The Development of Coating Technology for the Production of Mask Blanks for EUVL

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INTERNATIONAL SEMATECH

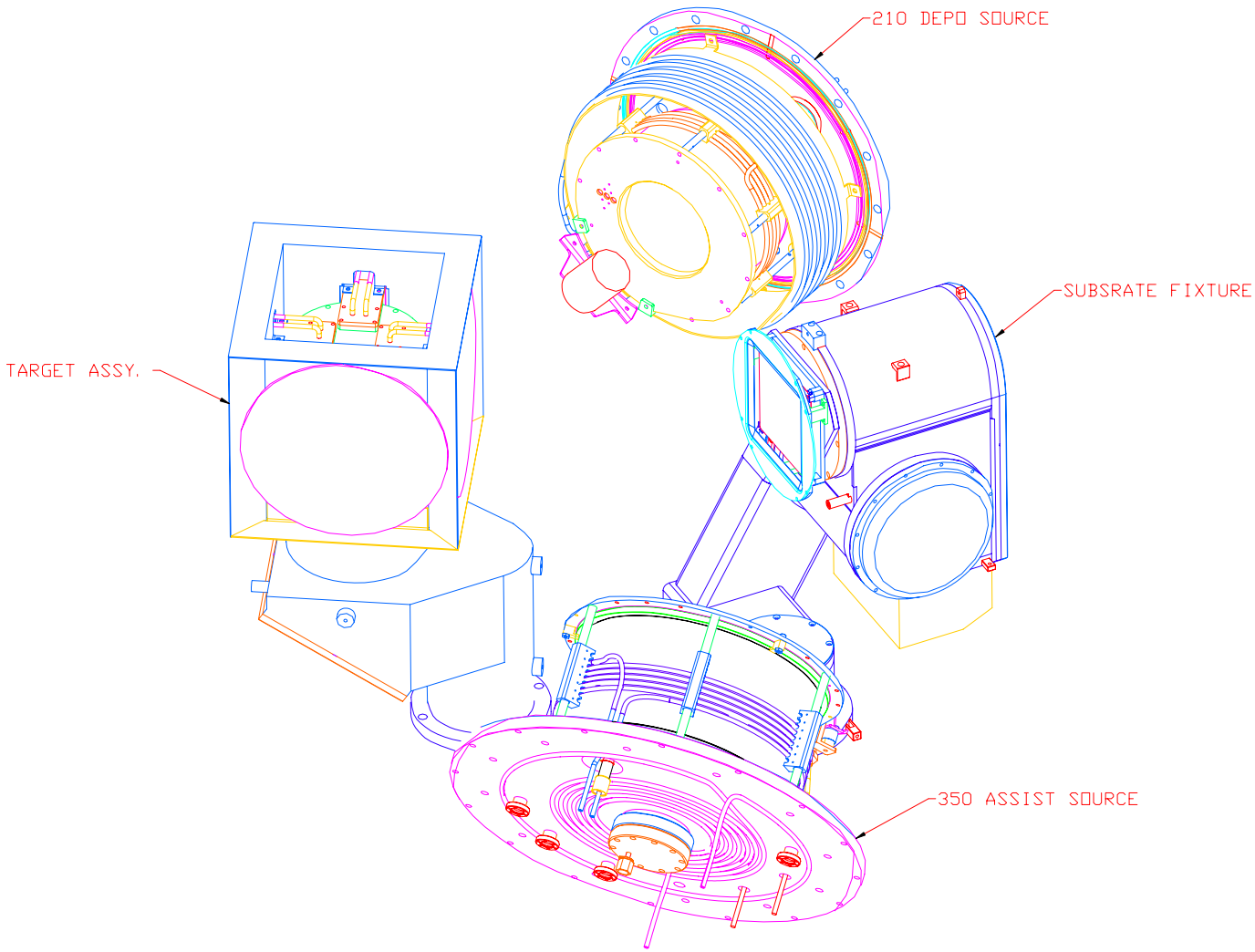
Outline

- Objective
- EUV reflectivity, uniformity and defect goals
- EUV reflectivity and uniformity achievements
- Summary

Objective

- Veeco is engaged with International SEMATECH and the Lawrence Livermore National Laboratory to establish a state-of-the-art Multilayer (ML) deposition tool for EUVL blank production.
- The work reported here is being performed at the ISMT MBDC,Mask Blank Dev. Center, (Albany, NY).
- We report here on work performed to establish and characterize a baseline Mo/Si multilayer coating process.
- Future work will be aimed at implementing a smoothing (ion-assist) process and performing defect characterization and root cause analysis with the goal to improve current tool capability to meet production specifications for EUVL mask blanks.

NEXUS LDD


210 DEPO SOURCE
SUBSRATE FIXTURE
TARGET ASSY.
350 ASSIST SOURCE

Unique Features of Ion Beam Deposition

- **Low particulate**
  - Plasma generation area and the wafer area are separated, ICP gridded source;
  - Optimized configuration: side sputtering, out of plane ion assist source position
- **Film microstructure: stress, density; and interface control with IBD**
  - Substrate Tilt control;
  - Primary beam and Assist beam species and energy, Assist flux;
  - Proper choice of geometry is critical in IBD to minimize amount of high energy ions, neutrals, and secondary sputtered material on the wafer.
- **IBD provides beam directionality**
  - IBD is a true low-pressure process ($\approx 2 \times 10^{-4}$ T), that results in gas phase collisional mean free path » target to substrate distance;
  - Naturally highly collimated sputtered species;
  - Deposition can be carried out at well defined impingement angles through wafer tilt
- **Excellent uniformity achievable through wafer tilt and rotation**

