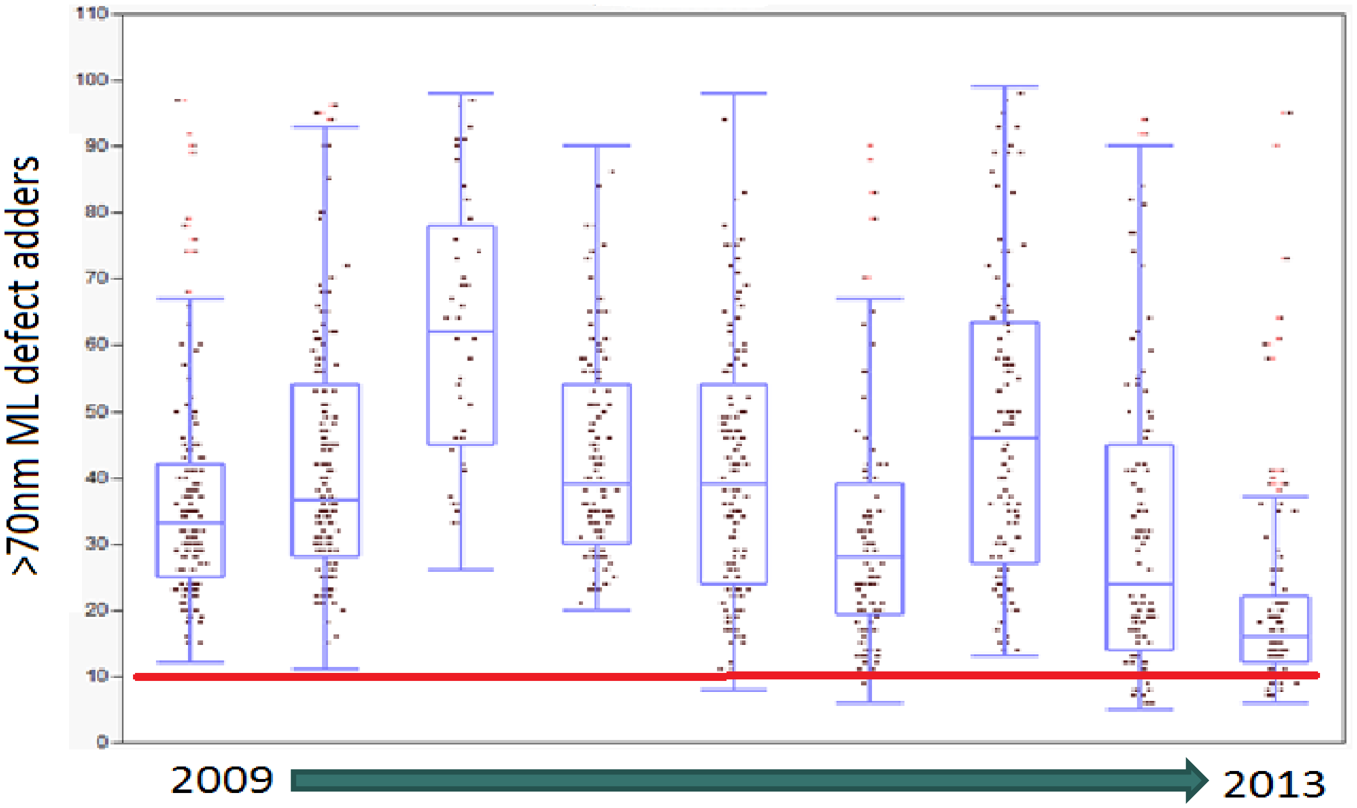
Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
M07	21	18.2857	12.6576	2.7621	12.524	24.047
M16	21	25.0476	10.8925	2.3769	20.089	30.006
M17	21	15.9524	11.9561	2.6090	10.510	21.395
M19	21	10.6667	5.3135	1.1595	8.248	13.085

