Recent Advances In The Development Of A Low-Defect Mo/Si Deposition Tool And Process For EUVL Mask Blanks

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EUVL Symposium
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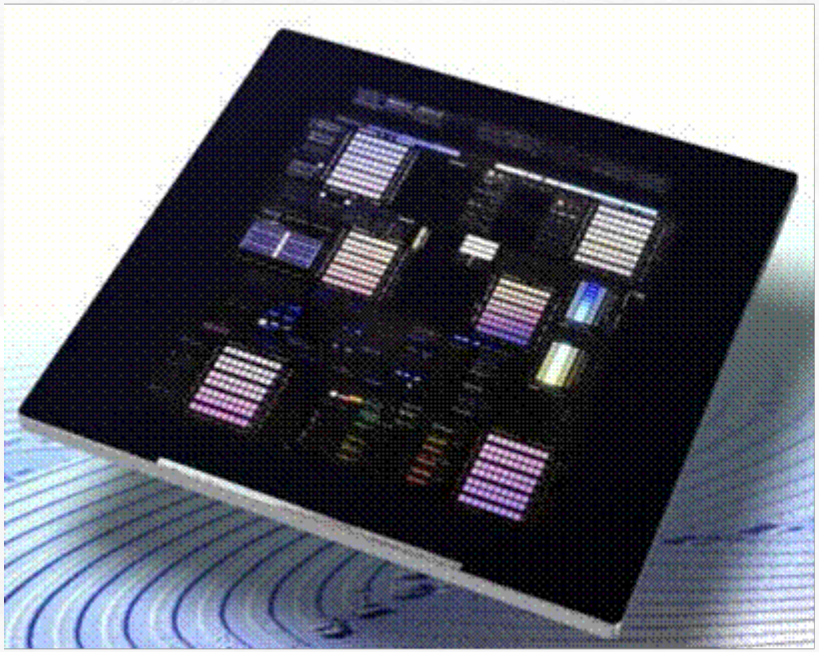
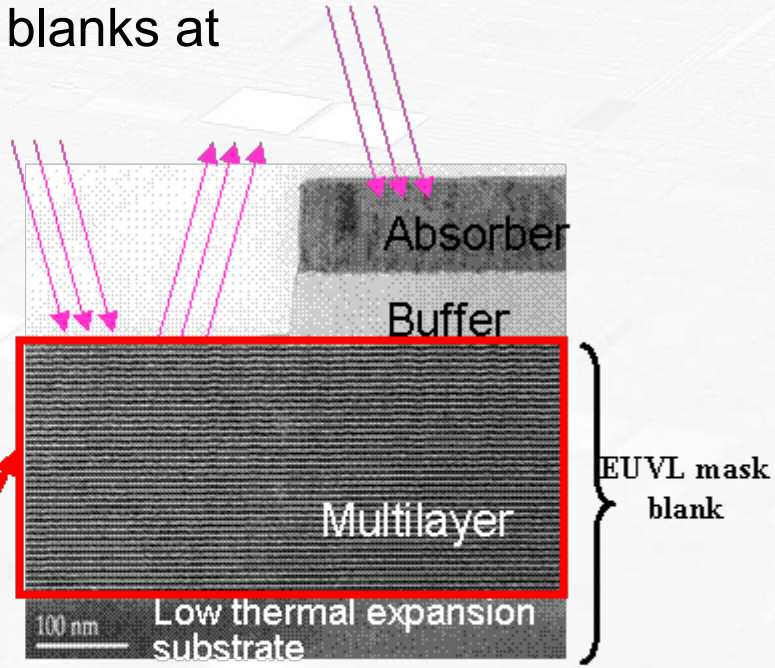
Extreme Ultraviolet Lithography (EUVL) Mask Blanks

- EUVL mask blanks have been identified as a critical area
- Masks must be extremely flat and defect free
- Major development effort on EUVL mask blanks at SEMATECH North



EUV mask



EUV mask construction

SEMATECH Focus

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SEMATECH Mask Blank Development Center (MBDC) Strategy

- Work with a tool 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 mask blank suppliers to drive the technology to produce low defect substrates and multilayer (ML) coated blanks.