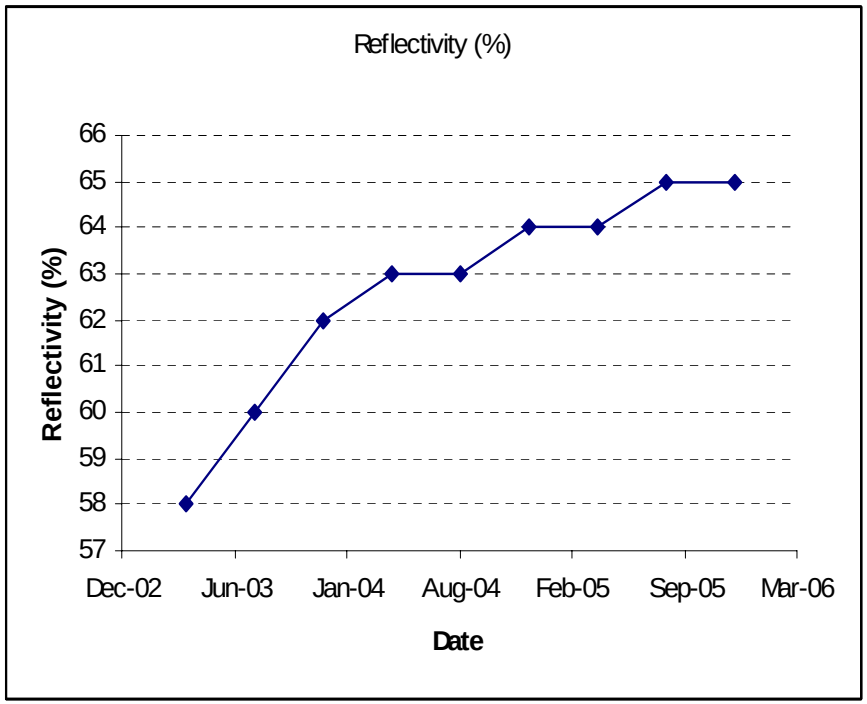
LDD IBD System Features

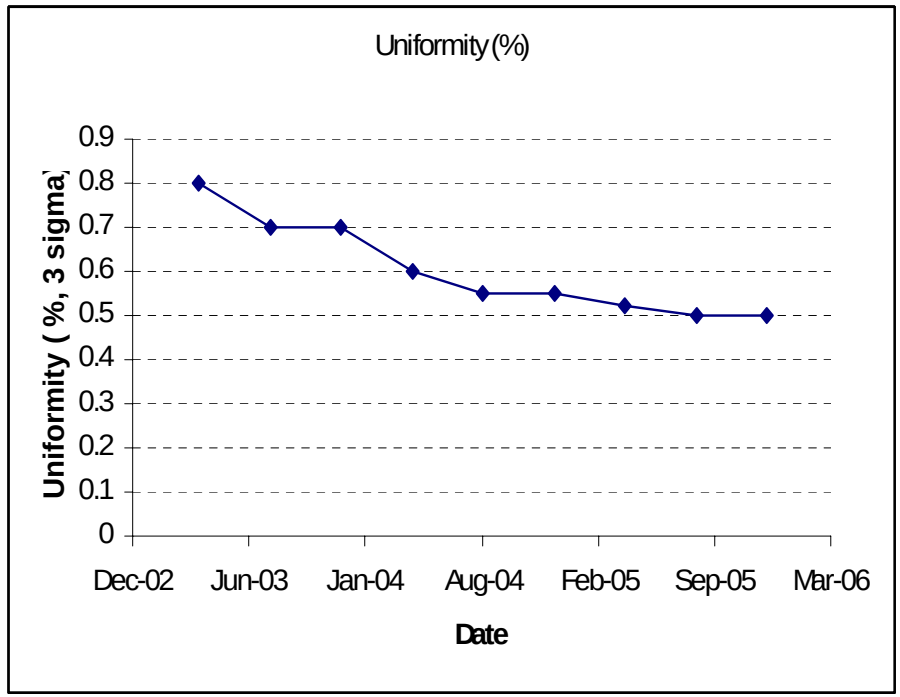
- **Deposition Source - Target distance optimized to confine ion beam on the target to better than 99.9% reducing backstreaming of sputtered material towards the source.**
- **Target - Substrate distance optimized to allow deposition rates around 0.5 to 2 Å/sec, and to obtain excellent thickness uniformity to 0.6 % without shapers.**
- **Assist source - Substrate distance optimized to provide excellent uniformity in preclean mode and to allow exceptional film property homogeneity**

ML Reflectivity and Uniformity Goals

- **High reflectivity increases contrast and throughput & lowers the cost per-exposure**
- **Uniform reflectivity is required by the process window budget (illumination uniformity requirement)**

