Recent progress in EUV mask blanks development at HOYA

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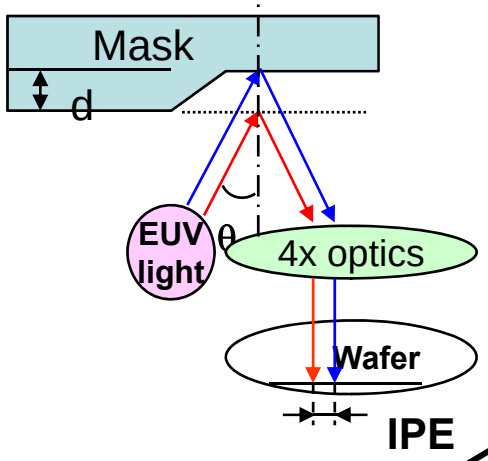
Outline

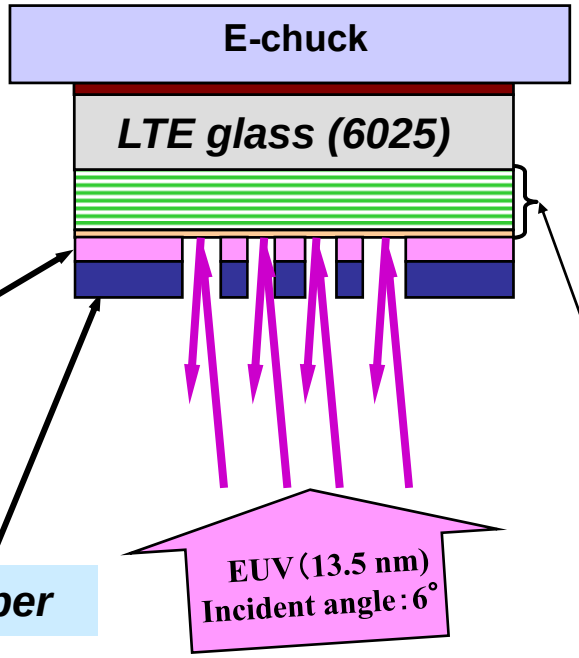
- Introduction
  - EUV mask and critical issues
  - HOYA EUV blanks
  - EUV blanks roadmap
- EUV blanks pilot line
- Recent performance of EUV blanks
  - Flatness improvement
  - Defect reduction (2002 – 2007)
  - EUV reflectivity
  - Absorber stack
- Summary

Reflective EUV mask and critical issues

50 nm PV flatness on both sides (in 142mm sq)

Zero defects ML @30nm
⇒Killer phase defects: 70nmW x 2nmH



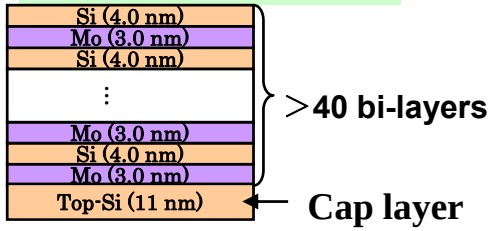


Buffer layer

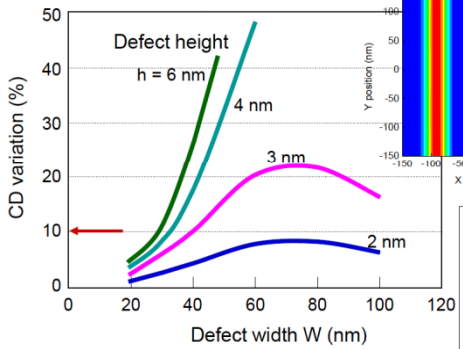
Protect layer for dry etching and absorber repair

