Beta-level EUV Mask Blanks for the 32nm Half-Pitch

Chan-Uk Jeon[1], C. C. Lin[3], Patrick Kearney[3], Won-Il Cho[1], Abbas Rastegar[3]
Richard Clark[2], and Anne Rudack[3]

[1] Samsung Assignee in Mask Blank Development Center, SEMATECH
[2] Intel Assignee in Mask Blank Development Center, SEMATECH
[3] Mask Blank Development Center, SEMATECH

Chan-Uk Jeon

MBDC Program Manager

SEMATECH

Albany, NY

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Contents

- EUV Mask Blanks
- EUV Blank Defect Mitigation
  - M7360 Introduction and Sensitivity Revolution
  - Cleaning Capability Improvement
  - Deposition Tool Evolution
  - Continued Pit Defect Mitigation
- Strategy To Go Forward
  - Substrate Pit Repair
  - Smoothing Process Development
  - 3rd Generation Inspection Capability
- Conclusion

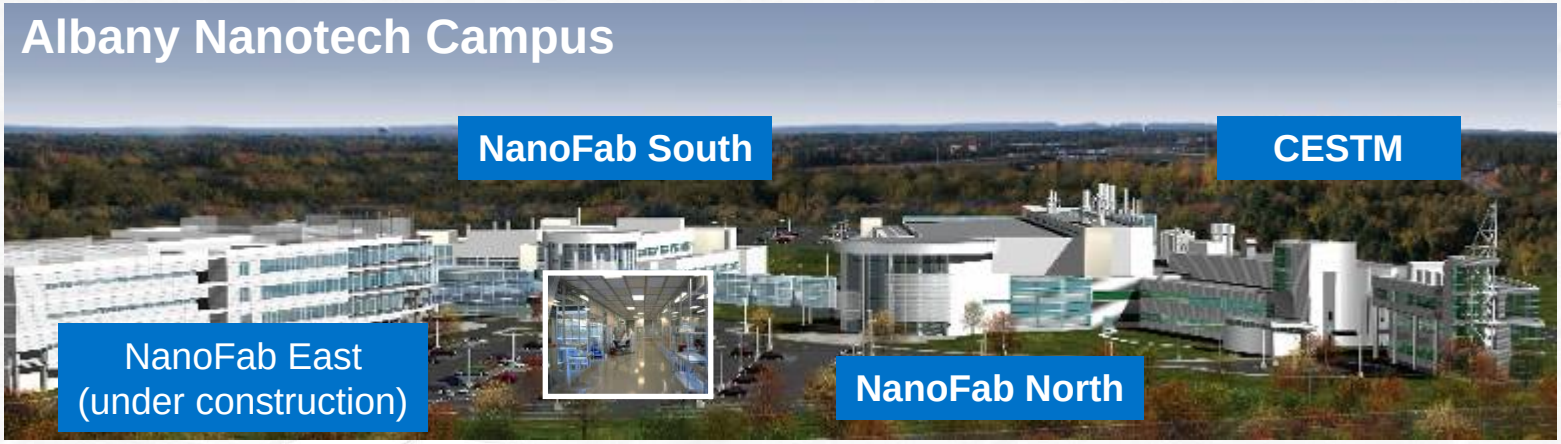
EUVL Critical Technology

2003	2004	2005	2006
1. Source power and lifetime including condenser optics lifetime	1. Availability of defect free mask	1. Resist resolution, sensitivity & LER met simultaneously	1. Reliable high power source & collector module
2. Availability of defect free mask	2. Lifetime of source components & collector optics	2. Collector lifetime	2. Resist resolution, sensitivity & LER met simultaneously
3. Reticle protection during storage, handling and use	3. Resist resolution, sensitivity & LER met simultaneously	3. Availability of defect free mask	3. Availability of defect free mask
4. Projection and illuminator optics lifetime	▪ Reticle protection during storage, handling and use	4. Source power	4. Reticle protection during storage, handling and use
5. Resist resolution, sensitivity and LER	▪ Source power	▪ Reticle protection during storage, handling and use	5. Projection and illuminator optics quality & lifetime
6. Optics quality for 32-nm half-pitch node	▪ Projection and illuminator optics lifetime	▪ Projection and illuminator optics quality & lifetime	

Ref: Steering Committees of 2nd-5th International EUV Symposia, 2003-2006

The EUV source is top ranked, but the defect-free mask is still one of the challenges.