Industry Defect Goals

(*total* mask blank defects, i.e., ML coating plus substrate)

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

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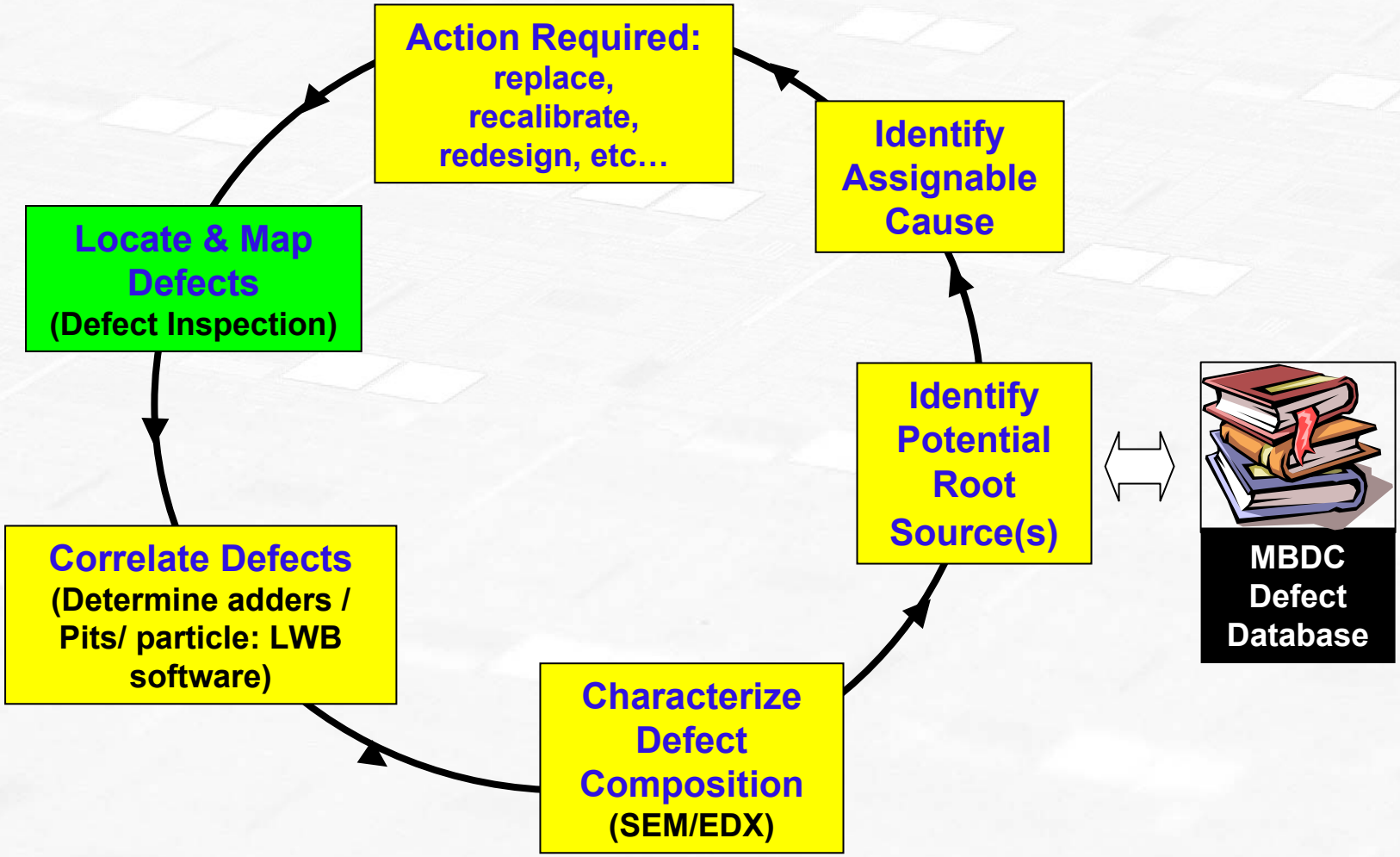
Root Cause Defect Analysis Strategy



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Significant Progress Has Been Made In Defect Reduction Since Last Year's Symposium

	Last Year's EUVL Symposium	This Year's EUVL Symposium
ML coating-added defects	0.105 def/cm2	0.01 def/cm2
Total defects (substrate plus ML)	0.32 def/cm2	0.025 def/cm2

For defects ≥ 80 nm (PSL equivalent size)