- Current deposition run is performing with greater consistency and at lower defect levels
  - Improvement @ 70nm* in mean and 3sigma
  - Range is narrower
  - Repeatable defect signature between mask blanks
- Major step towards validating that IBD can support HVM manufacturing of EUV mask blanks

* SiO_2 equivalent

History of low defect deposition



- Plot of added defects/mask > 70 nm for past 5 years
  - Red line drawn at > 10 defects/plate
- Single digit defect yield is still a challenge – currently at 11% up from 0% in 2009
- Need to see the 4th quartile move below zero

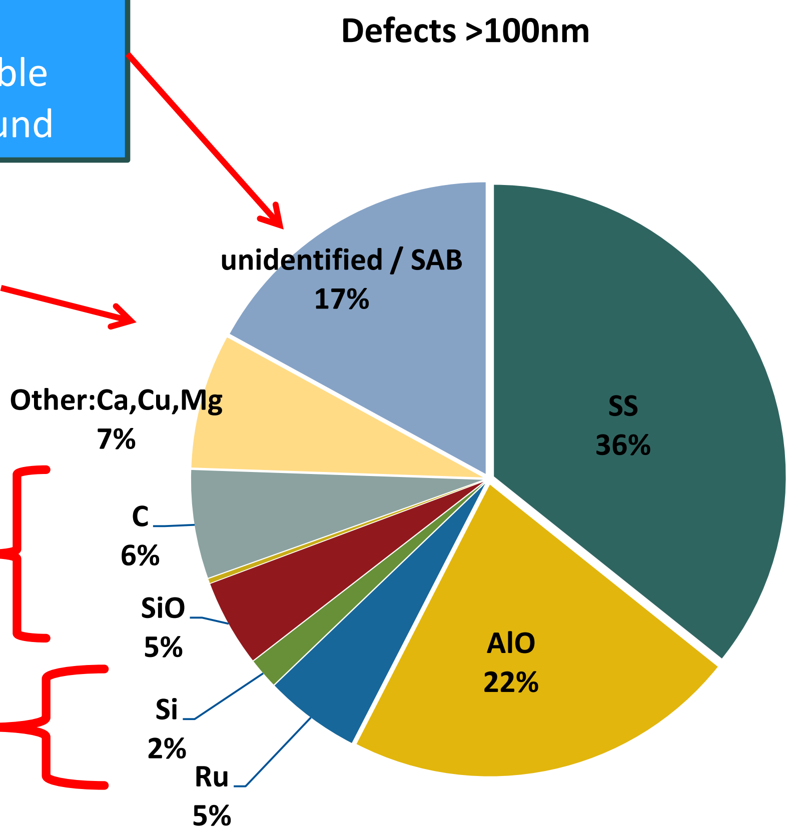
Composition of Mask Blank Defects from Most Recent Marathon

core too small to EDS, or indistinguishable from background

Substrate decoration (cleaning residue)

Reticle handling

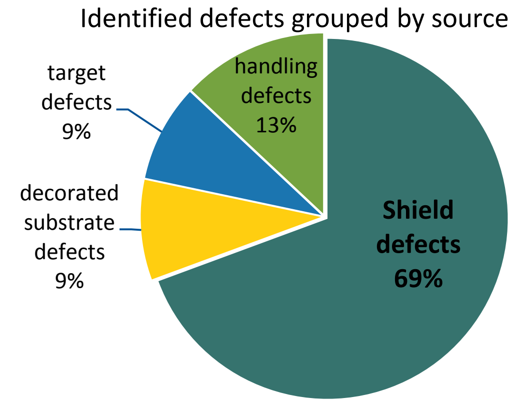
Deposition target



Current 2013 defect composition (analysis of 35 mask blanks)

Mainly from surface of the alumina sandblast-textured SS shields;

Without these particles, relatively large numbers of 0-defect masks can be yielded!