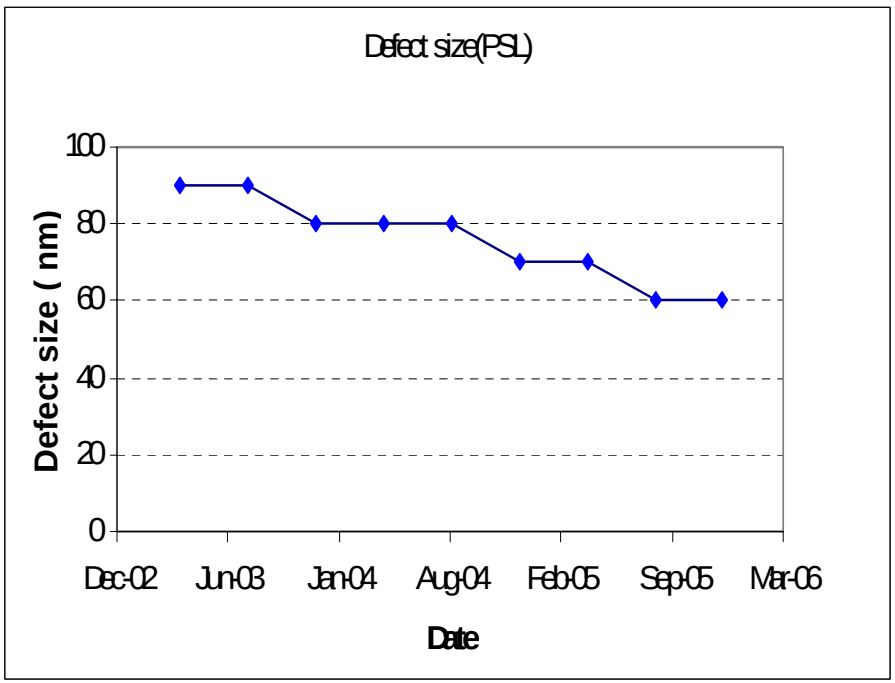
Multilayer Performance Goals

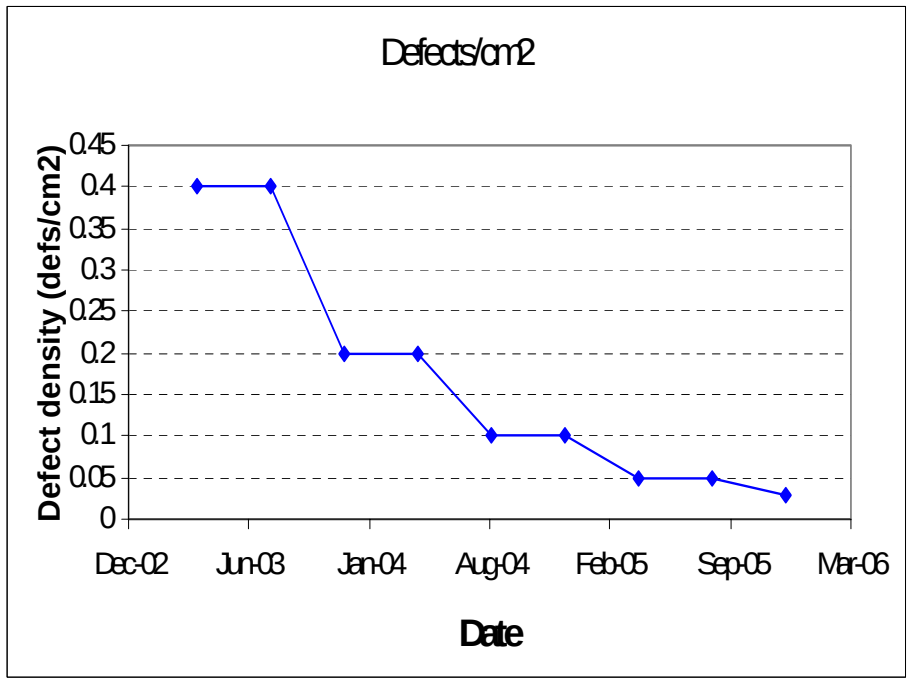




ML Defect Reduction Requirements & Goal

- **Lower defect density are required for cost efficiency and yield**
- **Defect size decreasing with technology node**



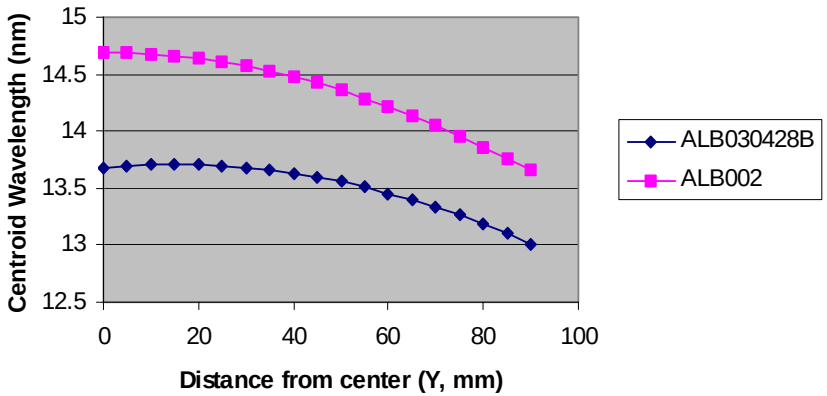


EUV Deposition Process Improvement

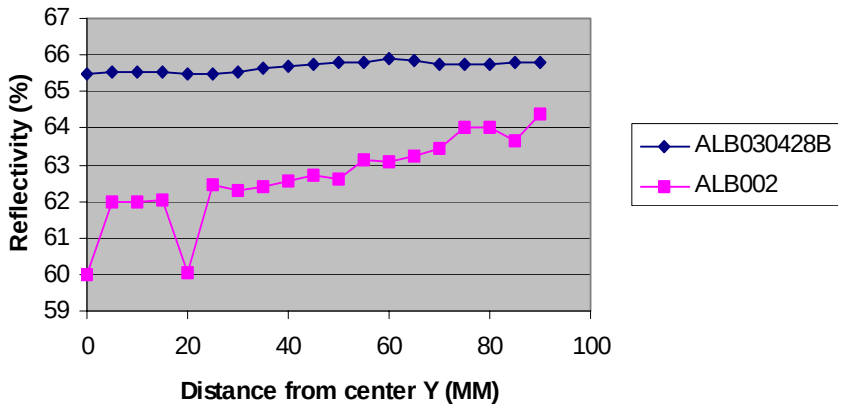
May 2003

Centroid uniformity = 0.7nm 3sigma

Centroid Wavelength (nm)



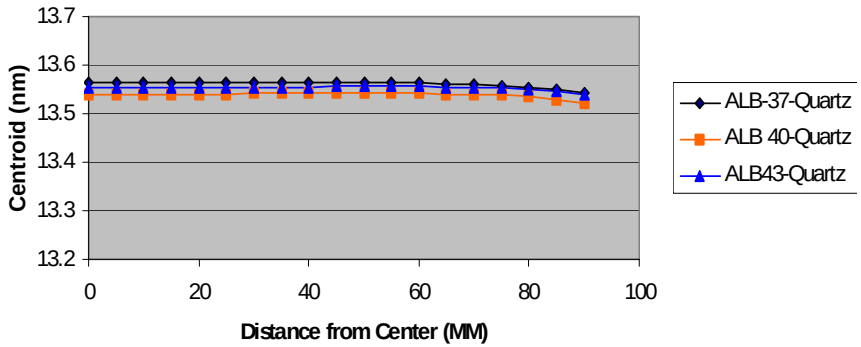
Reflectivty (%)