Absorber

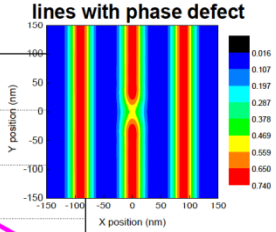
Mo/Si multilayer

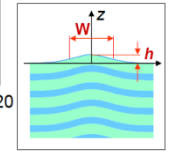


Simulation results



Projected image of 45 nm dense lines with phase defect





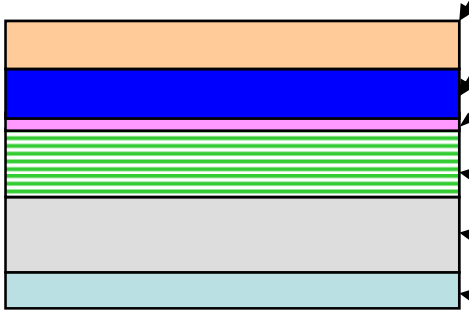
T. Terasawa et al. PMJ2004

LTE: Low Thermal Expansion

High EUV reflectivity:>67%
depending on throughput in EUVL

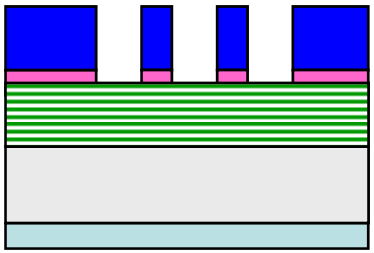
HOYA EUV mask blanks

EUV blanks w/ buffer

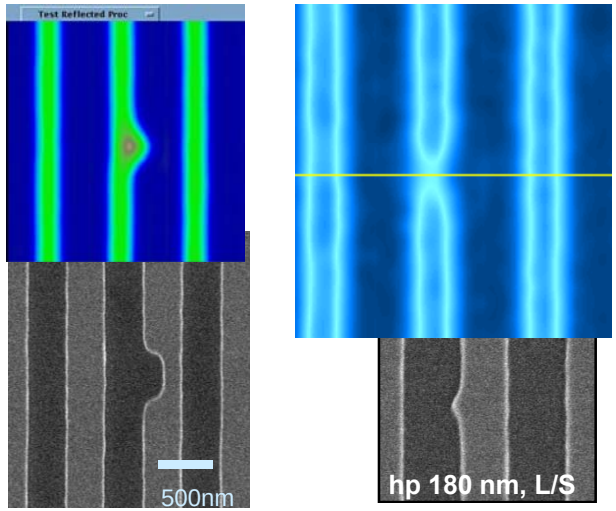


- ***CA resist***
- ***LR-TaBN absorber***
  LR: Low Reflectivity@190–270 nm
- ***CrN buffer layer***
  Protect layer for repair
- ***Mo/Si multilayer (ML)***
- ***LTE glass (6025)***
- ***Backside film***

Mask repair
- FIB
- AFM
- EB

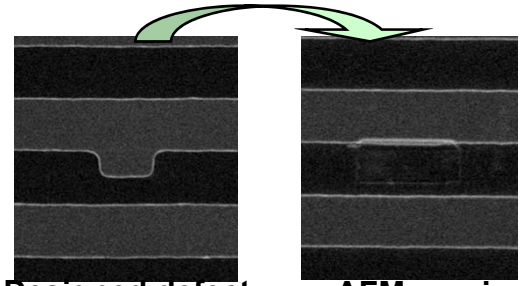


High mask inspection contrast



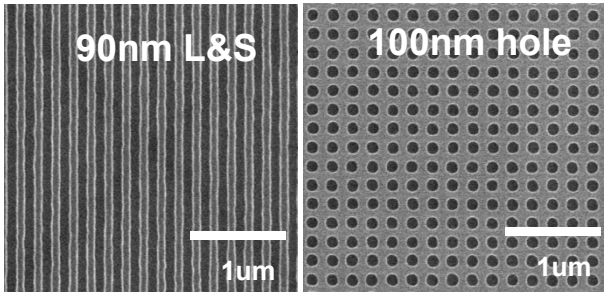
KLA5XX @ 257nm* NPI-5000@199nm**

*Damage less AFM repair**



Designed defect AFM repair

Fine patterning capability @300nm resist*



* T. Abe et al, BACUS 2006 ** T. Amano et al, BACUS 2007

✓It has been verified that LR-TaBN absorber is suitable for EUV mask fabrication

EUV blanks roadmap

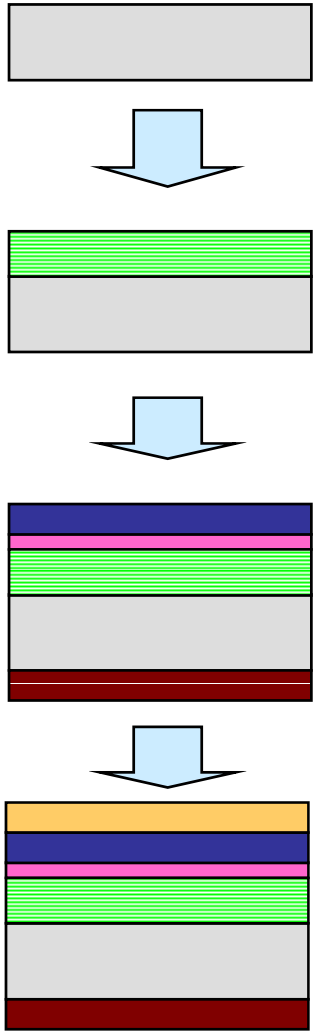
CY	2005	2006	2007	2008	2009	2010
DRAM hp	80 nm	70 nm	65 nm	57 nm	50 nm	45nm
HOYA (Blanks Div.)	α blanks ★Local polisher ★polisher	★Cleaner ★Sputter ★XRR	β blanks		γ blanks	
Sub. material	QZ	QZ/LTEM	LTEM	LTEM	LTEM	LTEM
Flatness	400nm	200nm	150nm	100nm	75nm	50nm
ML defects (def/cm²)	0.1@150nm	0.6@80nm	0.4@70nm	0.3@60nm	0.2@50nm	0.2@40nm
Peak Reflectivity (R)	63%	63%	64%	65%	66%	66%
λ uniformity	0.1nm	0.06nm	0.05nm	0.04nm	0.04nm	0.04nm
Absorber thickness uniformity	NA	+/-2%	+/-1.5%	+/-1%	+/-1%	+/-1%
Absorber defects (def/cm²)	NA	0.4@150nm	0.6@80nm	0.3@80nm	0.2@70nm	0.2@60nm
Defect inspection				350	New t	

Minimum requirement Current delivery spec. — Routine target for delivery — Technical target for future

- β EUV blanks (
  - Supply higher quality blanks for full field mask used in alpha tool
  - Improve EUV blanks quality toward production target
    - Verify low defects at smaller size by improving fabrication processes
    - Attain <50 nm PV on both sides using local polishing process

