ASML NXE:3100 PRE-PRODUCTION EUV SCANNER PERFORMANCE AT IMEC

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NXE:3100 stability

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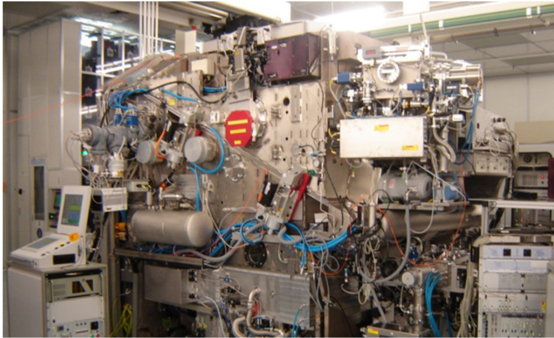
IMEC EUV LITHOGRAPHY TOOL ROADMAP



2006 - 2011	2011 - now	2014
ASML Alpha-Demo tool 40nm → 27nm LS 0.25 NA	ASML NXE:3100 – pre production 27nm LS, 22nm LS 0.25 NA	ASML NXE:3300 – production 22, 18nm LS 0.33 NA

NXE:3100

Main specifications

- Field size: 26x33mm^2
- NA=0.25 and σ=0.81
- 6 off-axis illumination conditions available
- MMO vs NXT:1950i < 7nm

Interfaced to TEL LITHIUS™ Pro - EUV
Discharge Produced Plasma source

SUSS MicroTec
MaskTrack Pro

EUV Technologies
Outgassing tool

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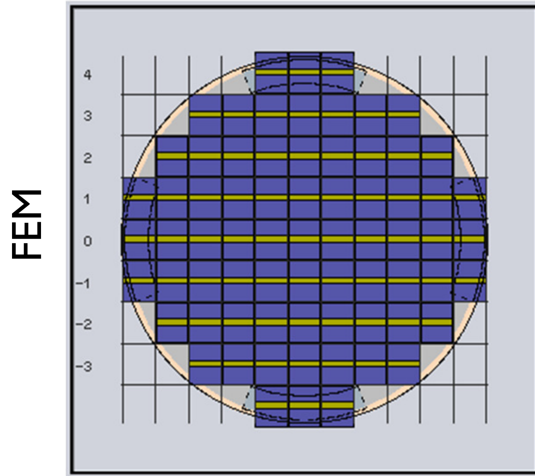
NXE:3100 stability
- Monitoring scheme
- Productivity
- CD control
- Overlay control
- Out of band radiation

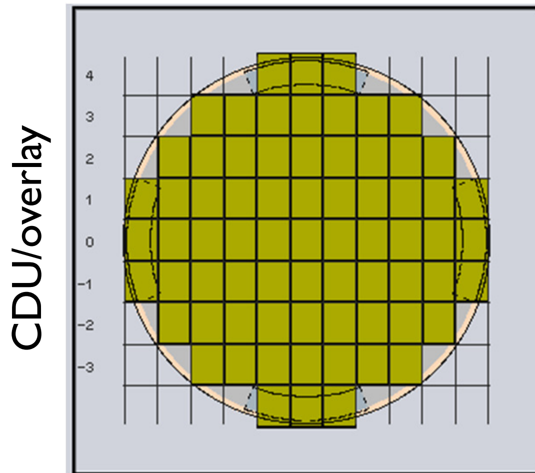
Outlook to 3300
Conclusions

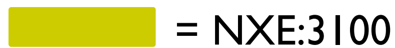
MONITORING PROCEDURE ON NXE:3100

FEM



CDU/overlay



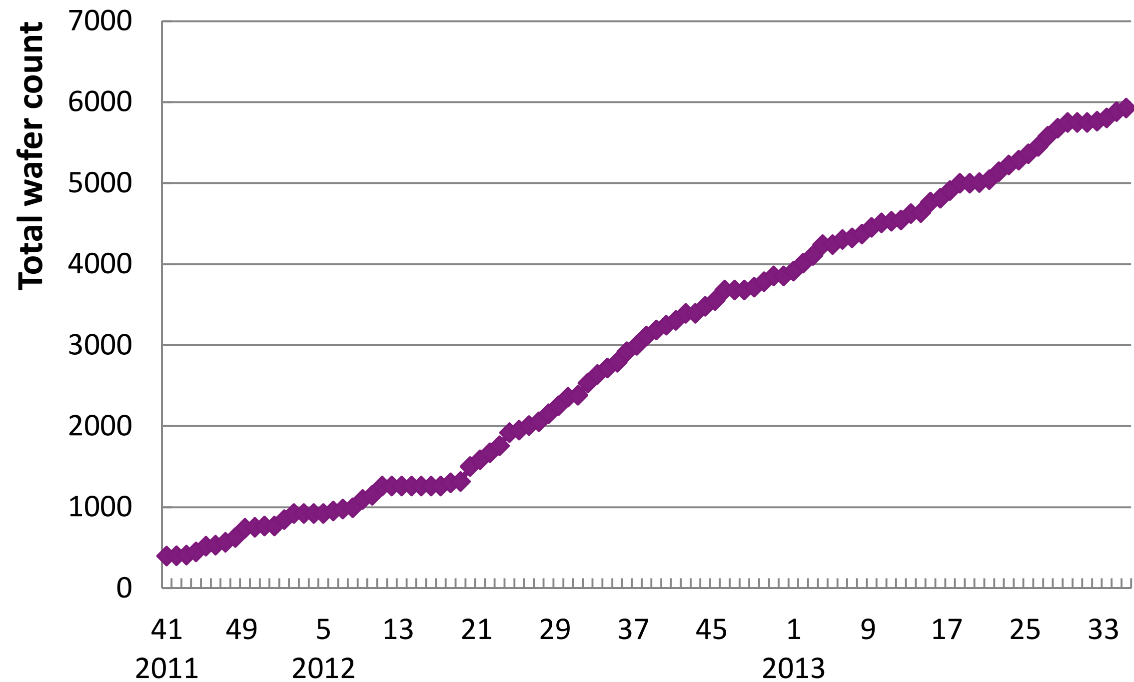


= NXE:3100

Test\logging	Target	Parameters
Power	Productivity	Power at IF, RS, WS
FEM wafer	CD control	27nm LS BE, BF, EL, DOF
Uniform wafer	CD control	27nm LS CDU
	Overlay control	Grid, IF residuals
Ilias	Lens stability	Lens aberration terms
Al mask exposure	Out of band radiation stability	% OoB