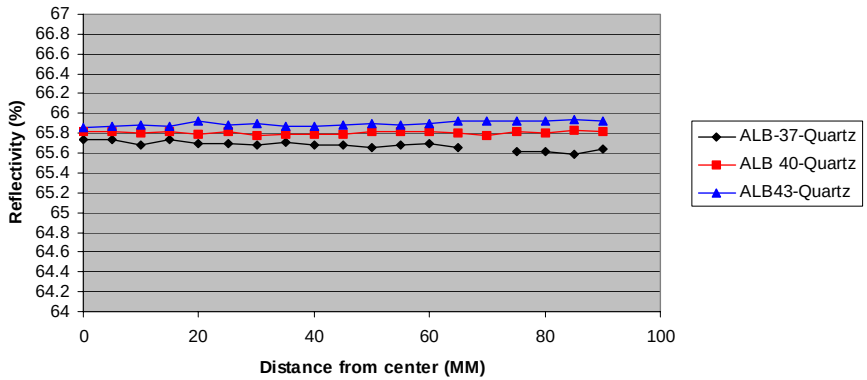
July 2003

Centroid uniformity = 0.01nm 3sigma (Goal < 0.07nm)

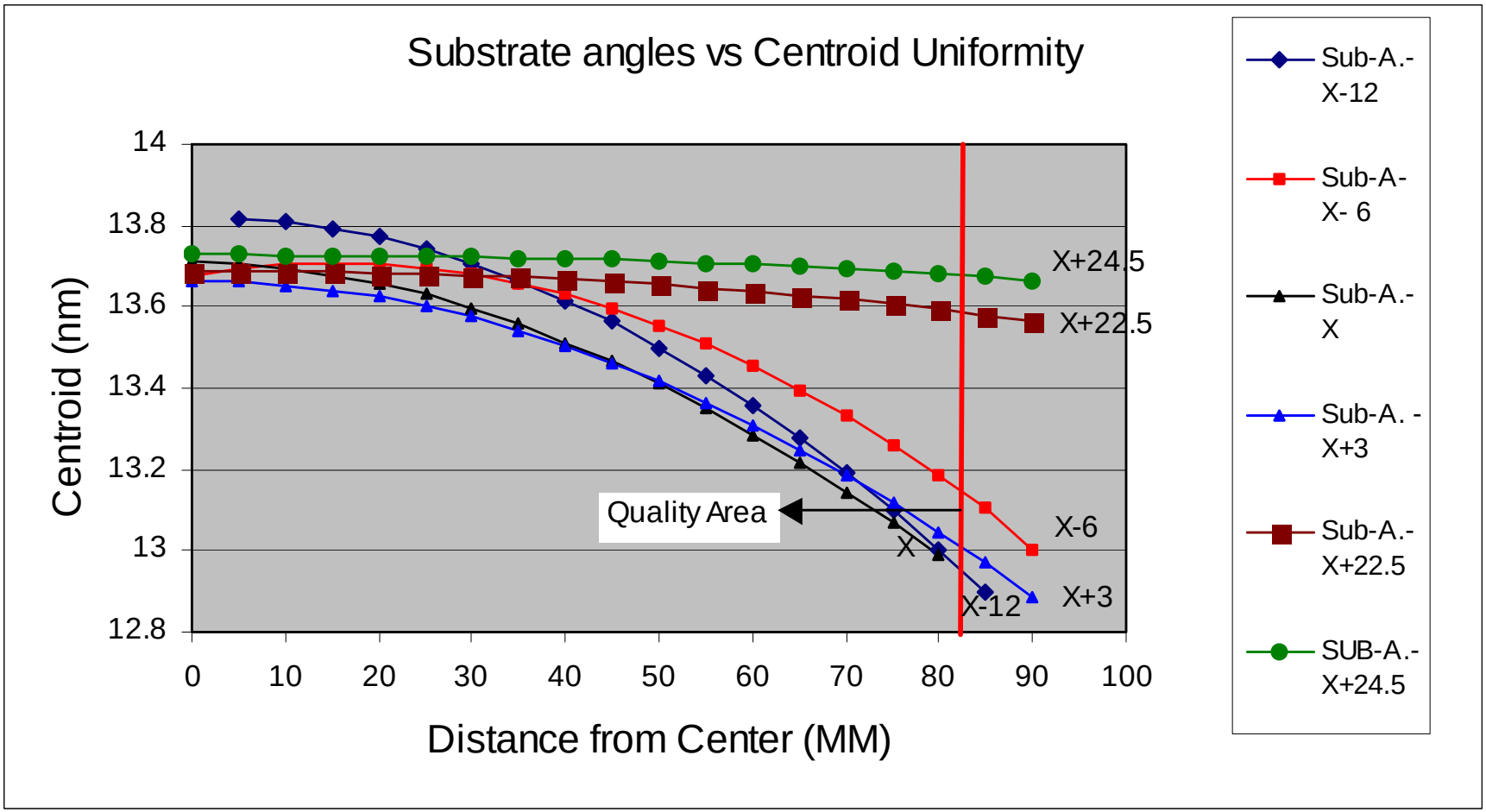
EUV Centroid on quartz



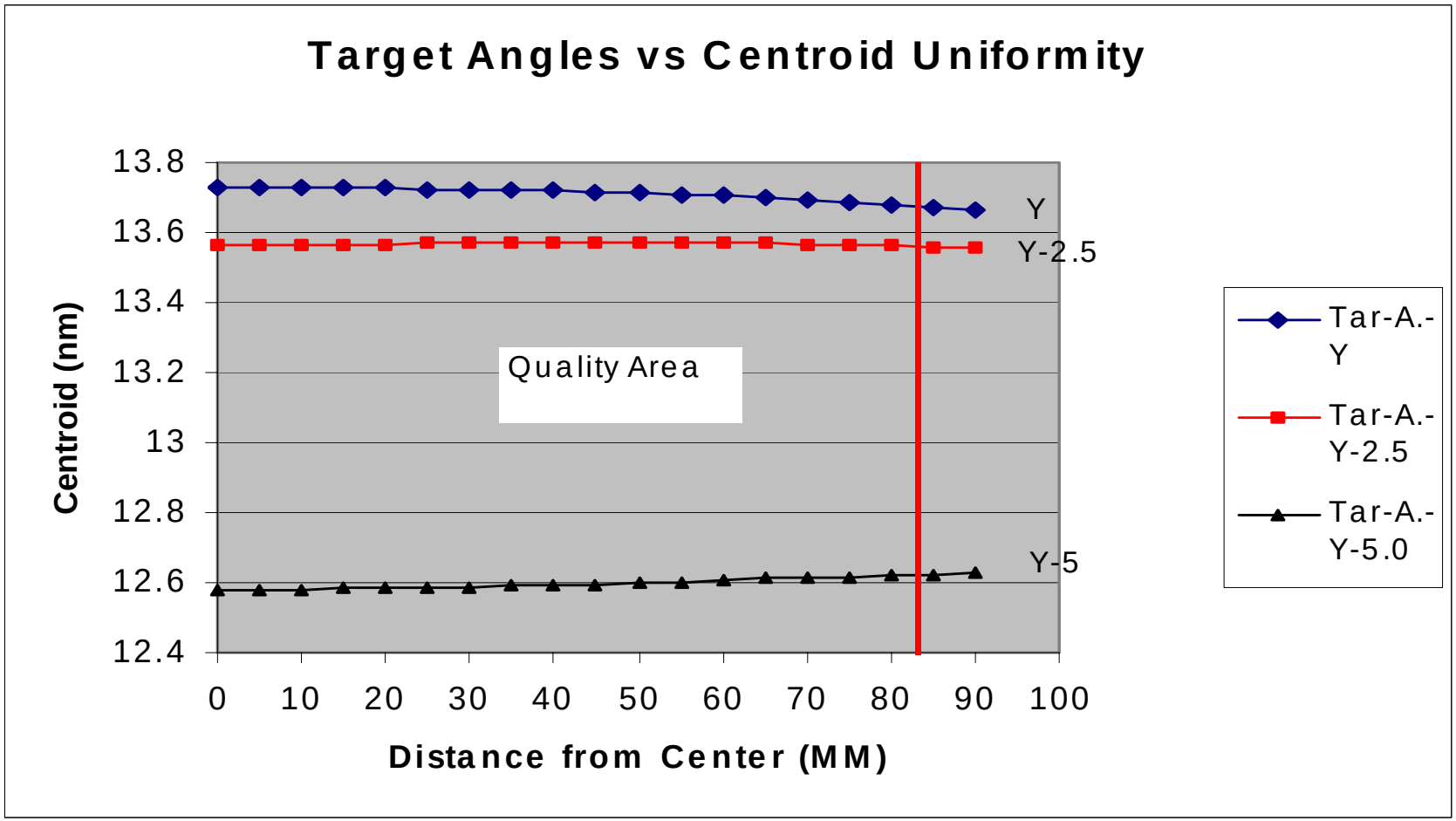
EUV Reflectivity on Quartz



We achieved optimal Centroid Uniformity through Substrate Angle Optimization