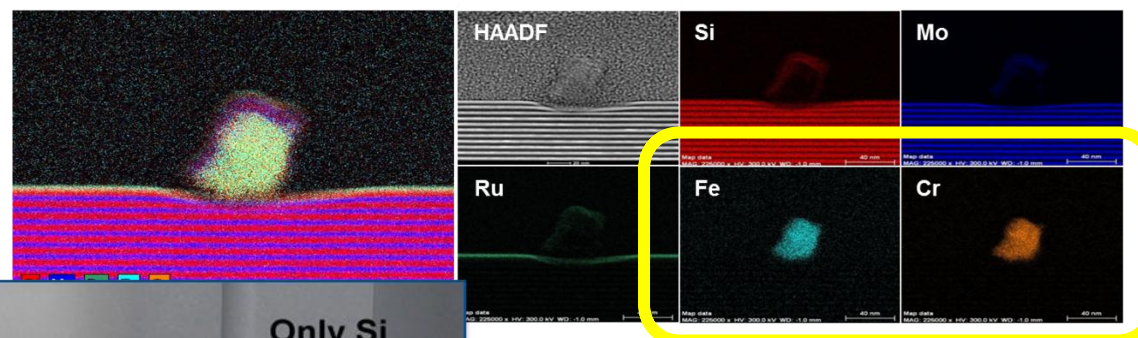


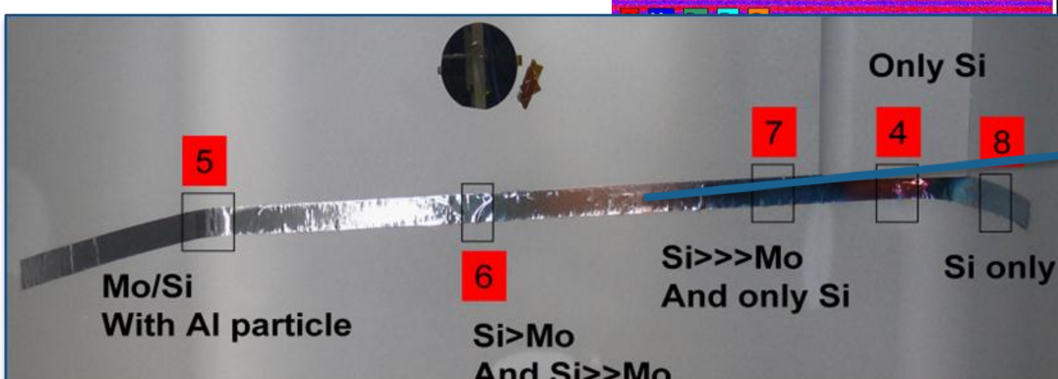
The leading source of "killer" defects remains shield generated.

Source of Large Defects

Defects sputtered from IBD chamber shields

- According to the early ion source modeling virtually all of the ion beam should hit the target
- Many mask blank defects added during the ML deposition process look chemically like shield material
  - Testing indicates that the majority of these defects are liberated by the ion beam missing the target and hitting the shields
  - Understanding why the ion beam miss the sputtering targets is crucial to reducing defects