β EUV blanks pilot line at HOYA

Local polisher
Touch polisher
Cleaner



Substrate polish (by local polish and touch polish) and clean

Flatness measurement

Defect inspection (M1350)

Mo/Si ML and Si capping layer deposition (by IBD)

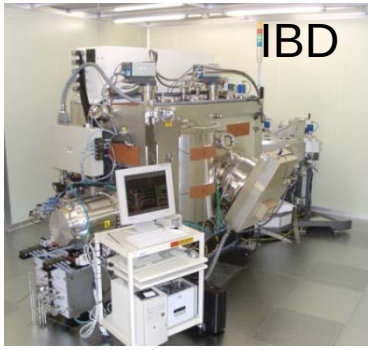
Defect inspection (M1350)

CrN buffer and LR-TaBN absorber deposition
Back side film coat (by magnetron sputtering)

Defect inspection (M1350)

EB resist coat and bake

Defect inspection



✓**Successfully built pilot line for β EUV blanks**

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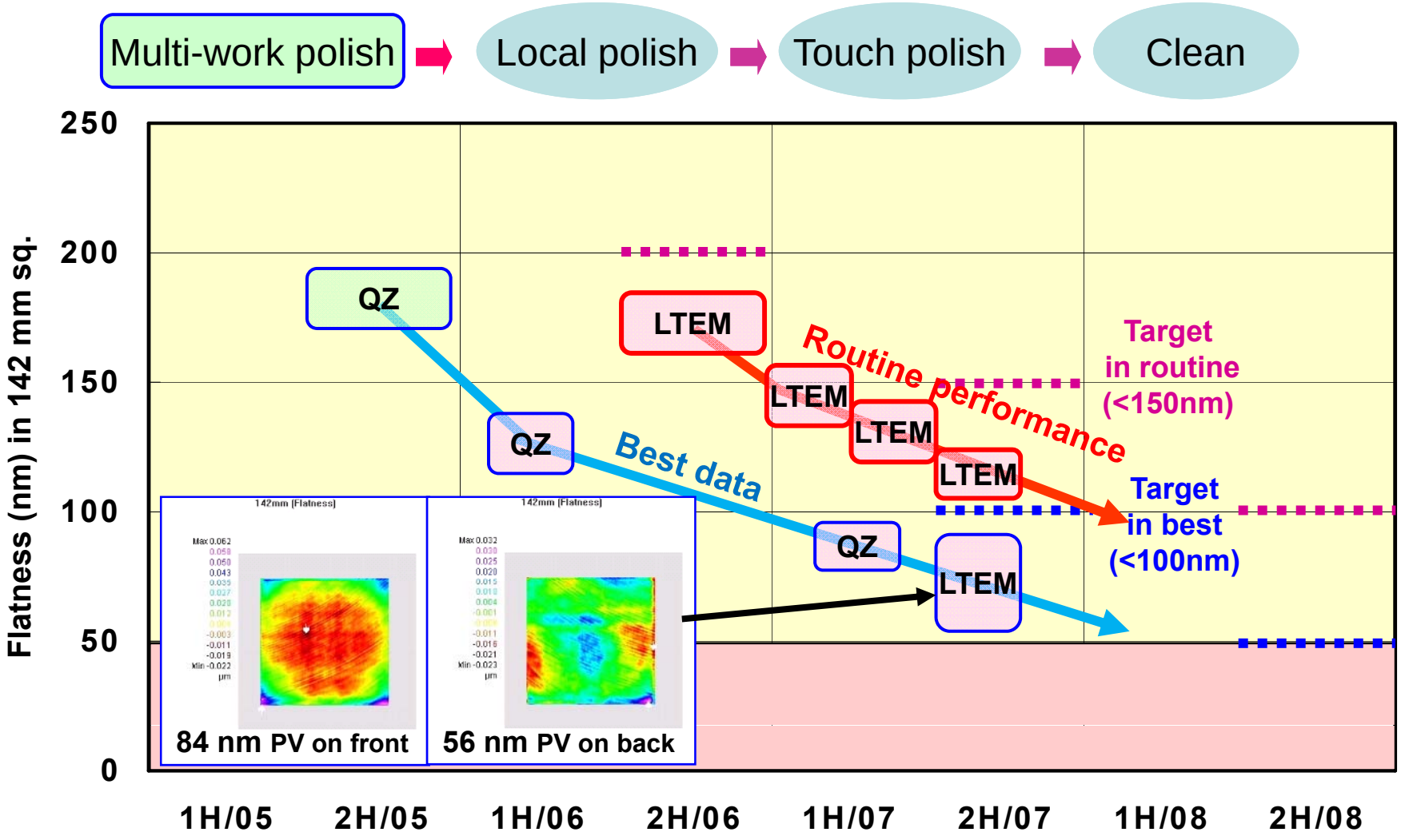
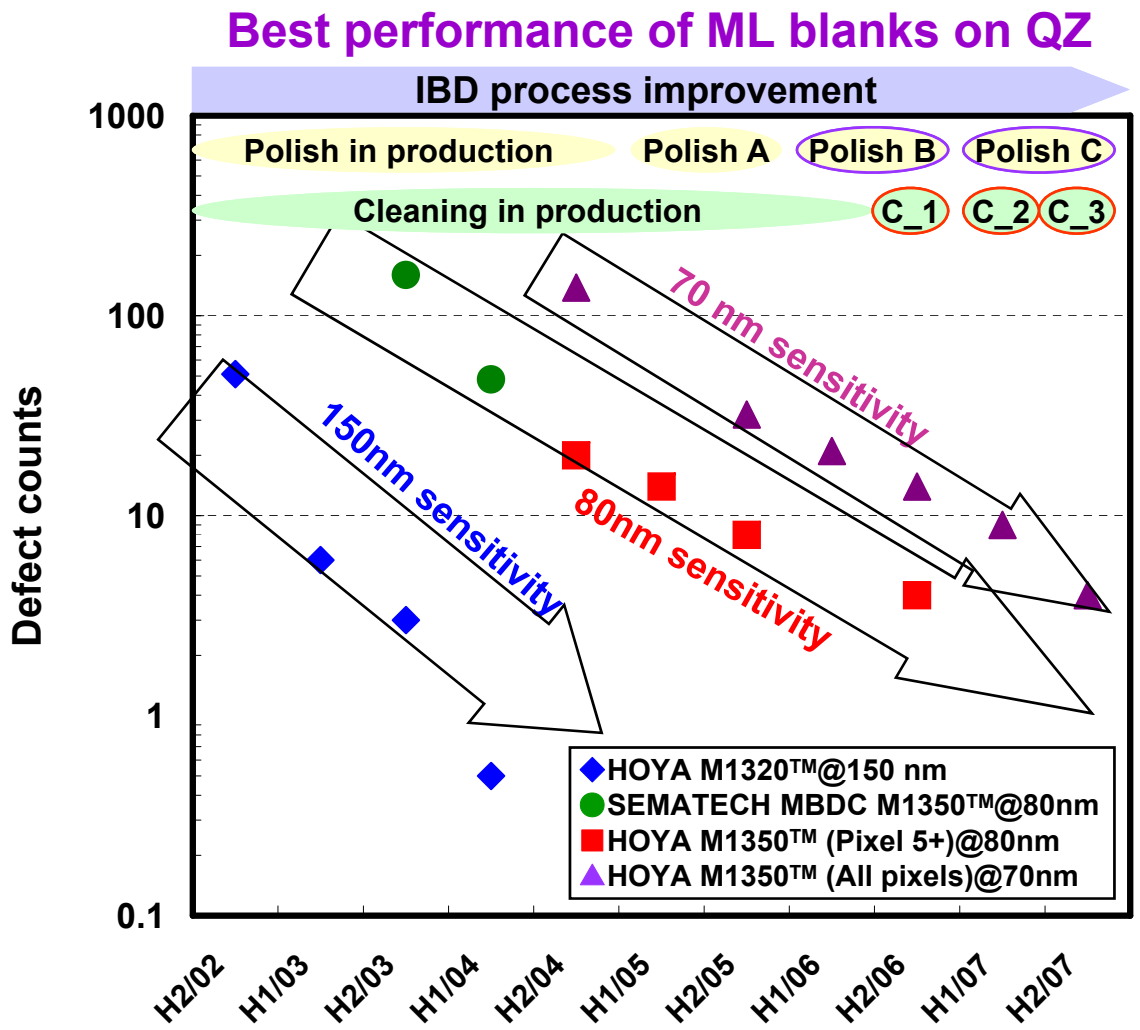
- **Recent performance of EUV blanks**
  - **Flatness improvement**
  - **Defect reduction (2002 – 2007)**
  - **EUV reflectivity**
  - **Absorber stack**
- Summary