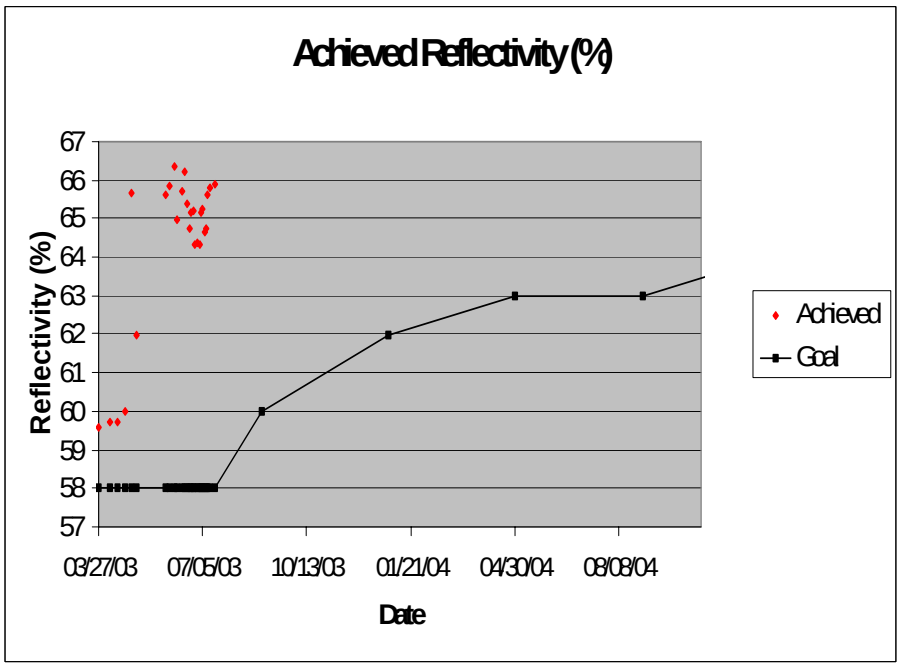


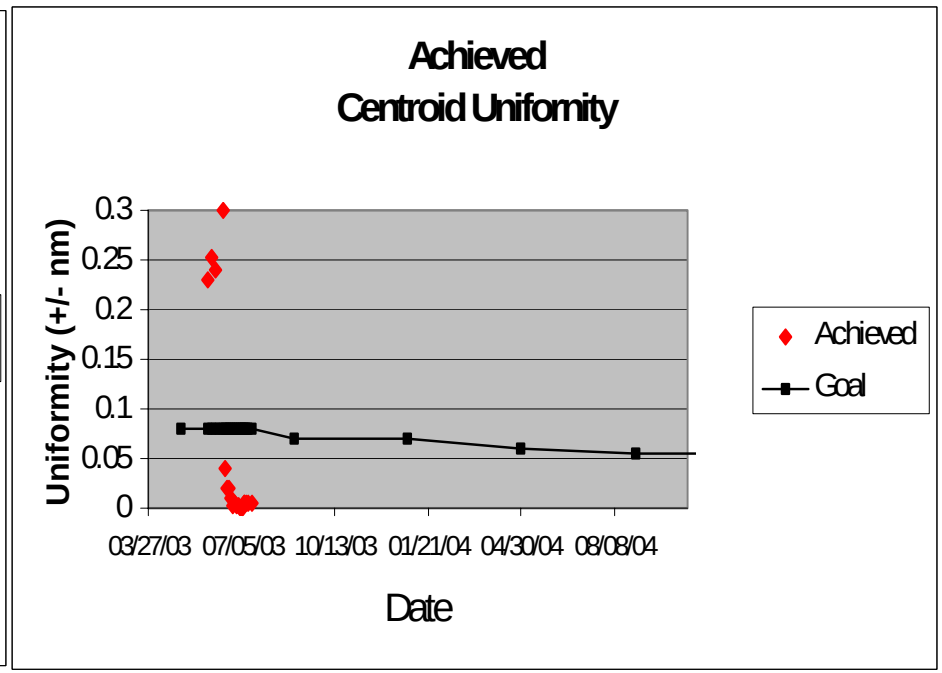
We achieved optimal Centroid Uniformity through Target Angle Optimization



Substrate angle has a bigger impact than target angle on the uniformity

We have already achieved and exceeded the goal for Reflectivity & Uniformity