NXE:3100 PRODUCTIVITY
CUMULATIVE WAFERCOUNT

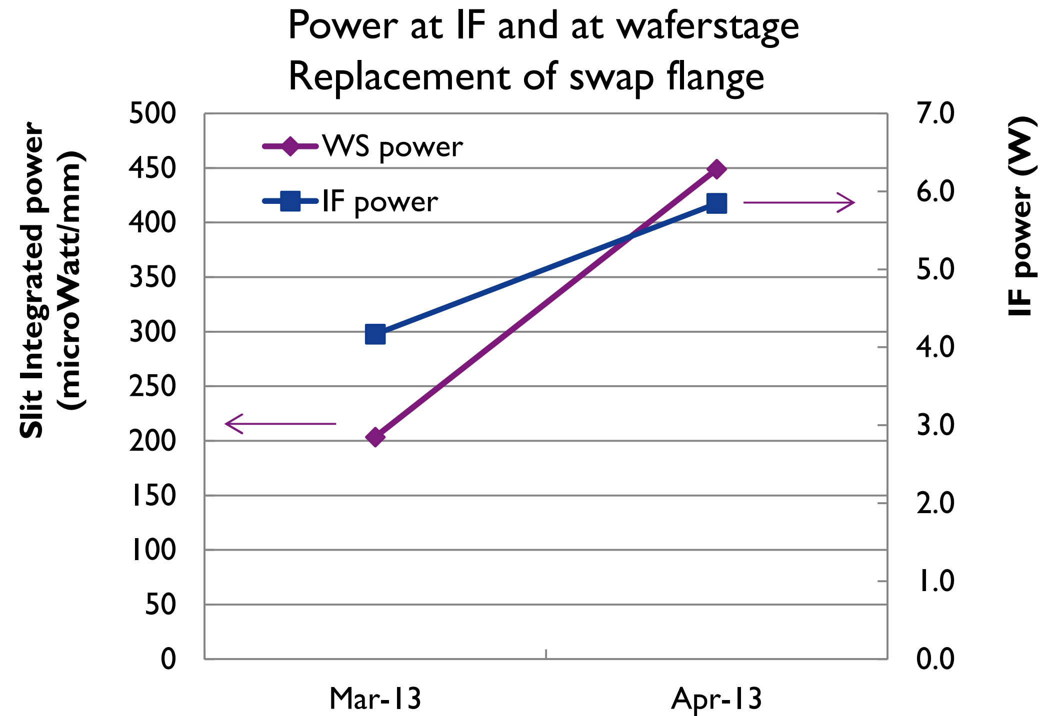
- 24/7 operation
- DPP source 2013 average power at IF 4.9W
- Average power at waferstage 310 microWatt/mm
- Average 2013 throughput 2-3 full wafers per hour
- Average system uptime 2013 ~52%



Cumulative wafercount of exposed wafers now exceeds 6000 wafers on NXE:3100

NXE:3100 PRODUCTIVITY
COLLECTOR LIFETIME AND IMPACT ON POWER

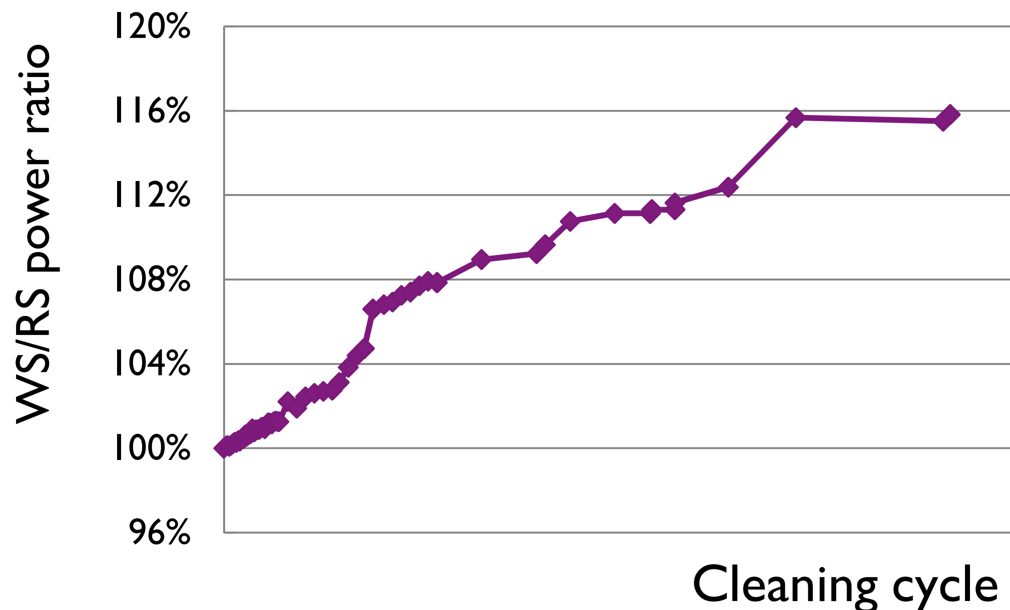
- NXE:3100 DPP source was operated using the same swap flange (collector mirror + debris mitigation) for 9 months
- Due to low power on system, it was then decided to replace the swap flange (collector + debris mitigation system)
- Both power at IF and power at waferstage were recovered, improving productivity
- Post-mortem confirmed collector erosion and Sn accumulation in debris mitigation system