Flatness improvement on substrates

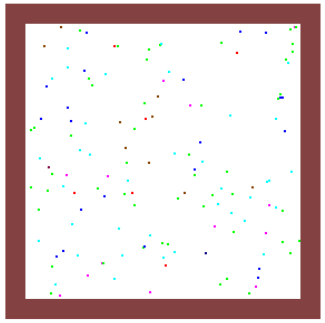


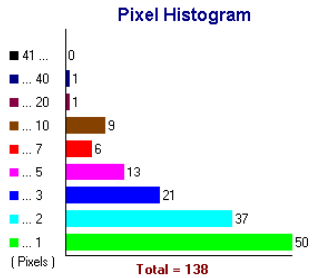
- **Best flatness of ~80nm and routine flatness of ~120nm were attained**

Defect reduction on ML/QZ blanks (2002 ~ 2007)



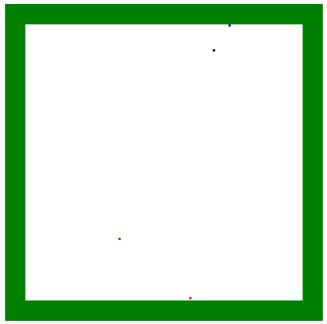
H2/2004

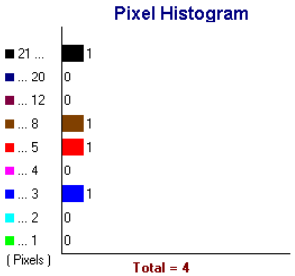




138 defects
(0.79 def/cm²)
[All Pixels @70nm]