Mask Blank Development Center



→Formed MBDC team January ’03

→Major tool qualified (LDD & M1350) October ’03

 # Achieved 1st ML Total Defect 1.25 def/cm^2 @80 nm April ’04

→Deposition tool & process upgraded March ’05

 # Champion Total Defects 0.09 def/cm^2 @78 nm June ’05

 # New champion Total defects 0.10 def/cm^2 @56 nm Sep. ’07

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MBDC EUV Blank Infrastructure

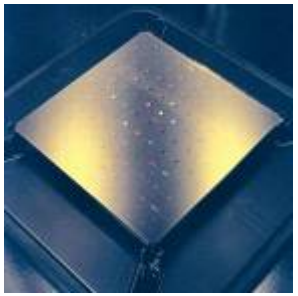
ASC5500 Cleaner

AFM

FIB/SEM

M1350

M7360



Defect-free Mask Blanks

Veeco Nexus

EUV Reflectometer

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Blank Inspection Revolution

- Lasertec MAGICS tools
  - Multi-beam confocal microscopy

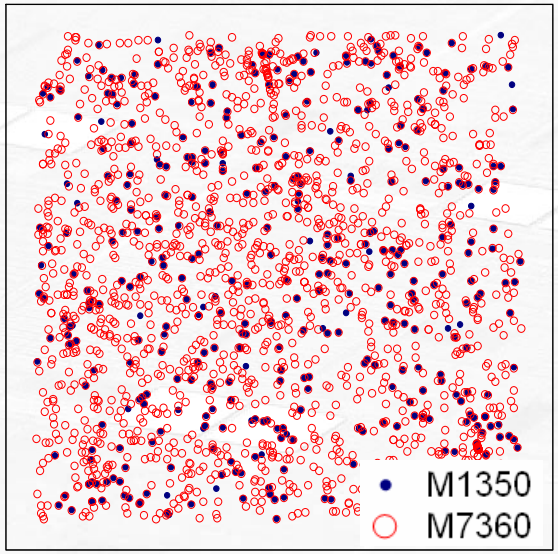
M1350 (1st generation)

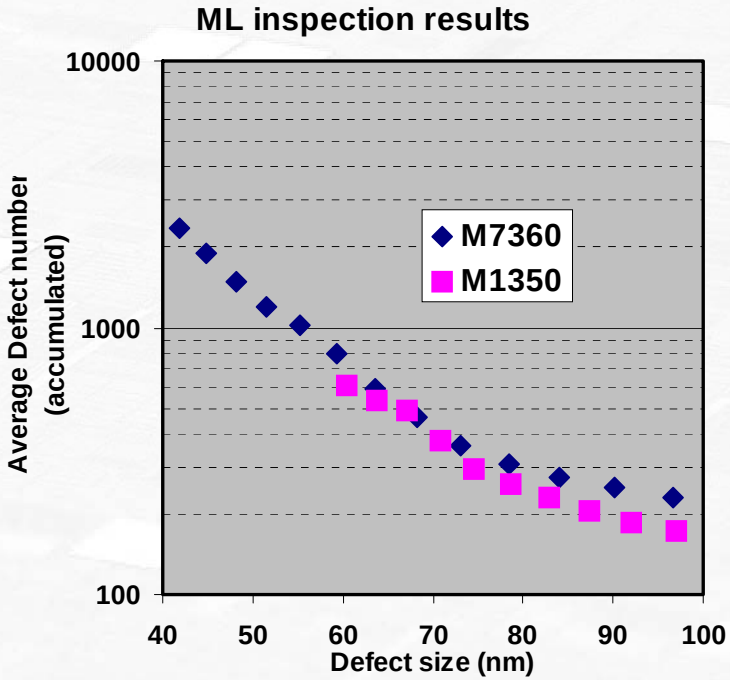
- 488 nm laser
- Sensitivity (PSL equivalent)
  - ✓51 nm (Qz)
  - ✓67 nm (ML)
- 30 min./plate
- Since 2003