Process Repeatability

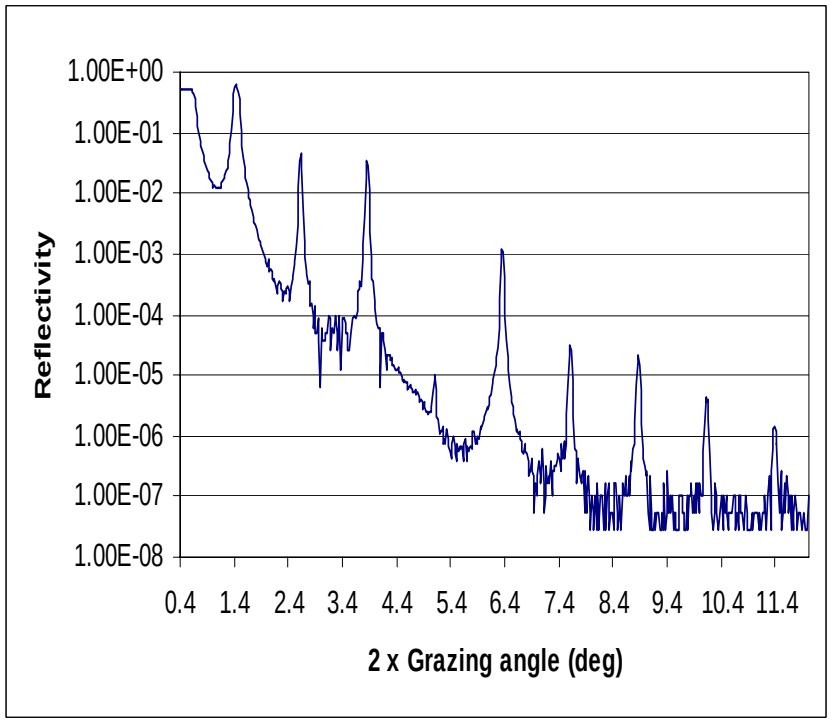
Silicon Strips

	Reflectivity	3 Sigma	Centroid(nm)	3 Sigma
ALB035	65.23	1.23	13.58	0.0114
ALB036	65.17	1.41	13.57	0.0099
ALB038	65.15	1.59	13.54	0.0129
ALB039	64.64	1.92	13.56	0.0108
ALB041	64.73	1.86	13.56	0.0111
Average	64.984		13.562	
3 sigma	0.83		0.04	