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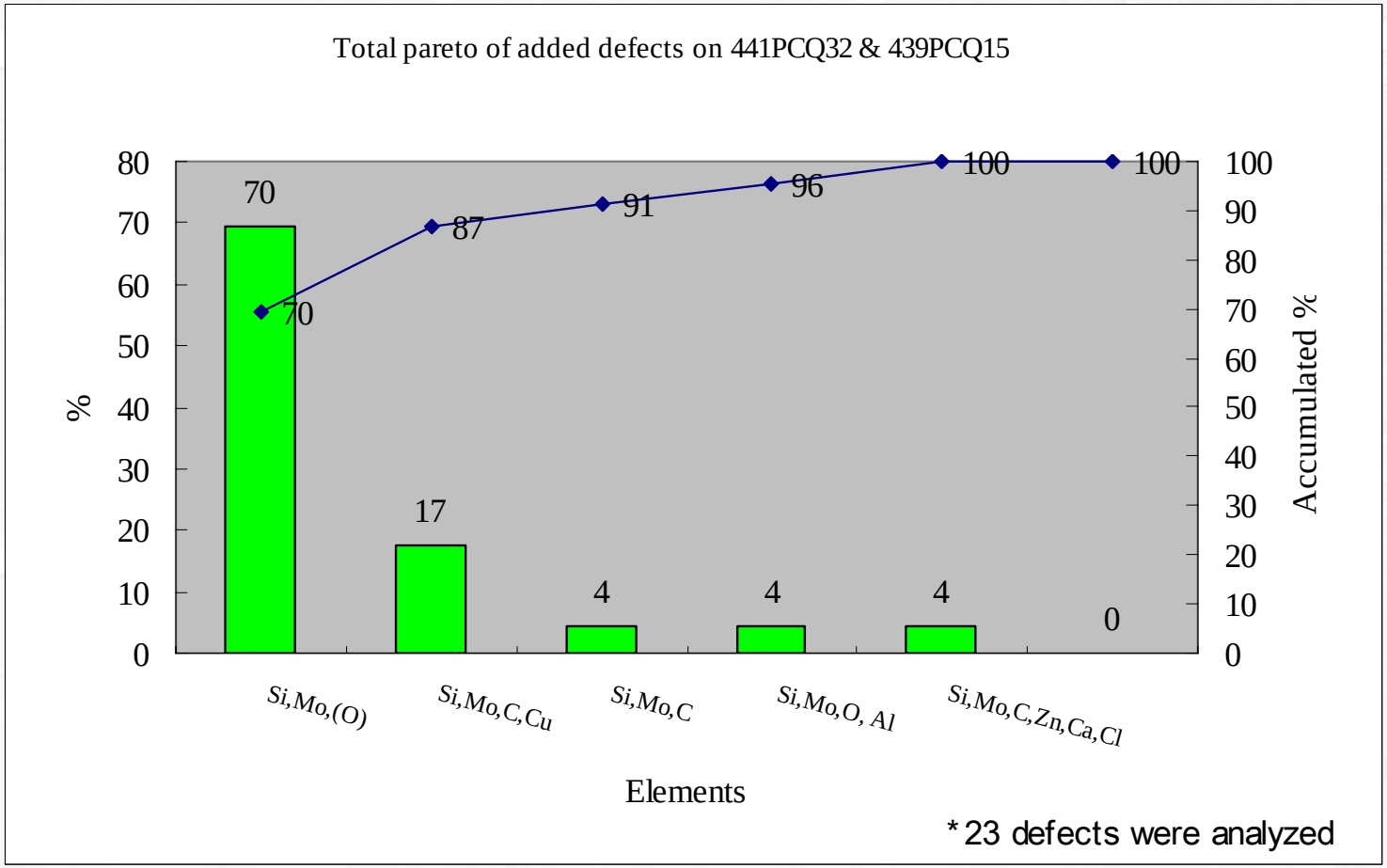
Pareto Plot Corresponding To Last Year's Defect Numbers Suggested That *Si, Mo* And C *(Organics)* Dominated.