M7360 (2nd generation)

- 266 nm laser
- Sensitivity (PSL equivalent)
  - ✓~35 nm (Qz)
  - ✓~50 nm (ML)
- 90 min./plate
- Since 2006

Sensitivity Improvement

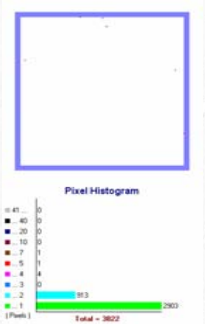


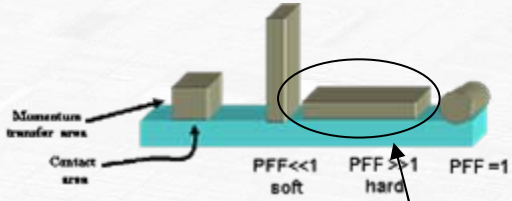


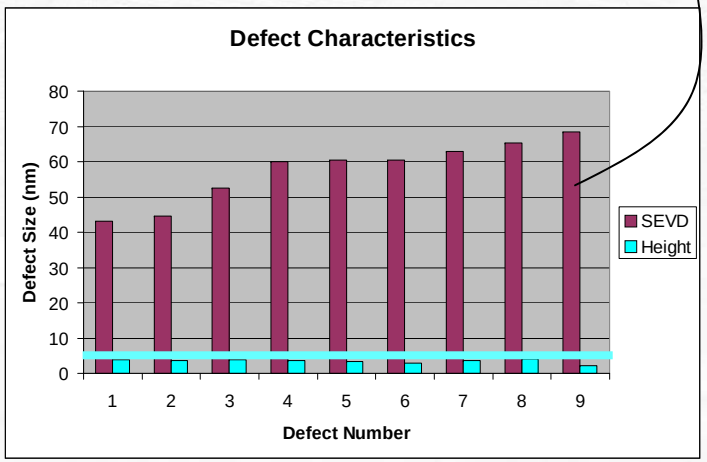
- With the high sensitivity of the M7360, we can see more than 4X as many defects as we could with the M1350.
- Enhanced inspection capability gives the MBDC an enhanced development capability (cleaning, ML deposition, and handling processes).

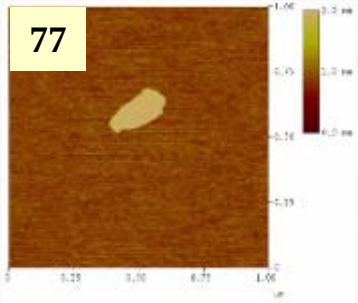
Accelerated Cleaning Capability

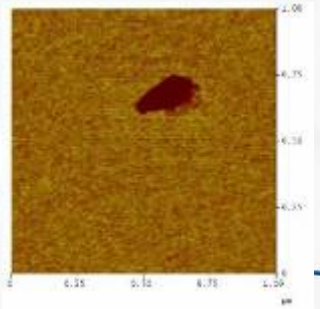
- Demonstrated zero particle density@ 30 nm
- Demonstrated removal of all defects with height > 4 nm
- Demonstrated removal of 10 nm deposited particle by single cleaning
- Demonstrated removal of all remaining defects by multiple cleaning
- Demonstrated all remaining hard defects were embedded











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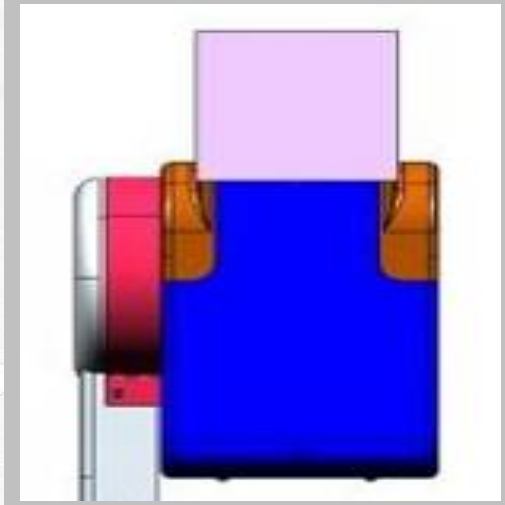
Deposition Tool Evolution