DPP collector mirror lifetime exceeded 6 months under normal operation conditions

NXE:3100 PRODUCTIVITY
LENS TRANSMISSION

- Lens transmission can be estimated by power measurement at waferstage and at reticle stage
- After 1 year of use, cycles of lens cleaning were started using on-board cleaning and lens transmission improved by ~16%

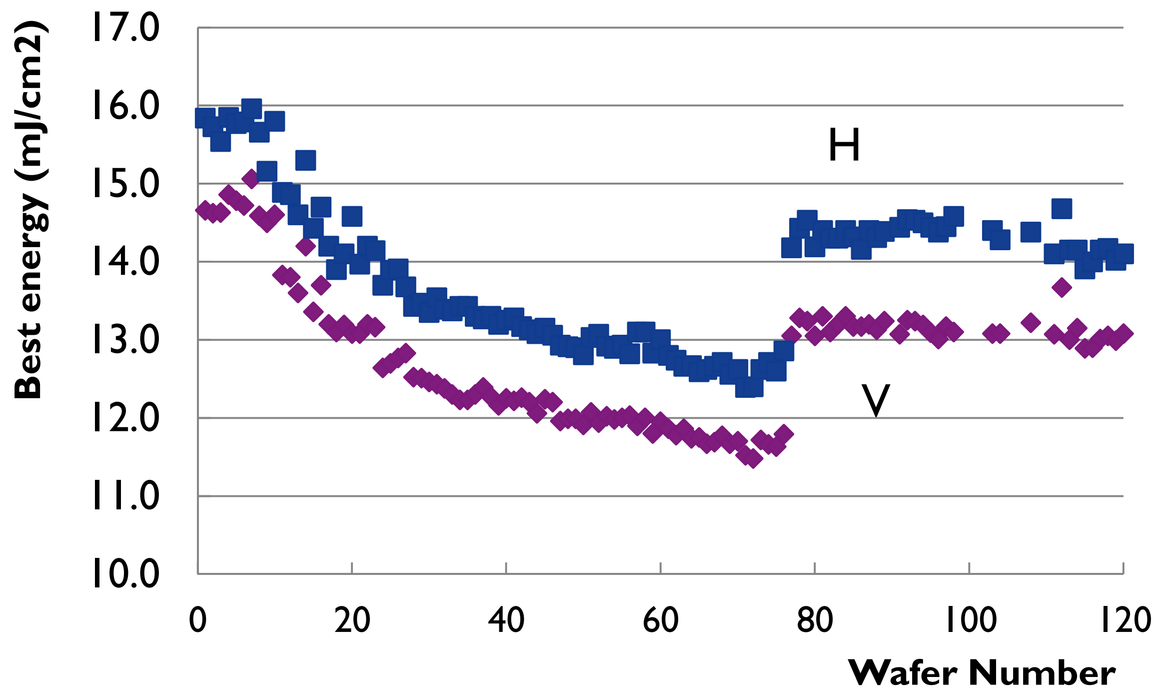


Lens transmission only showed limited impact of one year system use
First demonstration of scanner on-board lens cleaning in the field

ASML
imec

CD CONTROL OVER 21 MONTHS

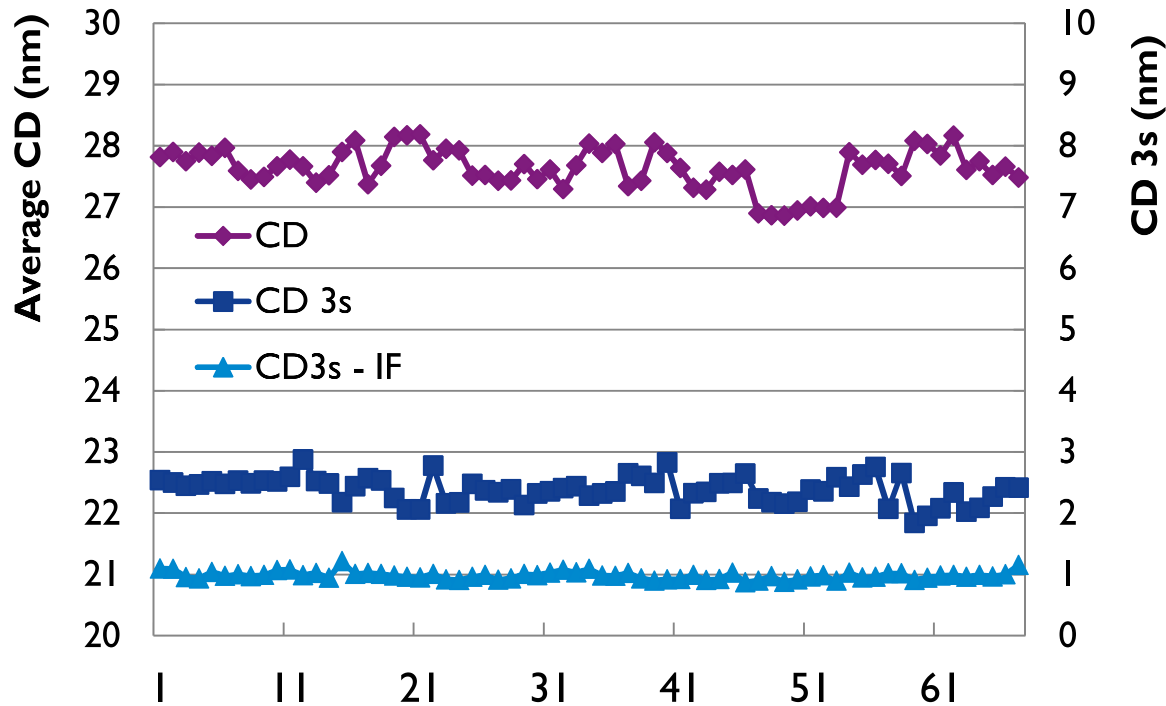
BEST ENERGY 27NM H AND V LS FROM 12/2011 – 08/2013