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A Number Of Improvements Were Implemented

- Analyzed and improved fab handling protocols and upgraded mask blank transfer station (based largely on carbon-based organics in pareto)

- Upgraded shields and redesigned primary ion source (based largely on Mo,Si in pareto)

- Upgraded Si target to have a lower resistivity (based largely on Si in pareto)

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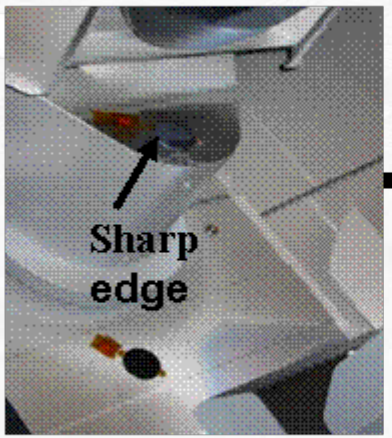
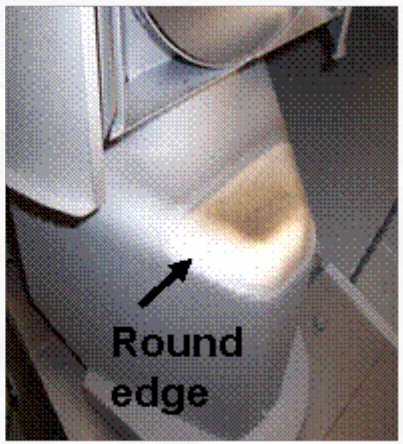
Examples Of Changes That Were Implemented

Target Fixture Front Shield

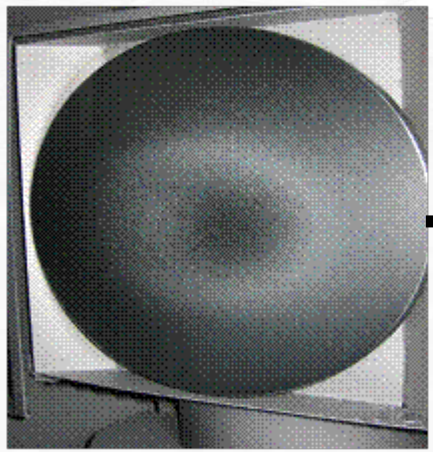


Before upgrade



After upgrade

Target Shield Upgrade



Before upgrade

After upgrade

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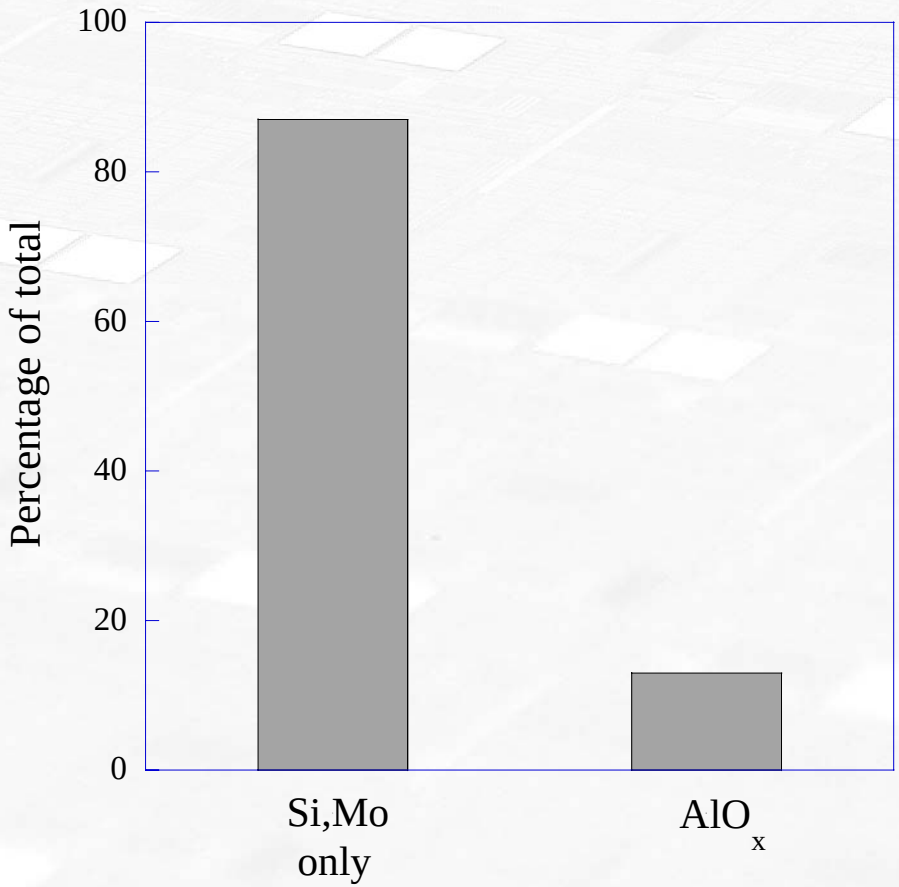
Recent Defect Pareto Plot (after changes were implemented)

- No organic defects were observed.
- (Mo,Si) and AlO_x defects dominate.