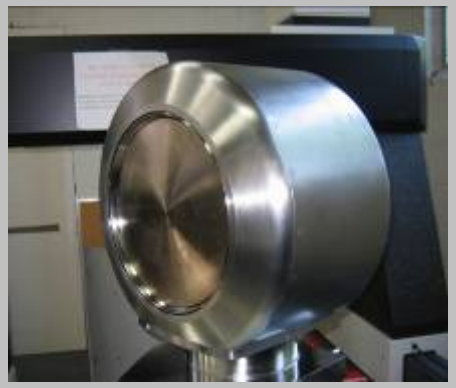


Low Profile Fixture

Minimize coating near substrate

ESC Development

Minimize back side contamination



Target Shield Upgrade

Minimize deposition on the shield

Door Upgrade

Minimize the deposited thickness on chamber wall

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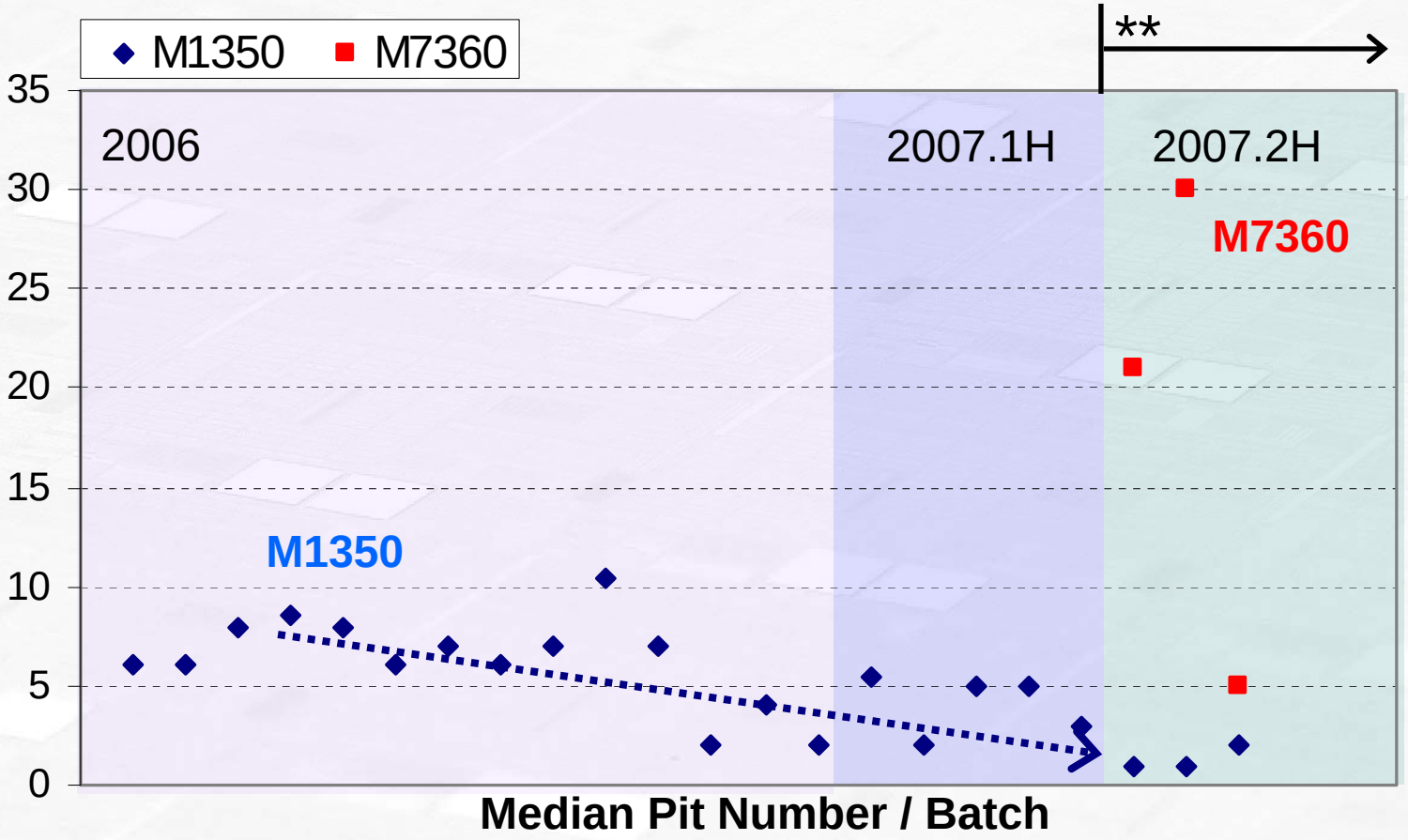
Substrate Pit Improvement