H1/2007





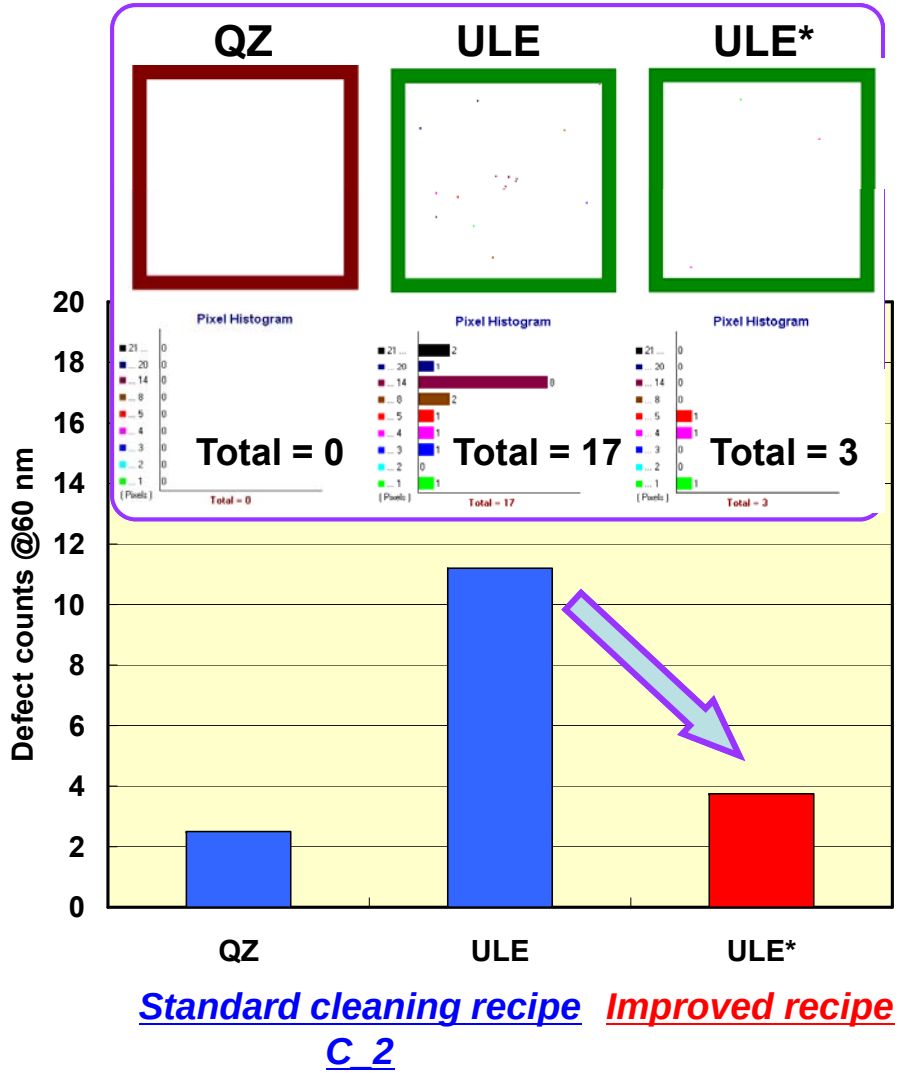
4 defects
(0.02 def/cm²)
[All Pixels @70nm]

- **Defect reduction is progressing, and 4 defects@70nm was demonstrated**

Low defects LTE glass substrate

Properties	LTE glass ULE™ (Corning)	Quartz	SEMI spec.
Composition	SiO_2 doped with TiO_2	SiO_2	
Structure	Non-crystalline	Non-crystalline	
Coefficient of thermal expansion (ppb/℃)	<±10 [<±5]	500	Class A:±5 Class B:±10 Class C:±20 Class D:±30
Density (g/cm^3)	2.21	2.21	2.1 - 2.6
Elastic modulus (GPa)	67.6	73.1	65 - 91
Refractive index	1.48	1.46	1.4 - 1.6

- Meet class B of CTE in SEMI spec.
- Similar polishing rate to QZ
  - Same flatness controllability to QZ
- Slightly week chemical durability to QZ
  - Needs cleaning process for LTEM



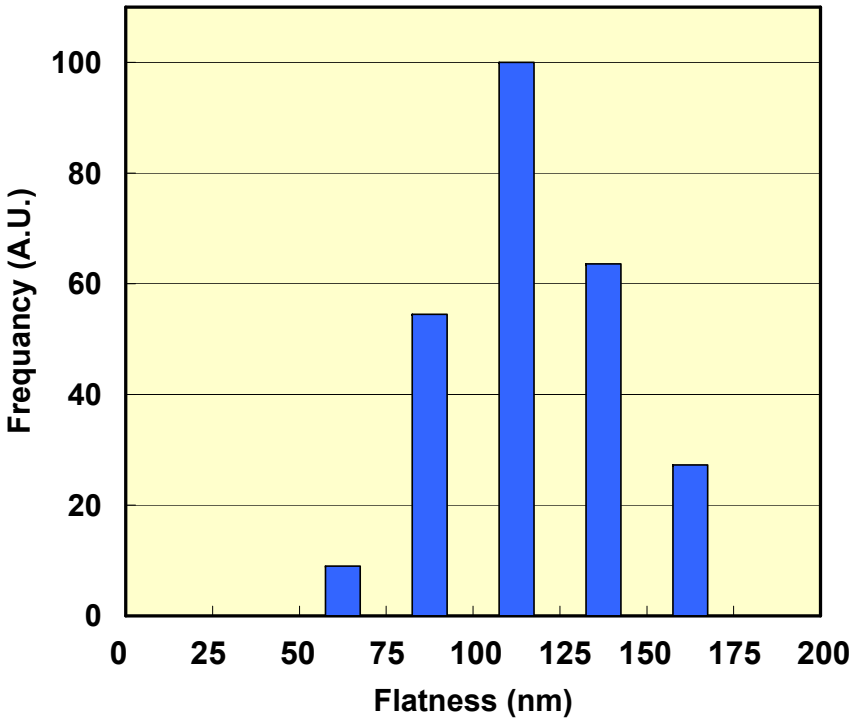
Standard cleaning recipe *Improved recipe*
C_2