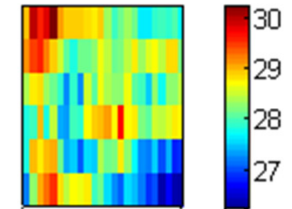
Best dose of 27nm H and V LS showed a gradual drift over the first 10 months of operation – was solved by more frequent calibration of NXE:3100 WS sensors to reference

CD CONTROL

27NMV LS CD STABILITY OVER 10 MONTHS

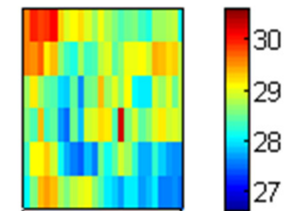


iF data
Mean = 28.21nm , 3σ = 2.21



07/09/2013

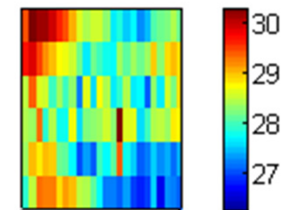
iF data
Mean = 28.59nm , 3σ = 1.80



10/08/2013

After repair of sensor drift, average CD, intrafield signature, and across wafer CD signature are stable over time

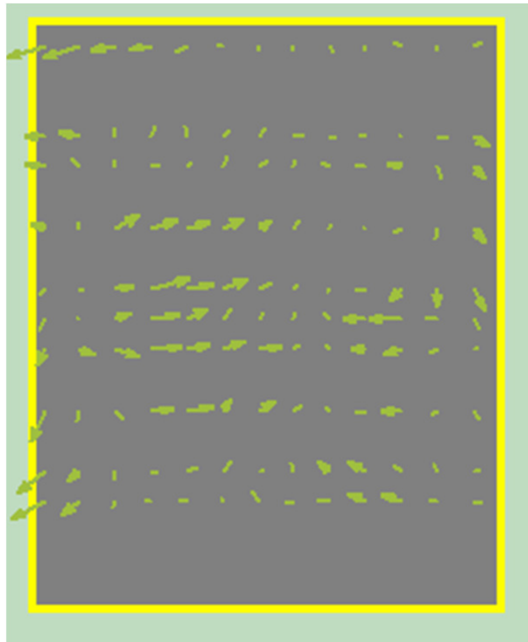
iF data
Mean = 28.24nm , 3σ = 2.29



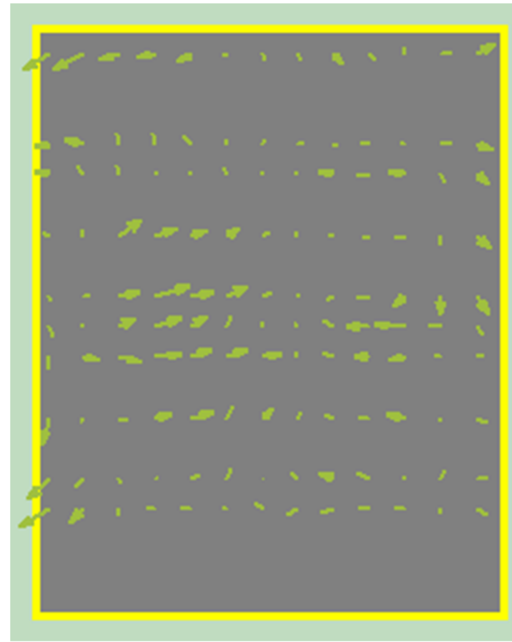
08/07/2013

OVERLAY CONTROL