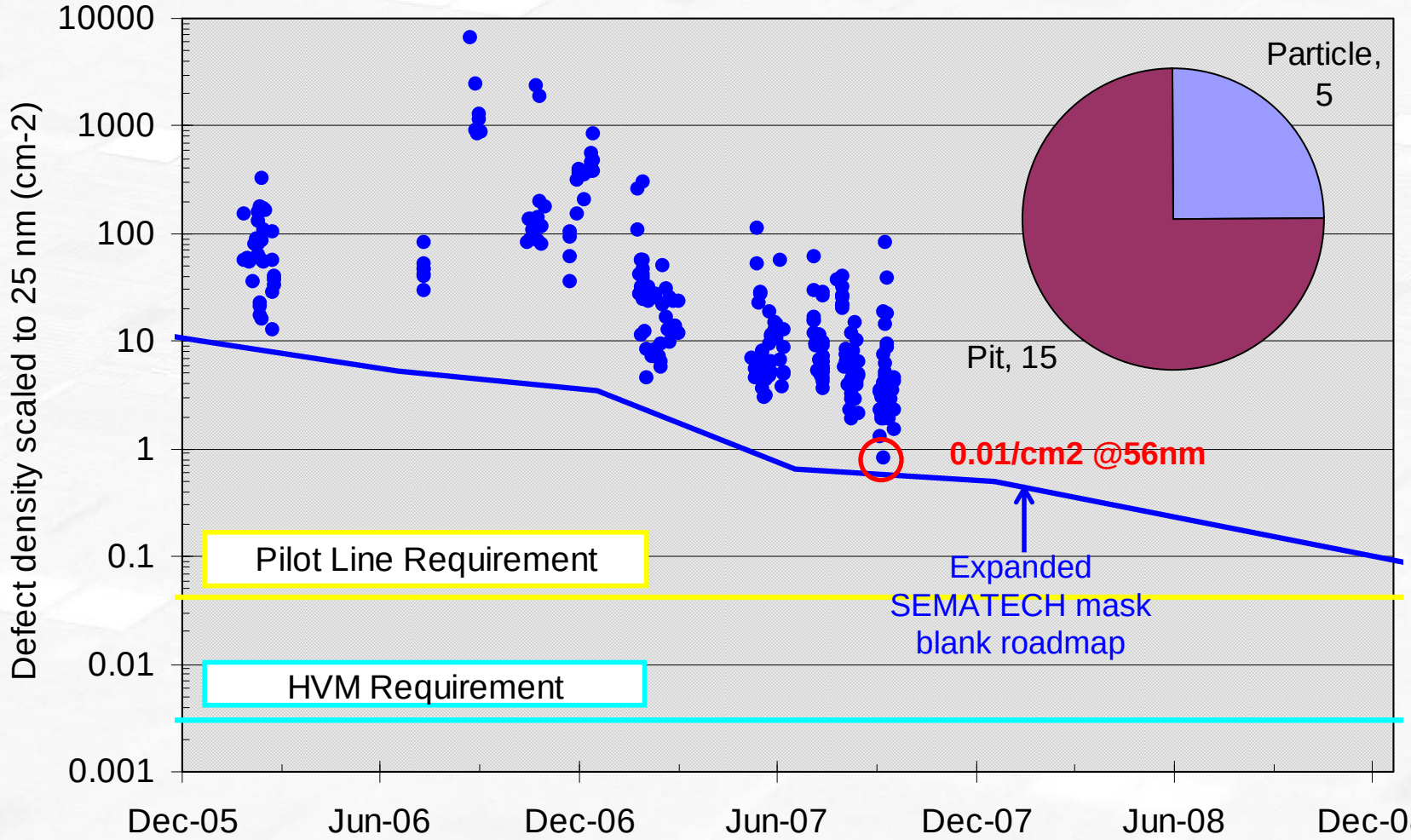


**M7360 has been actively applied, and suppliers have been expanded.

→ We were able to secure a limited quantity of extremely clean plates with < 10 pits each as measured on the M7360.