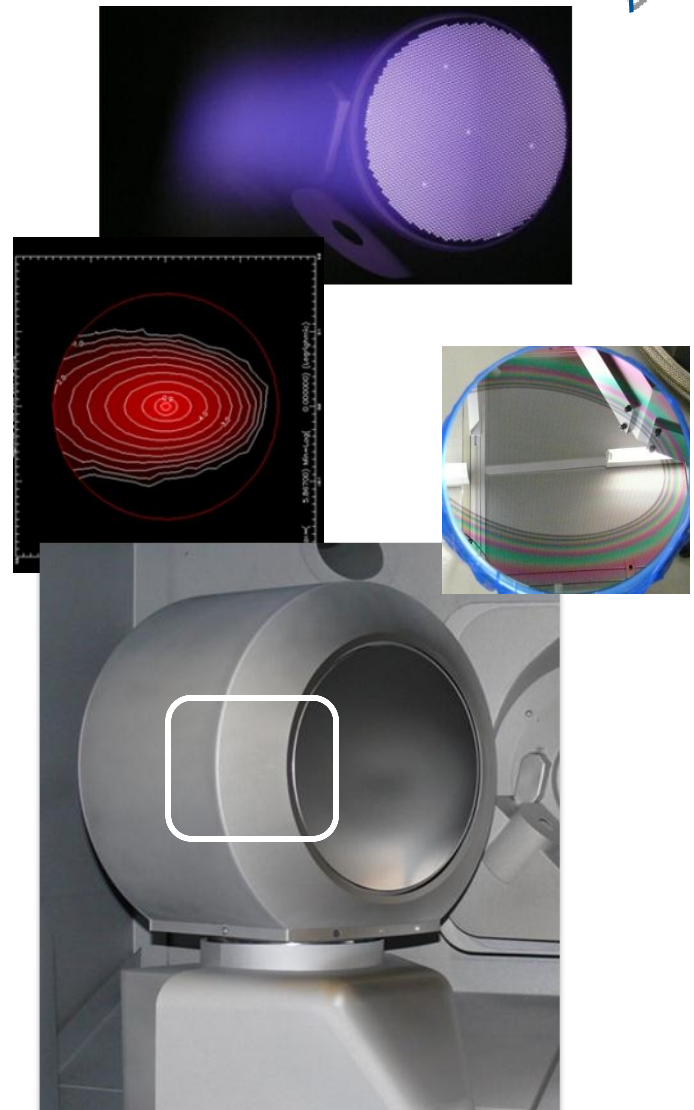




Area of net etch on shield

Improvement of Deposition
Ion Source Containment

- The IBD ion beam is not uniform across the target and has overspill off of the target
  - Resulting in etching
    - Edges of target
    - Shields near target
    - Door Shields and nearby areas
  - Primary source of the large size defects
- SEMATECH's current objective is to work with Veeco to improve ion source confinement
  - Testing new ion source operation parameters and high chamber pumping speeds
  - Veeco is working on improved ion optics with improve focusing