INTRAFIELD RESIDUALS FROM DECEMBER 2011 – AUGUST 2013

November 2011



September 2013

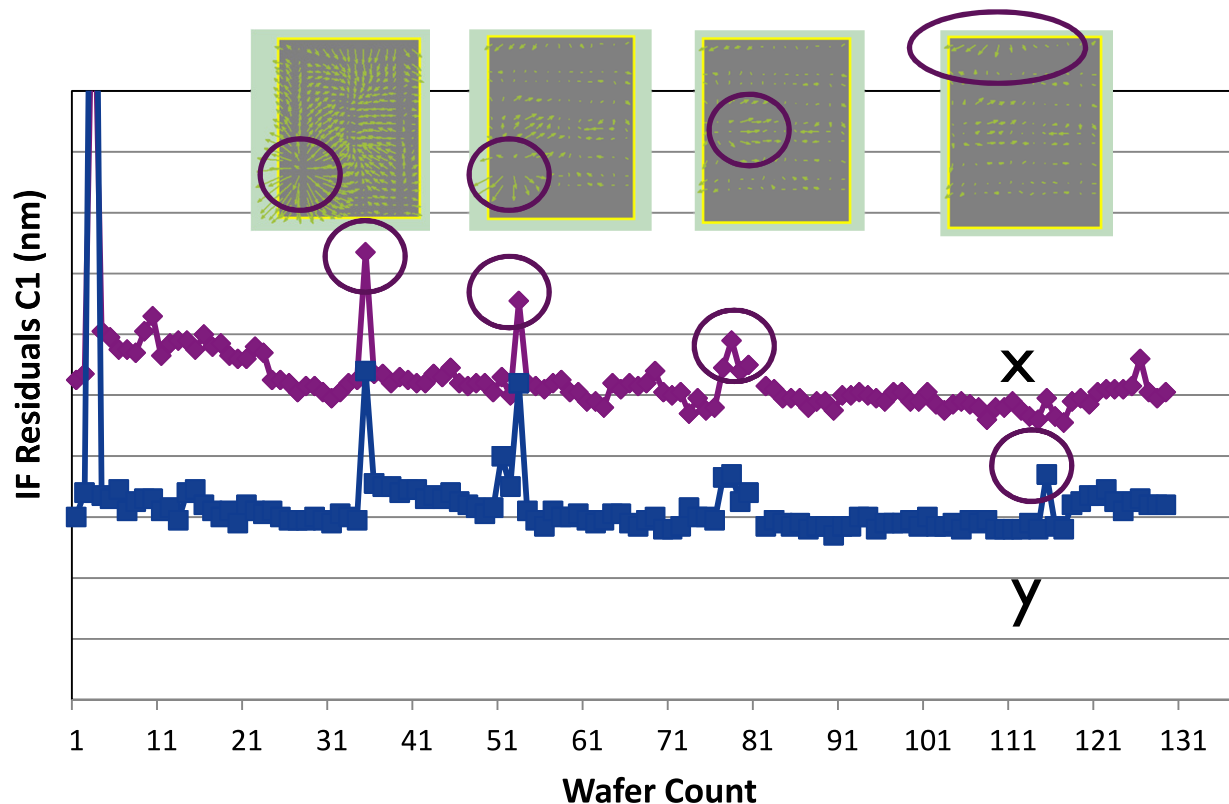


Intrafield distortion signature is stable over 22 months

First layer: XT:1450
Second layer: NXE:3100
After removal of 10 par OVL correction model

OVERLAY CONTROL

INTRAFIELD RESIDUALS FROM DECEMBER 2011 – AUGUST 2013

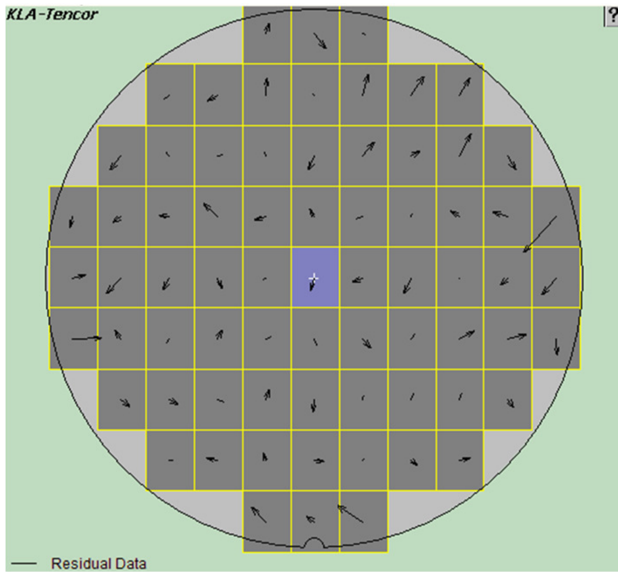


In 22 months, only 5 events when a particle was present on the reticle clamp during monitor. In the last 4 events, the particle could be removed without breaking vacuum

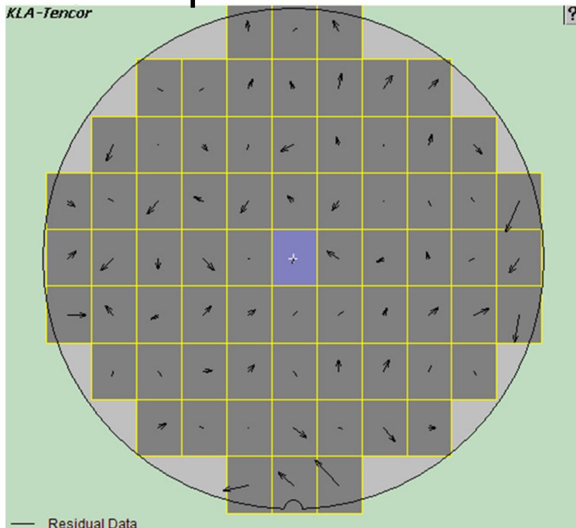
First layer: XT:1450
Second layer: NXE:3100
After removal of 10 par OVL correction model