Blank Defect Results (2006-07)

1,2,3 & 4



Cf) The data before June '07 was converted from M1350 to M7360.

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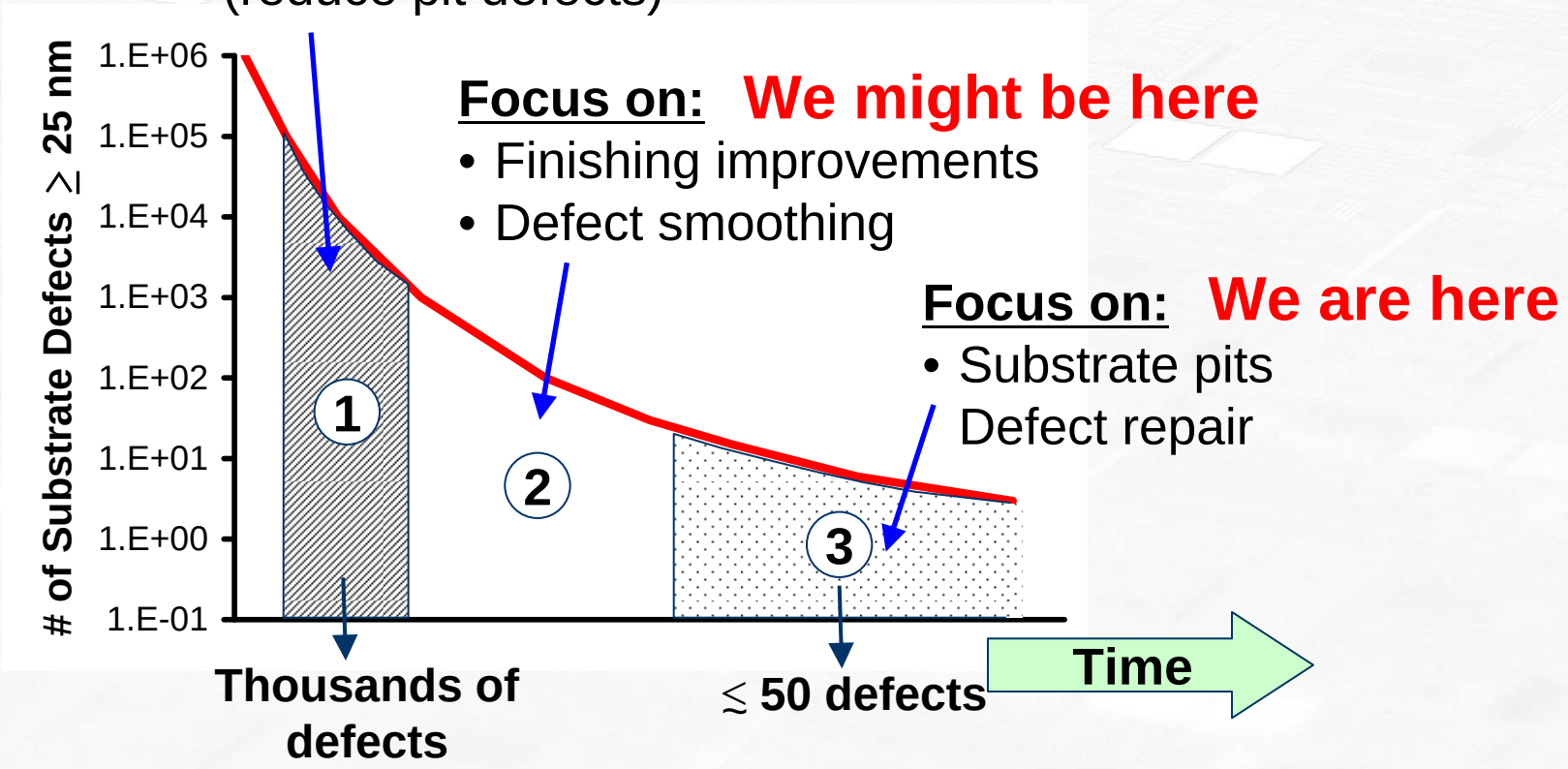
Substrate Pit Reduction Strategy