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Suspected Sources of Particles

Characteristic composition	Suspected root cause
Mo,Si	Flaking/shields Si target Mo target
AlO_x	Insulators (E-chuck, ion source, etc)

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We Reduced Defect Detection Sensitivity to 70nm (PSL Equivalent) For ML's

	≥ 70 nm defects	≥ 80 nm defects
ML coating-added defects	0.01 def/cm^2	0.01 def/cm^2
Total defects (substrate plus ML)	0.09 def/cm^2	0.025 def/cm^2

- Note that we expect to have a 40 nm detection capability verified and in use by next year's EUVL symposium

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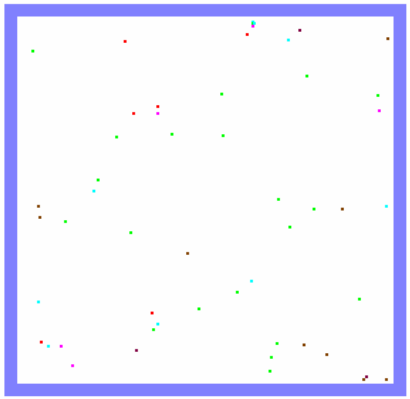
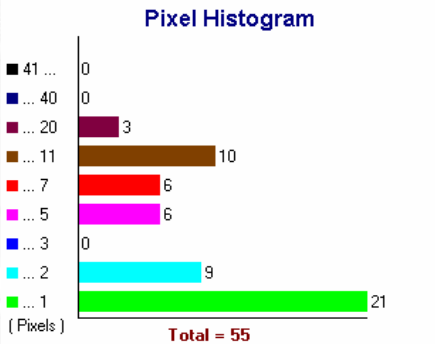
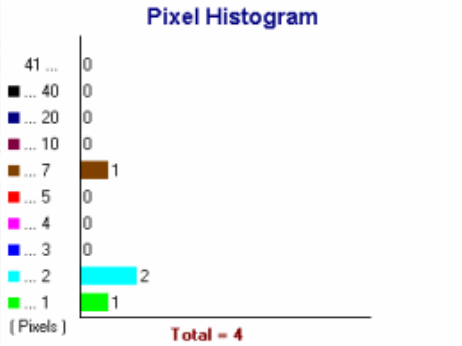
Cleaning Process Developments





MBDC's Cleaning

These results have since been repeated and exceeded



25 defects ≥54 nm

0.125 defect/cm^2

1 defect ≥54 nm

0.005 defect/cm^2

Source: Abbas Rastegar et al.

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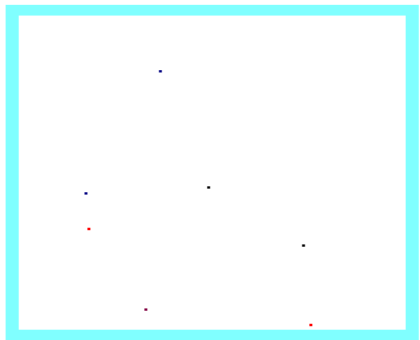
Total Defect Results (from champion data)

Total number of defects after multilayer coating . . .

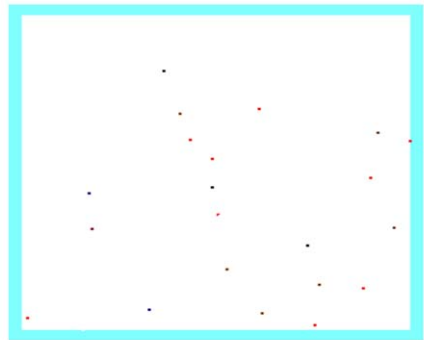
Pre

for ≥ 80 nm defects



5 actual defects
(2 false defects)

for ≥ 70 nm defects



18 actual defects
(3 false defects)

14 are pits from substrate,
2 are particles from substrate,
and 2 are added by ML.

With recent advances in coating defect reduction and substrate cleaning, pits are now a bigger issue than particles.