✓ULE substrates defects improved

Performance of ML blanks with LTE sub.

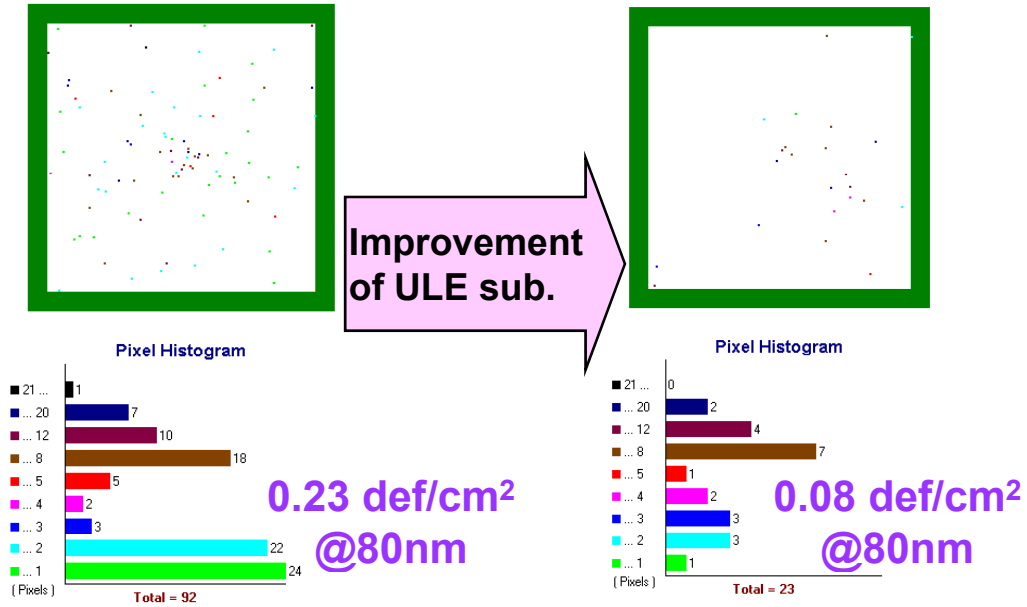
Target in 2007: <150 nm PV flatness, <0.4 def/cm²@70nm

Substrate flatness reproducibility



Average was 117 nm PV
23% was within 100 nm PV

ML blank defects inspected by M1350



92 defects
(0.53 def/cm²)
[All Pixels @70nm]

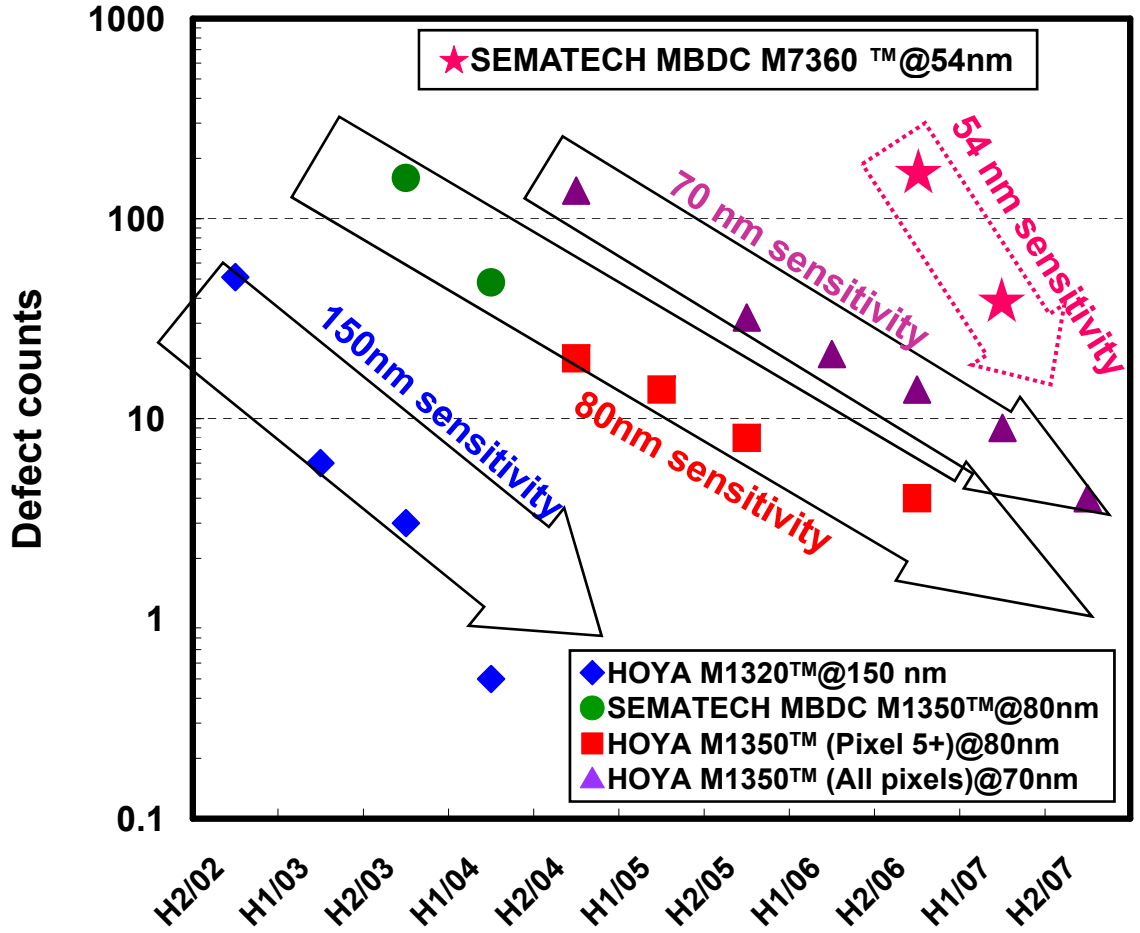
23 defects
(0.13 def/cm²)
[All Pixels @70nm]