Focus on:
- Substrate finishing (reduce pit defects)



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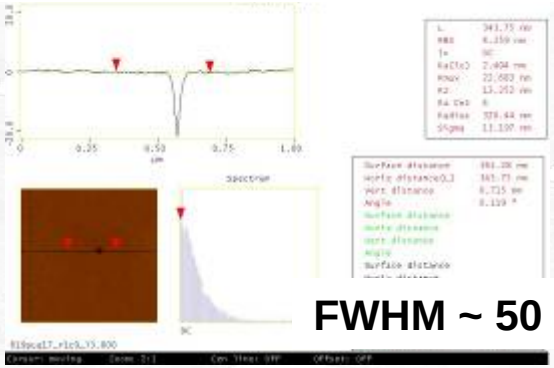
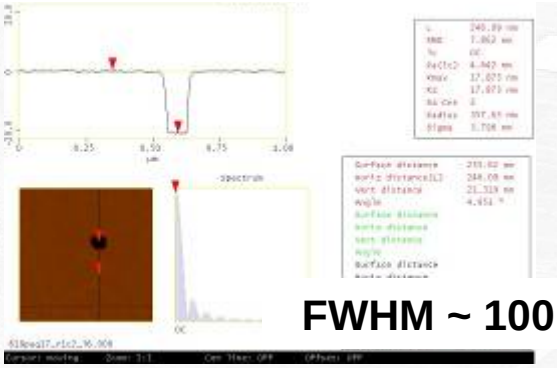
Smoothing Successfully Transferred

Depth : 21 nm → 0.55 nm



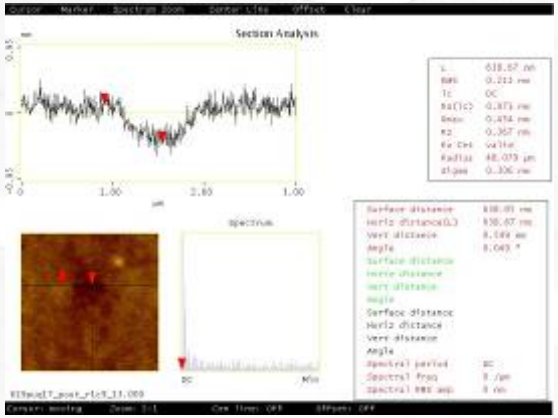
FWHM ~ 50 nm

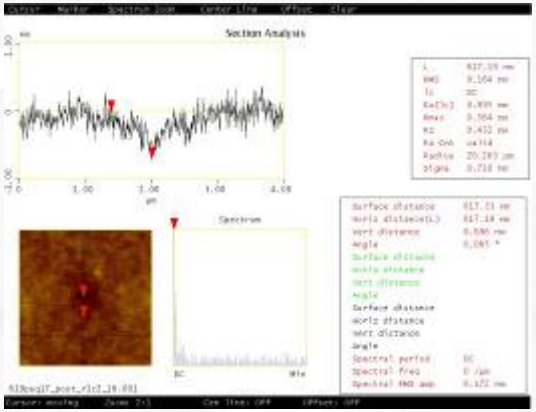
Depth : 21 nm → 0.6 nm



FWHM ~ 100 nm

Before





After

Smoothing renders 21 nm deep pits non-printable.