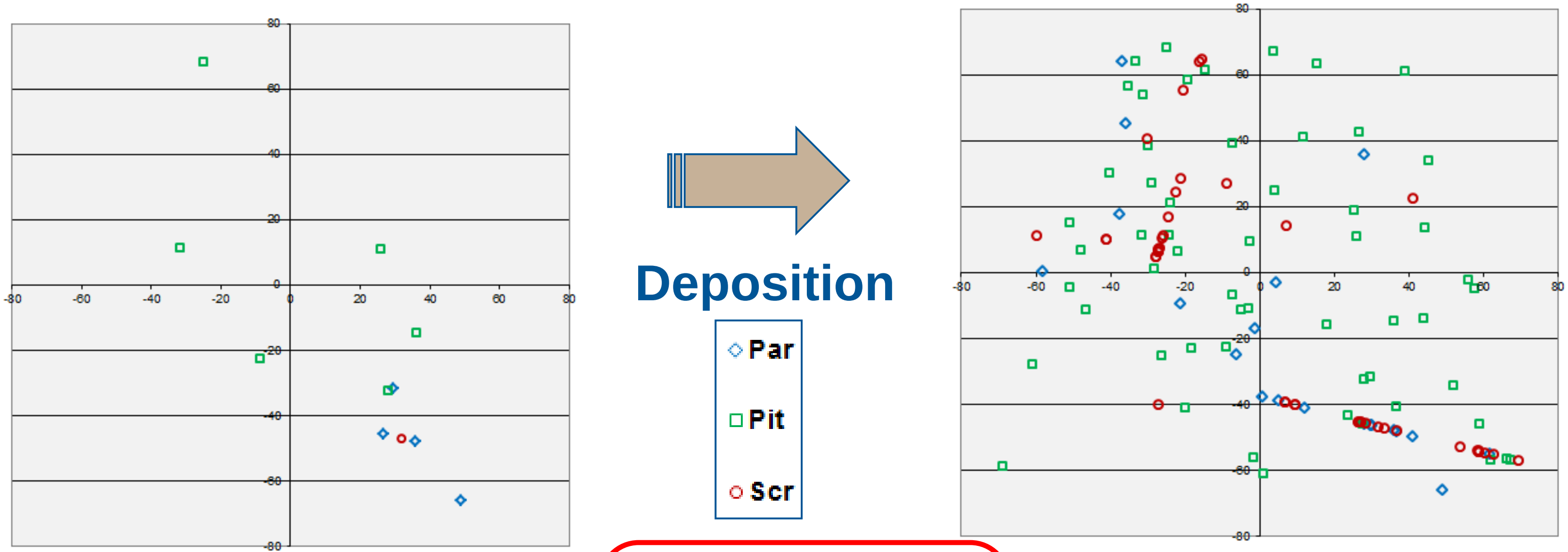


What is Know About the Etching

- Significant etching of the sections of the shields visible
  - Requires high energy atoms to strike the shields
  - Atoms come from direction of grids
  - Etching occurs far outside the predicted beam profiles generated through earlier modeling
- Ion density measurements show no ions in the area
  - Ion distribution is as predicted by ion beam theory
  - Upgrading metrology to validate but additional empirical testing indicates that this is assumption is valid
- Etching at locations without ions suggests high energy neutrals are doing the etching
  - Ion density measurement cannot detect neutrals
  - Neutrals must have been charged to obtain enough energy to etch shields
- Charge exchange collisions between grids of ion source can create a divergent beam of high energy neutrals
  - Currently investigating methods to validate this assumption
  - In parallel optimizing ion source operating parameters and evaluating alternative ion grid assemblies

Substrate Defects

Limitation in Detection



Defectivity	Pits	Scratches	Particles	Pit+Scr
Substrate @ 40 nm SiO_2 size	5	2	4	7
ML blank @ 43 nm SiO_2 size	56	43	21	99

- Majority of the small sized pits, bumps and scratches do not show up until after decoration by the multilayer deposition
- Current substrate inspection capability not able to detect these defects
  - This gap is not being adequately addressed by the industry
  - Employing a decoration technique to drive improvements but adds cycle time and complexity to isolating defects
- Although small in size the typically high counts eliminate the possibility of mitigation

Additional Near-term Mask Blank Challenges

- IDMs are using pre-production exposure tools
  - Mask lifetime is becoming a significant problem
    - Keeping the exposure surface of an EUV mask clean and particle free
    - Pattern and reflectance degradation due to repetitive cleaning
    - Damage to the CrN backside
  - Potential mitigation schemes
    - Pellicles
    - Changes in the ML film stack or capping layer to address cleaning damage
    - Possible move to a different backside coating

Summary

- SEMATECH's most recent efforts are targeted at reducing shield defects
  - The majority of defects adders are from the shields
    - Defect compositions are mostly alumina and stainless steel
    - Shields are made of stainless steel and grit blasted with alumina to increase roughness
  - Evidence indicates that a fraction of the ion beam misses the target due to scattering and other effects.
    - Ions hitting the shield liberate particles
  - Experiments are in place to verify the ion beam overspray hypotheses and the preliminary data shows that counts of large size defect can be modulated by changing process conditions
  - With Veeco; currently exploring new process conditions, tool modification and new ion optics designs to mitigate defects due to shield sputtering
- Hurdles remain in addressing substrate defects
  - Specifically the need for inspection capability with greater sensitivity

Key Takeaways

- Current assumption is that IBD can produce useable HVM mask blanks
  - Needs to reach a sustainable defect level where mitigation is possible
  - Every indication points to this being possible
    - Greatly improved process variability
    - Consistent mask blank defect signature
    - Still needs to be validated
- Substrate Quality
  - Surface defects and finishing continue to improve
  - Continuous improvement significantly hampered by lack of defect metrology
- In-fab Use of EUV Mask and Mask Lifetime
  - Need to insure that adders are not patterned
    - Move to pellicles
  - Mask lifetime – learning has just begun but already issues seen
    - Backside coating damage
    - Clean handling
    - Pattern mask cleaning