Pristine Quartz Plate

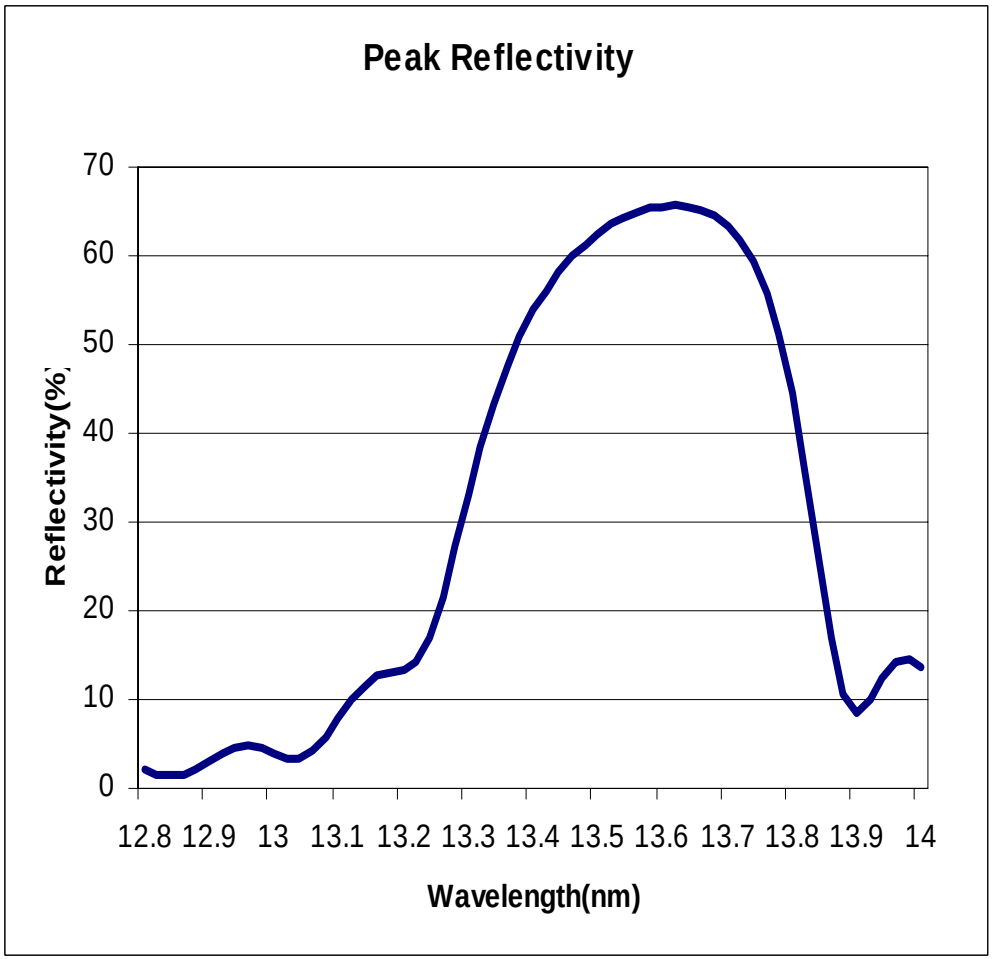
	Reflectivity	3 Sigma	Centroid(nm)	3 Sigma
ALB037	65.6	0.123	13.56	0.0168
ALB040	65.8	0.048	13.54	0.015
ALB043	65.89	0.075	13.55	0.0132
Average	65.76333		13.55	
3 sigma	0.45		0.03	

ML X-ray Reflectivity Measurement



There are no observable thickness errors or drifts in the coating.

Reflectivity Spectrum of ML Blank



Peak Reflectivity: 65.8%
Peak Wavelength: 13.62
Centroid Wavelength: 13.56 nm
FWHM: 0.528 nm

We have exceeded the P38 SEMI production specifications for Reflectance and Centroid uniformity

Current process status (7/18/03)

	Reflectance (%)	Centroid (nm)	FWHM
	65.8 +/- **0.075** (3 δ)	13.55 +/- **0.012** (3 δ)	0.53 +/- **0.0021** (3 δ)
P38-1102 SEMI Standard- class A	0.50%	0.05	0.006

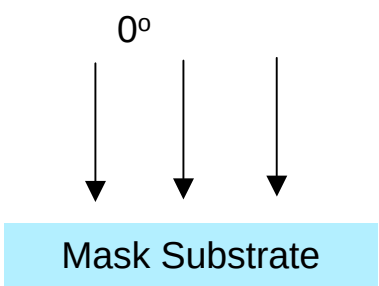
- Reflectance meet 2006 target spec.
- Uniformity meet 2007 production class A spec.

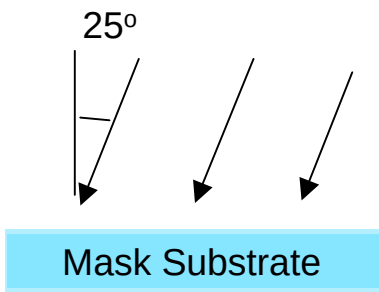
Initial tool evaluation for particle smoothing

- The current deposition tool at Albany, as well as other tools deployed with potential EUVL mask suppliers, do not allow for normal incidence etching

- These tools enable etching at up to ~25 degrees from normal incidence

- Will this be sufficient to use the multilayer smoothing process for substrate particle mitigation?