- **ML blanks meeting the target spec. can be produced on LTE substrate**

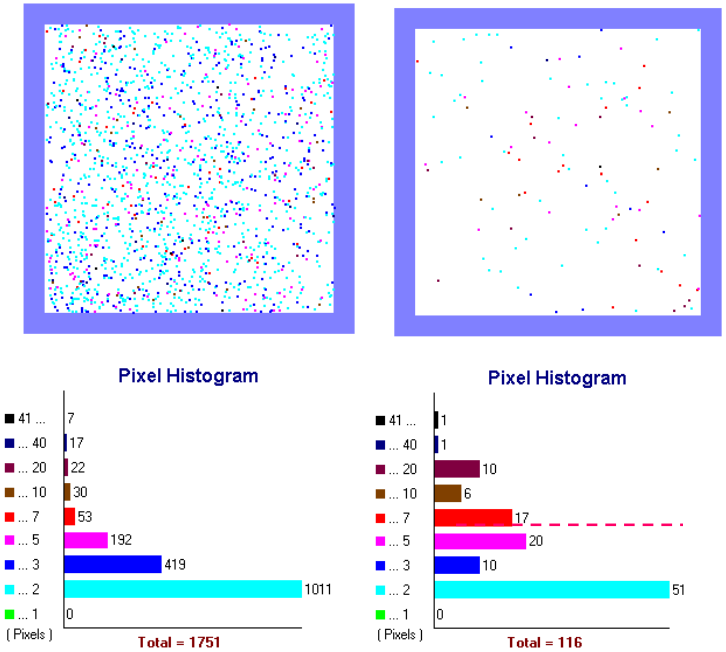
Challenging further defect reduction @M7360

Target in 2010: <0.2 def/cm²@40nm

M7360 inspection was done at SEMATECH MBDC



H2/2006 H1/2007



188 defects
(1.08 def/cm²)
[Pixel 5+ @54nm]

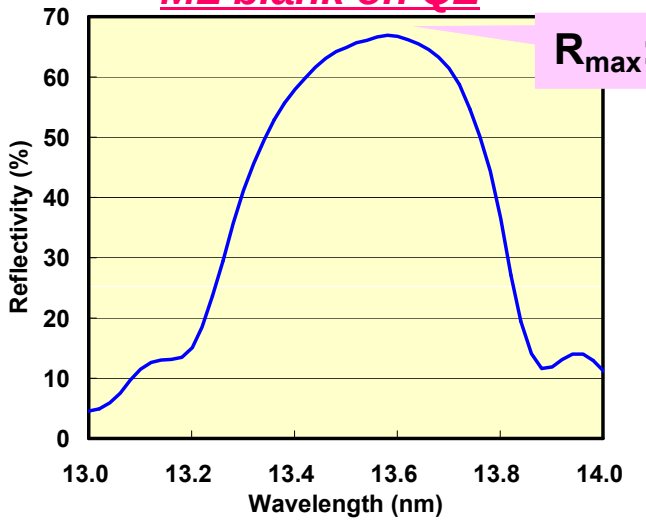
35 defects
(0.2 def/cm²)
[Pixel 6+ @54nm]

- **Started M7360 inspection, and 0.2 def/cm²@54nm was achieved in H1/07**

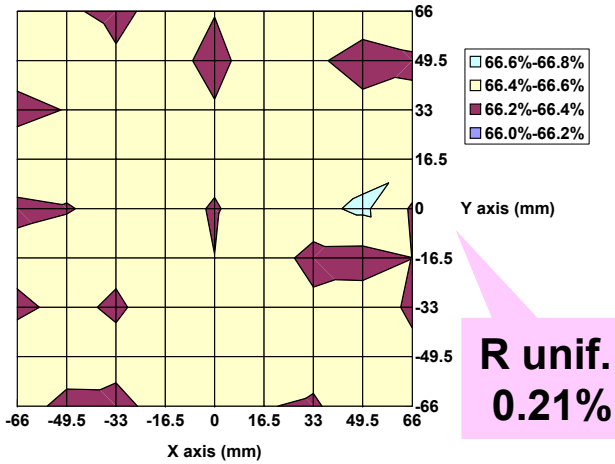
EUV reflectivity on ML blanks with LTE sub.