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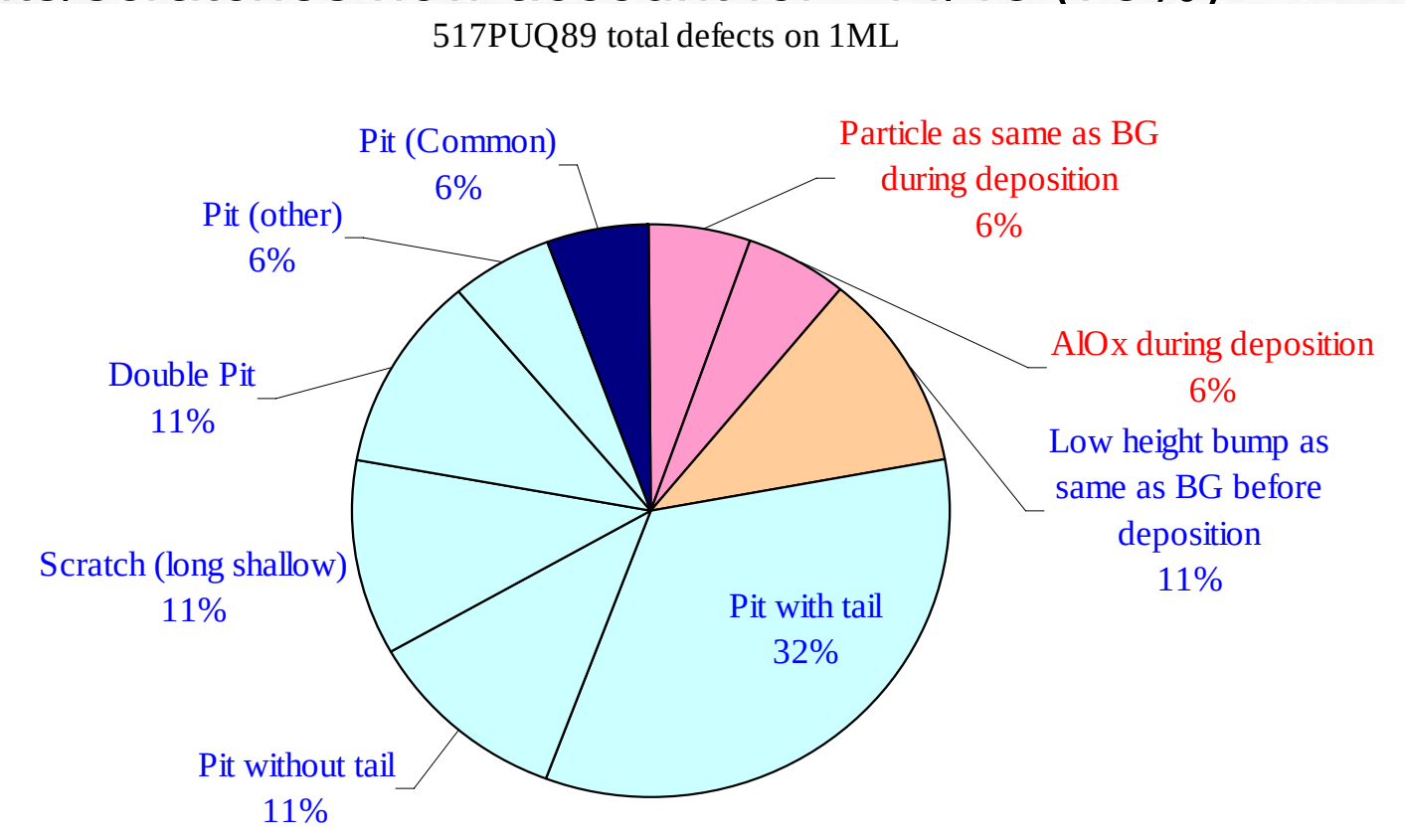
78% of total defects on champion plate are pits / scratches

- SEM/EDX examination of every defects on champion plate generated the following pareto.
- Pits/scratches now account for ~14/18 (78%)