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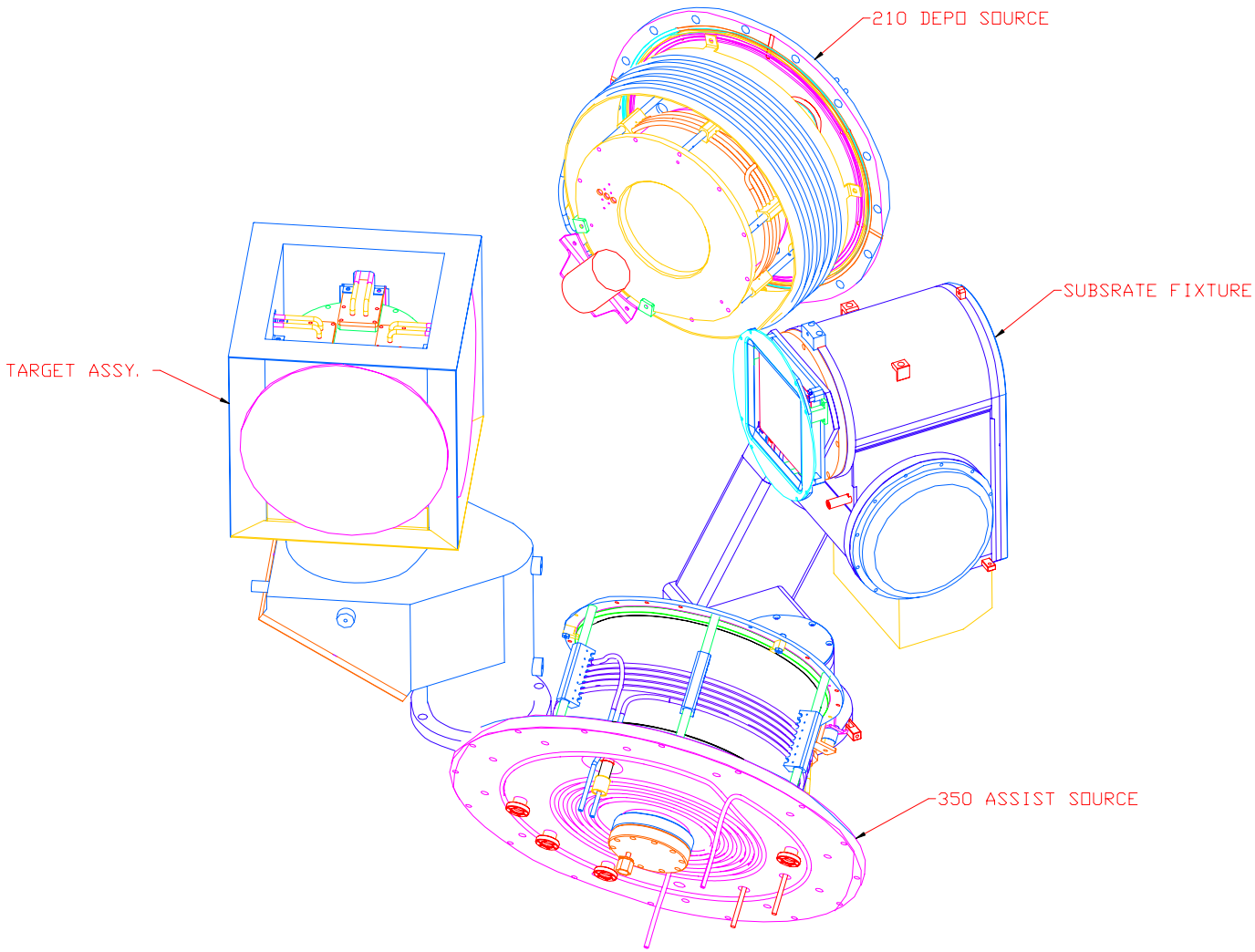
210 DEPO SOURCE
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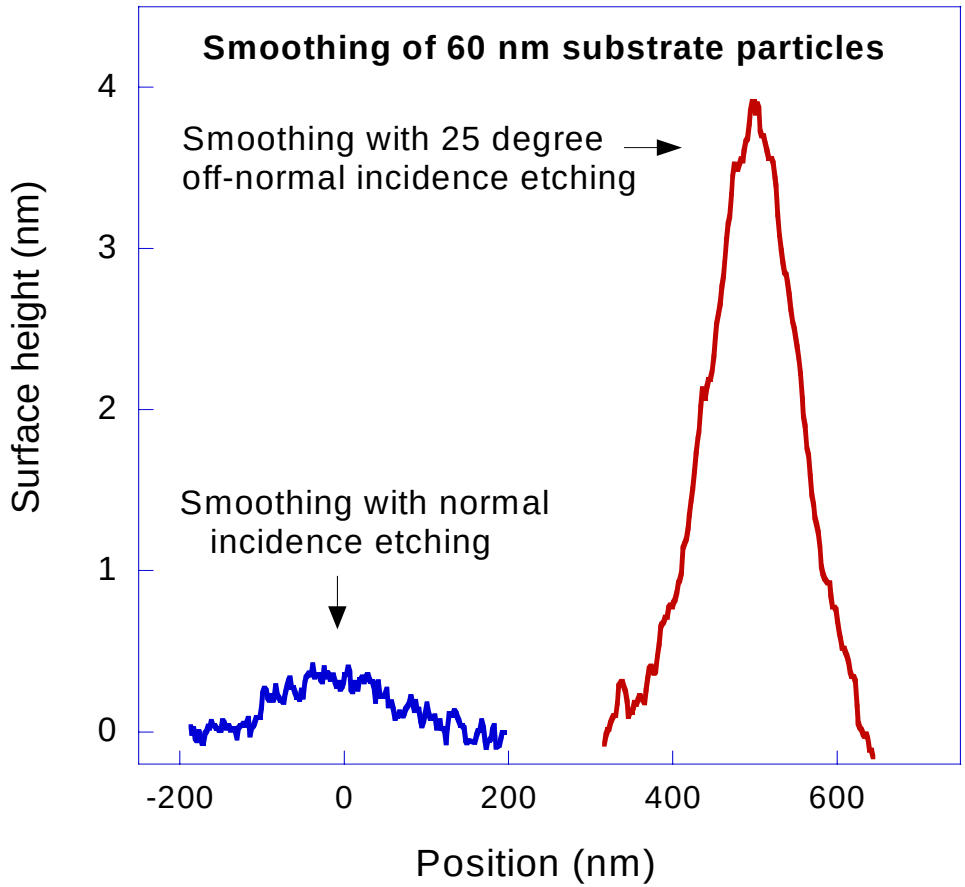
Ion Assisted Smoothing Process

- Current optimized process (without Ion-Assist) uses high substrate angle.
- LLNL Ion-Assisted (smoothing) process requires near normal incidence (0 degree) substrate angle.
  - 60 nm substrate defect reduced to 0.50 nm using Ion-Assist process at 0 degree substrate angle.
  - 60 nm substrate defect is 4.34 nm using Ion-Assist process at + 25 degree substrate angle.

A 25 degree etching angle decreases the effectiveness of the smoothing process



2004 Objectives / Goals
(All to be performed on ISMT tool at the MBDC)

- Perform defect Root Cause Analysis and initiate a project to develop ML deposition tool upgrades
- Assess and improve cleanliness of 2nd ion source smoothing process
- Demonstrate feasibility of 2006 multilayer mask blank performance target (0.1 defects/cm2 @ 80 nm) by end of year 2004.

Summary

- A Veeco Nexus Mo/Si multilayer deposition tool has been installed and accepted at the ISMT MBDC in Albany NY.
- An EUV reflectance of 65.8% has been achieved
- The wavelength uniformity is 0.012 nm (3 δ)
- The reflectance uniformity is 0.075 % (3 δ)
- The above reflectance and uniformity values were achieved well ahead of schedule and exceed the SEMI P38 specifications for 2007.
- Off normal etching is not optimal for particle smoothing. We have designed a straightforward modification to enable normal incidence etching on the tool
- While these results are very promising, the greatest challenges are ahead of us (defect reduction & mitigation).