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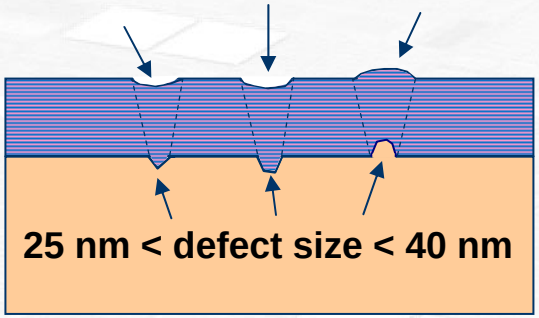
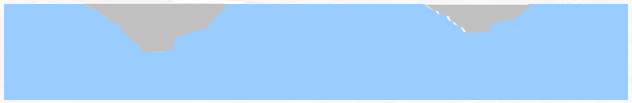
Pit Defect Repair Feasibility

ML decoration makes substrate defects < 40 nm "visible"



Assuming that # of substrate pits is countable and tolerable



1) Locate defects without marking using LT coordinates.
2) Reduce defect height/depth to <1 nm (non-printable).
3) Repair should survive in common cleaning.
4) Repair process should be very clean.

Challenging Requirements → In discussion with suppliers

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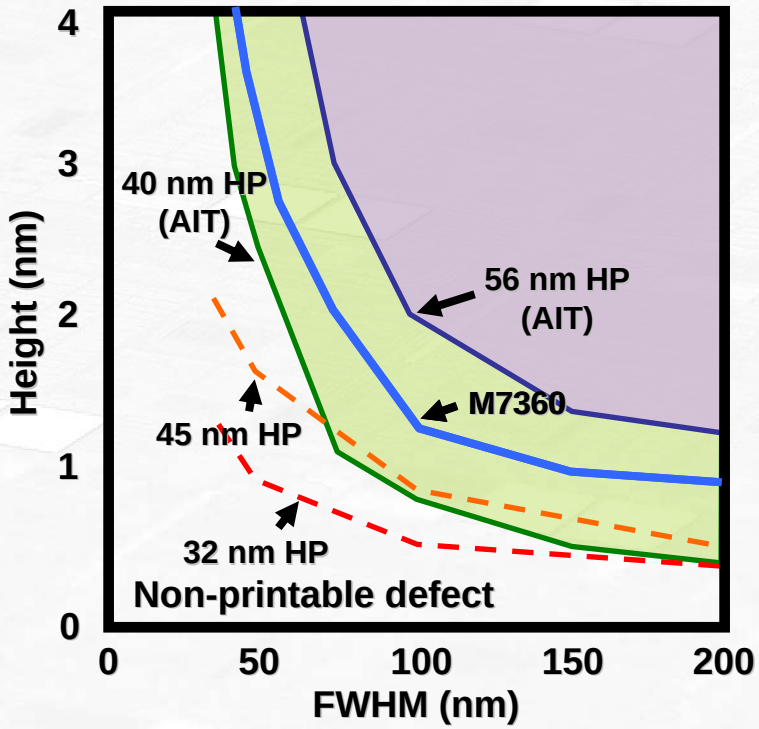
Printability & Inspection Capability



Lasertec M7360 can support pilot line EUVL mask blanks, but we need a higher sensitivity machine for 32 nm HP HVM.

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Conclusion

- EUV mask blank defectivity was dramatically decreased.
  - MBDC achieved 0.10/cm^2 defect @ 56 nm in the M7360.
  - EUV blank suppliers showed great progress over 2007.
- EUV mask blanks will likely be ready to support EUV beta tool pilot-line operation in 2009 if current development efforts are maintained.
- Pit defects dominate the defect Pareto today.
  - Substrate quality improvement is important.
  - Pit defect repair feasibility should be investigated.
  - Clean smoothing process should be developed at the same time.
- A new generation of inspection tools is required to support 32 nm HP HVM specs (mid-term).

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Thank you

for your attention