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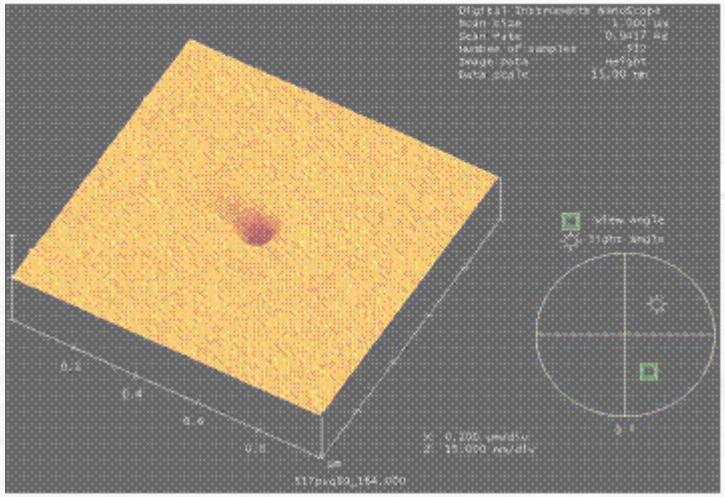
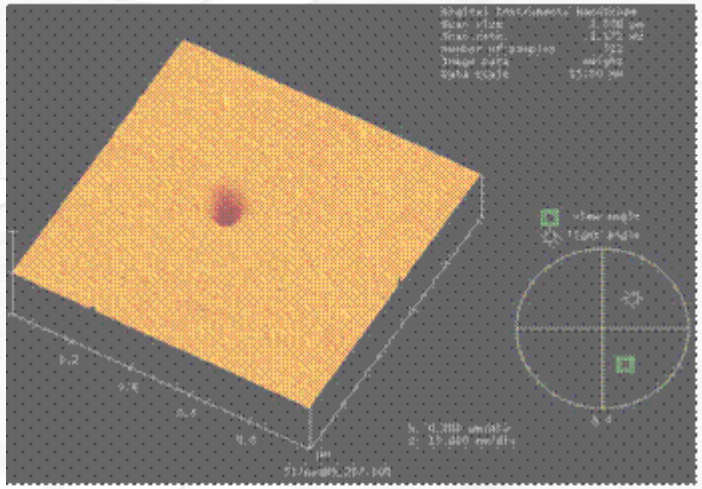
Images Of Different Types Of Defects

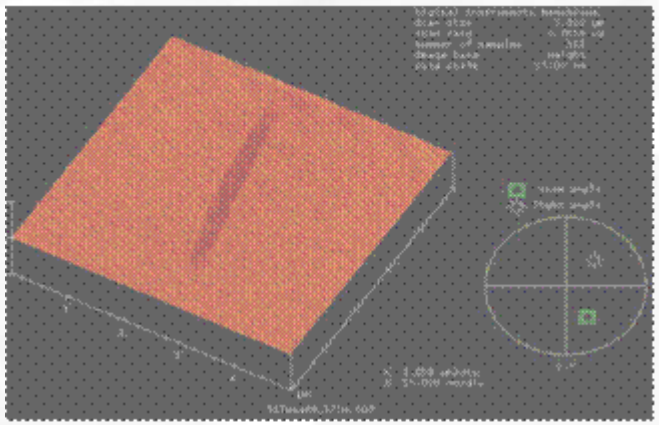
Pit with tail



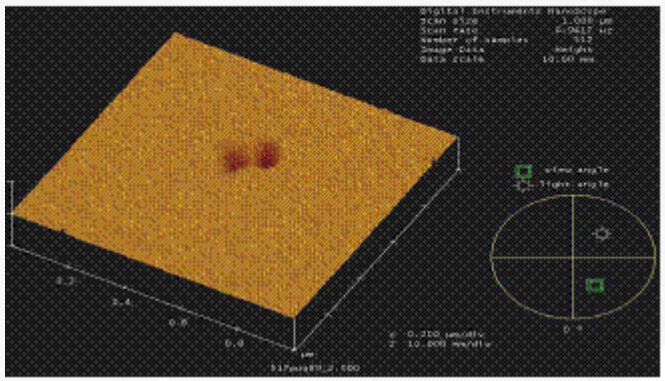
Pit without tail



Substrate scratch (shallow



Double pits



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Strategy To Address Pit Defects

1. Work with suppliers to reduce pit defect density on incoming substrates.
2. Evaluate and implement defect smoothing
   - Install new smoothing module on existing ML coating tool by end of this year.
   - Improve cleanliness of LLNL smoothing process to render it manufacturable.
3. Evaluate potential of cleaning processes to generate pits.