OVERLAY CONTROL
GRID RESIDUALS FROM 12/2011 – 09/2013

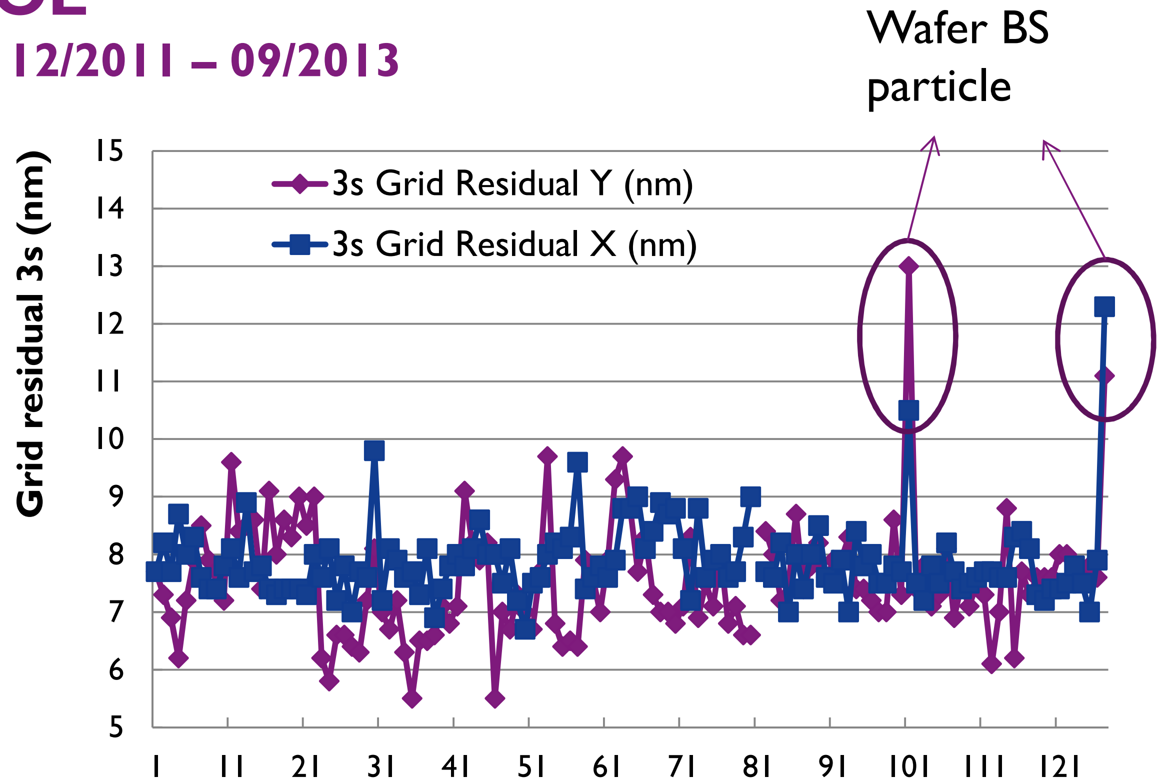
November 2011



September 2013



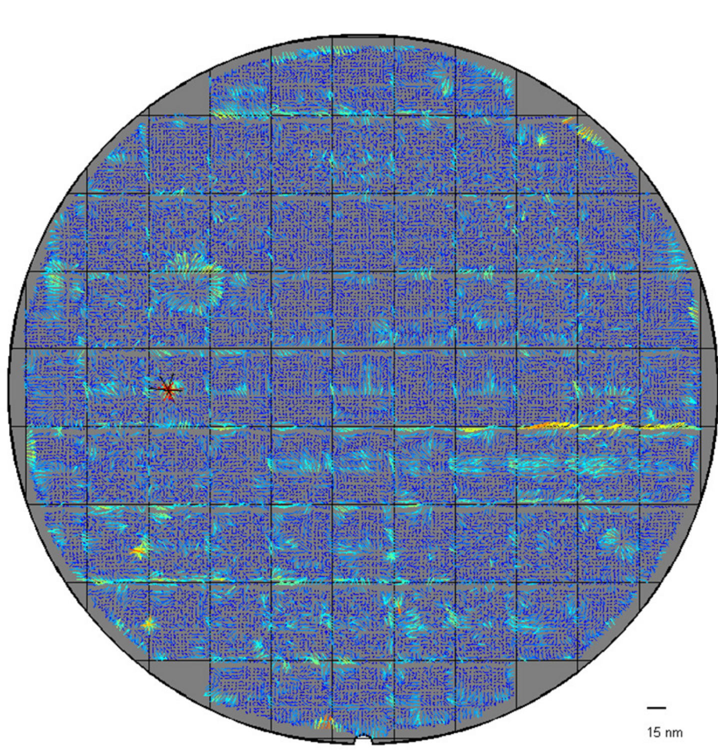
Wafer BS particle

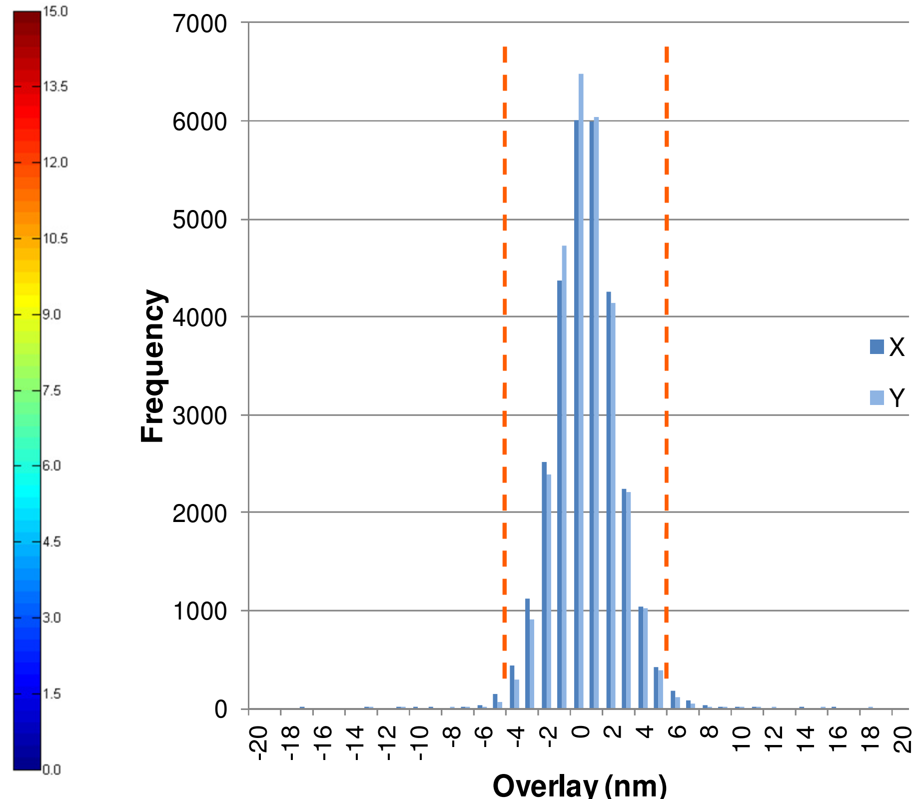


Wafer grid residual 3s is stable to within +- 1nm and has a stable signature

First layer: XT:1450
Second layer: NXE:3100
After removal of 6 par OVL correction model