Target: >66% peak reflectivity

ML blank on QZ



R_{max}: 66.8%



R unif.: 0.21%

50 bi-layers Mo/Si ML blanks

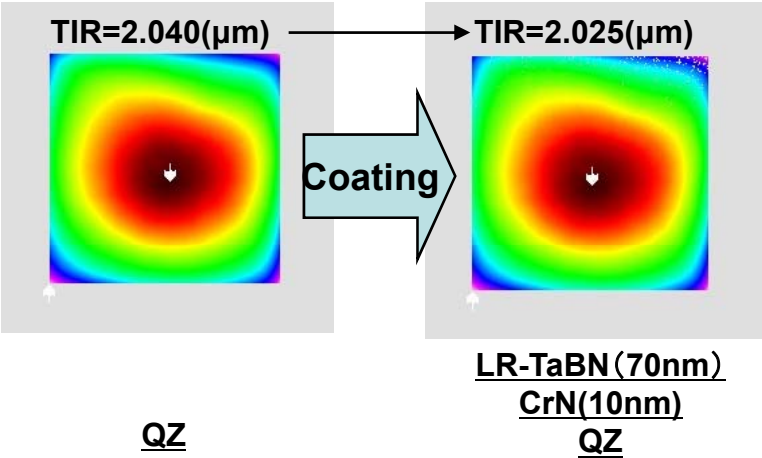
		Blank on ULE	Blank on QZ	Target in 2010
Peak reflectivity (R_{max})	Mean	66.4%	66.8%	>66%
	Range	0.35%	0.21%	<0.5%
Centroid wavelength (nm)	Mean	13.541	13.550	13.53 +/-0.03 (for ADT)
	Range	0.0286	0.0278	<0.04
FWHM (nm)	Mean	0.5340	0.5344	>0.5
	Range	0.0033	0.0028	<0.005

EUV reflectivity was measured by reflectometer located at Selete

- **ML blanks with excellent EUV reflectivity performance demonstrated**

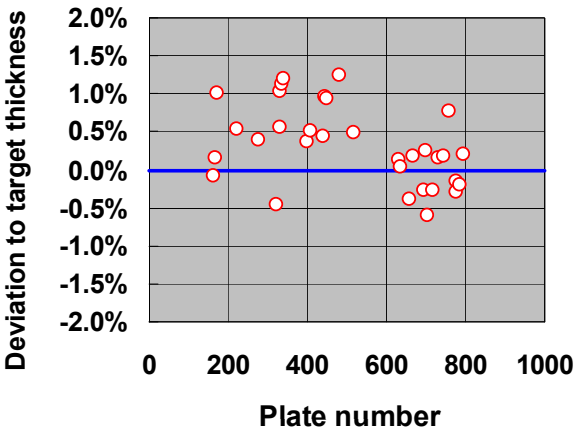
LR-TaBN/CrN blanks performance

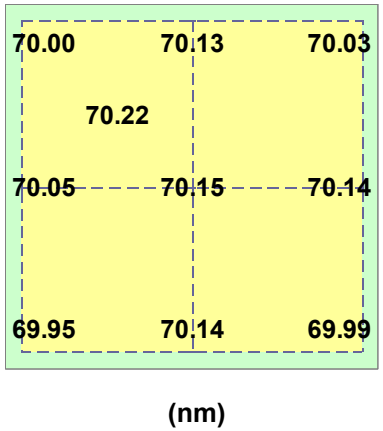
Low stress performance



Flatness change 0.015(μm)
Compressive stress 20(MPa)

High thickness homogeneity





Inter plate: <±1.4%
70 nm ±1 nm

Intra plate: ±0.19%
0.27 nm PV

	Current performance	Target
Absorber stack thickness uniformity	<+/-1%	<+/-1%
Mask inspection contrast @257nm	>75%	>60%
Absorber stack stress	<200 MPa	<200 MPa

- LR-TaBN/CrN stacks with low stress and high uniformity were obtained

Summary

- **Defects, flatness and EUV reflectivity on EUV blanks have been improving toward production target**
- **ML blanks with only 4 defects at 70 nm sensitivity inspected by M1350 were demonstrated on QZ substrate as best**
- **EUV blanks on LTE glasses with high flatness of ~100 nm and with low defect density of less than 0.4 def/cm^2 at 70 nm can be produced and supplied for alpha EUV exposure test**

	Current best performance		Target in 2010
Substrate	LTEM	QZ	LTEM
Front flatness	84 nm	89 nm	<50nm
Back flatness	56 nm	83 nm	<50nm
Total defect density	0.08 def/cm^2@80nm 0.13 def/cm^2@70nm	0.02 def/cm^2@70nm 0.2 def/cm^2@54nm	0.2 def/cm^2@40nm
EUV peak reflectivity	66.4%	66.8%	>66%
λ uniformity	0.018 nm	0.018 nm	<0.04 nm

Acknowledgements

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