In parallel, we continue to:

-Reduce particle defects in ML films

-Improve our defect detection sensitivity

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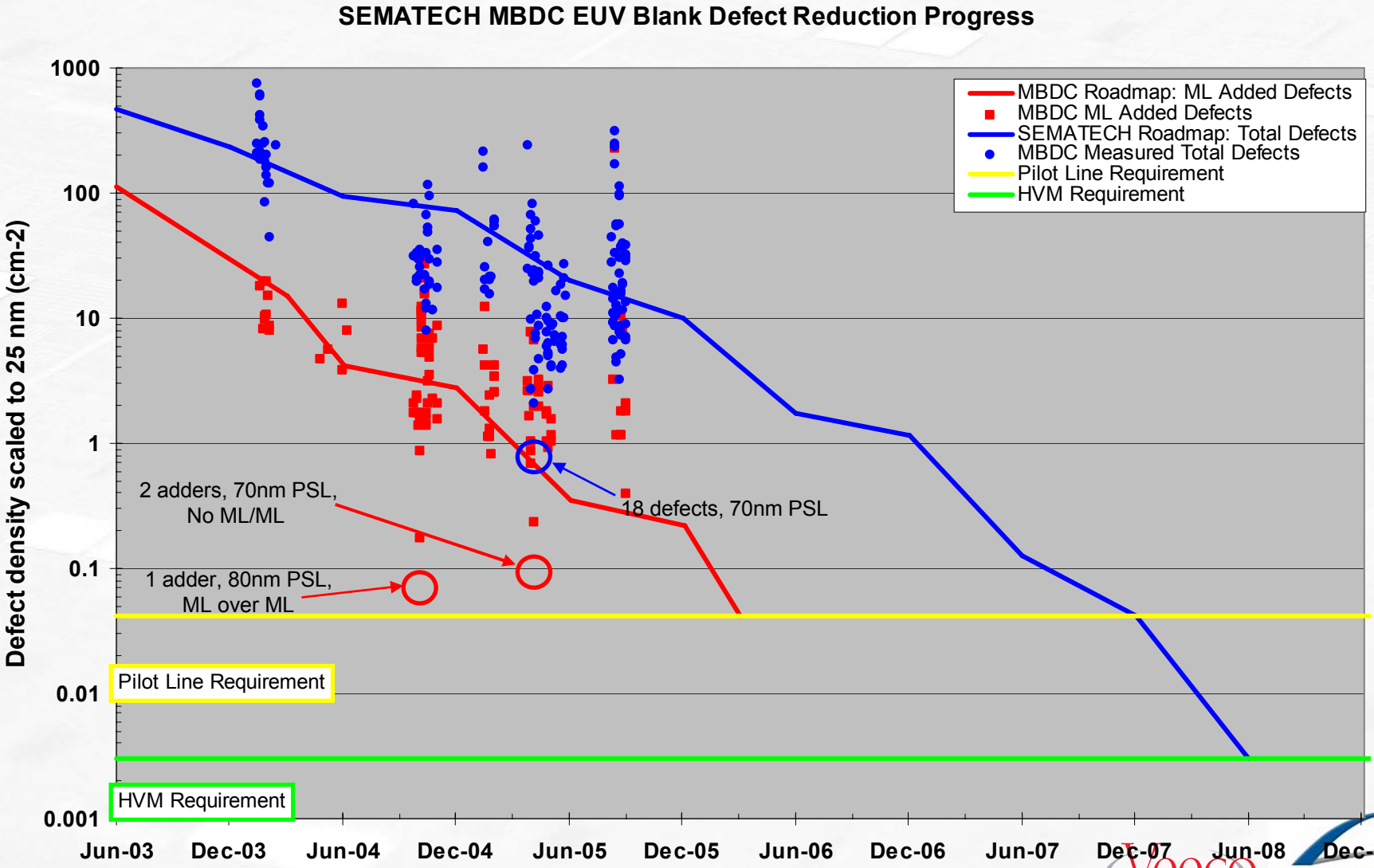
Project Defect Reduction Trend

- Defect density data scaled to 25 nm defects
- From 70nm → 25 nm needs 23x improvement (estimated to power curve)



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Conclusions

- MBDC/Veeco demonstrated **≥10x reduction in added and total mask blank defects** since last year's Symposium
- Root cause analysis, hardware upgrades, and improved process protocol were responsible for these improvements.
- Most remaining defects are substrate pits, and a program has been generated to address those defects

***Coating-added* defect density results:**

- Champion EUVL Mask blank had 2 added defects ≥ 70nm (PSL equivalent), or 0.01 defects/cm^2.

***Total* defect density results:**

- Champion EUVL mask blank had 18 total defects ≥ 70nm (PSL equivalent), or 0.09 defects/cm^2.

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Acknowledgements:

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