NXE:3100 BEST ACHIEVABLE MEASURED OVERLAY – CPE AND iHOPC APPLIED





X: |Mean|+3σ: 6.0nm

Y: |Mean|+3σ: 5.6nm

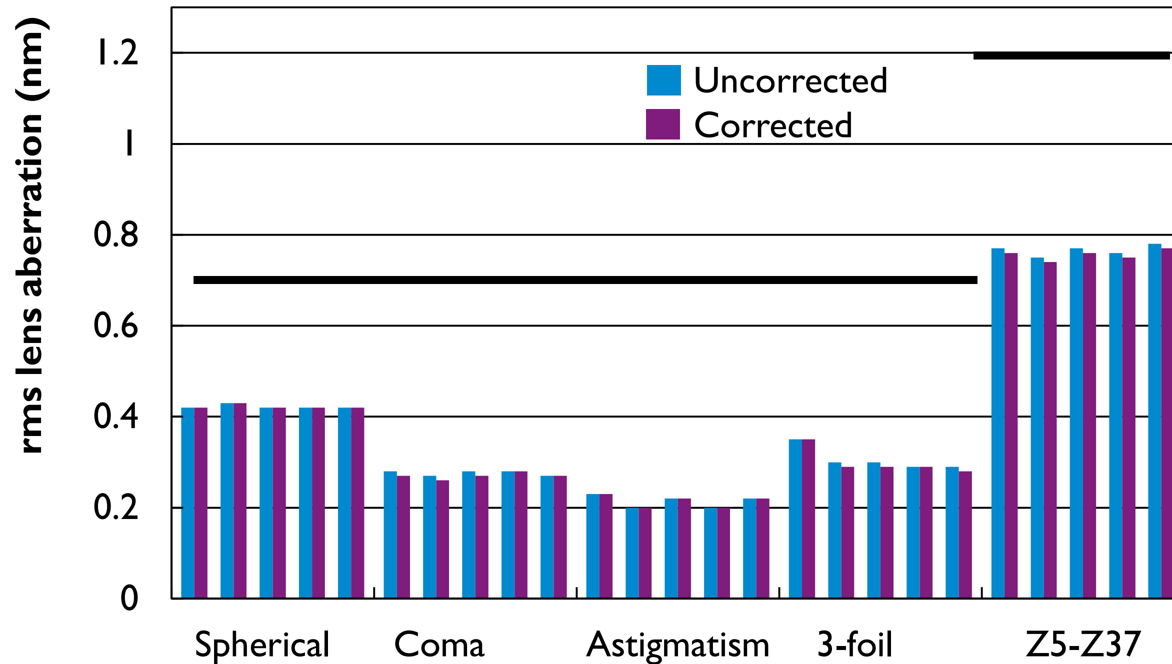
Reference grid from NXE:3100, second layer on XT:1900i

1 wafer, 83 fields, 26x33mm^2, 17x22 pts/field

Applying 10-parameter, CPE and iHOPC corrections, brings measured overlay down to 6nm |Mean|+3σ

J. Hermans 2012 SPIE 8332

NXE:3100 LENS ABERRATIONS
RMS ERROR FROM 5 MEASUREMENTS OVER 10 MONTHS

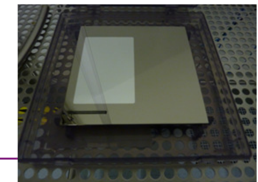


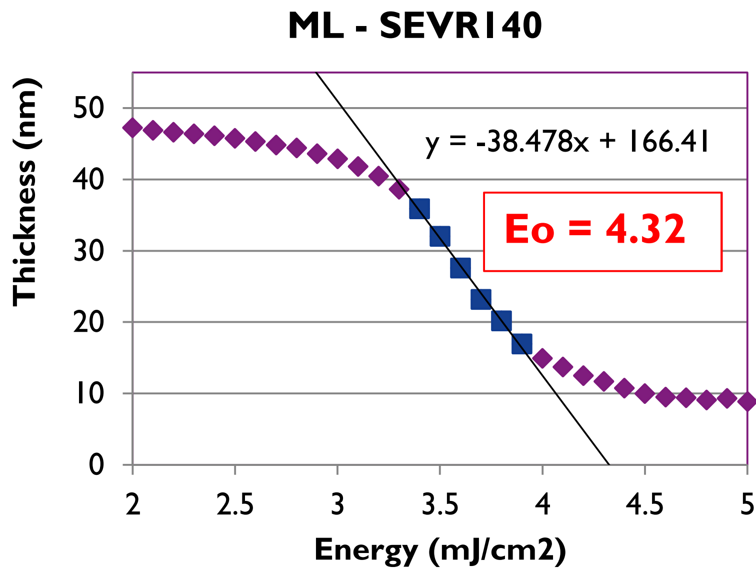
Lens aberration measurement over 9-month timeframe shows that aberration signature remains well in specification

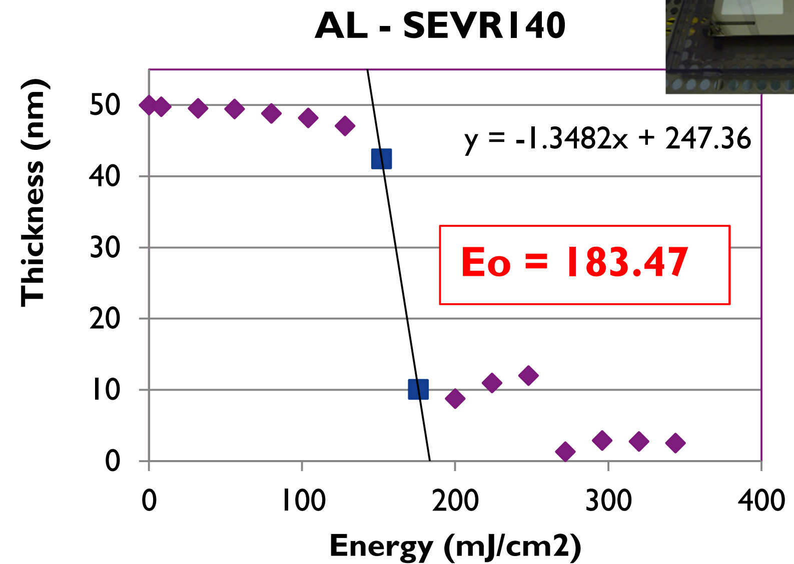
MEASUREMENT OF OUT-OF-BAND COMPONENT

DOSE-TO-CLEAR OF AL COATED MASK AND ML MASK

$$OoB(\%) = 100 \cdot \frac{Dose\ to\ clear\ with\ ML\ mask}{Dose\ to\ clear\ with\ Al\ mask}\ \%$$



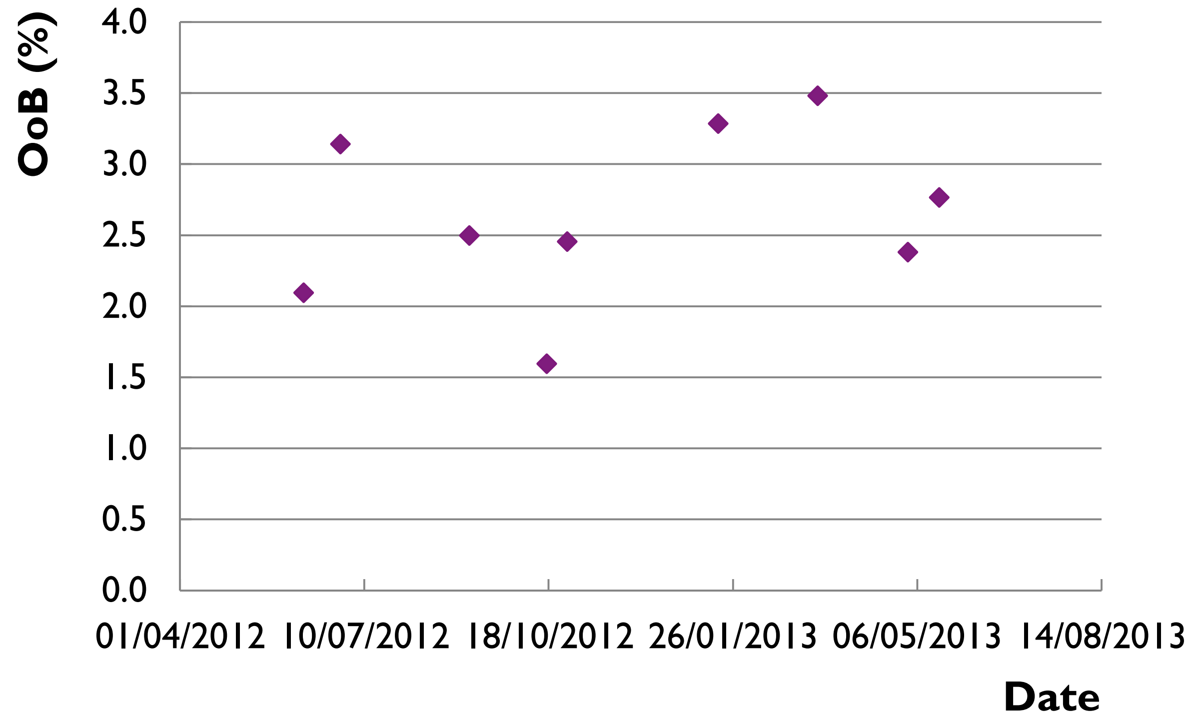




OoB (%) in SEVR140 resist on NXE:3100 (DPP) = 2.4%

MEASUREMENT OF OUT-OF-BAND COMPONENT

DOSE-TO-CLEAR OF AL COATED MASK AND ML MASK



OoB measurements shows variability in 1.6-3.5% range (DPP source), which exceeds the reproducibility of the test (0.02% 3s)
Not correlated to major interventions on system

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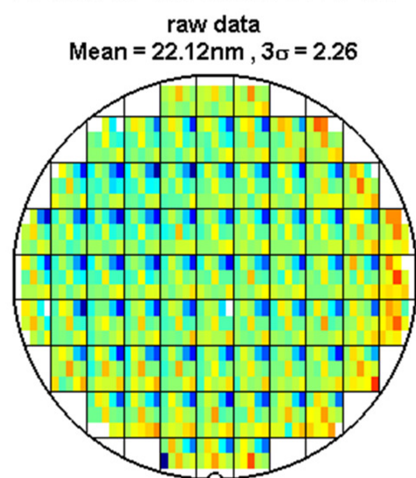
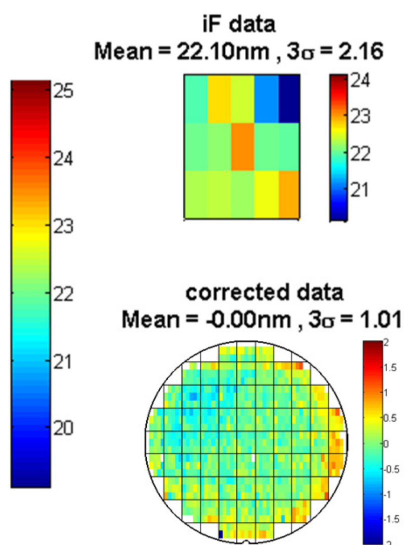
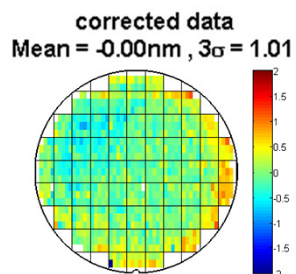
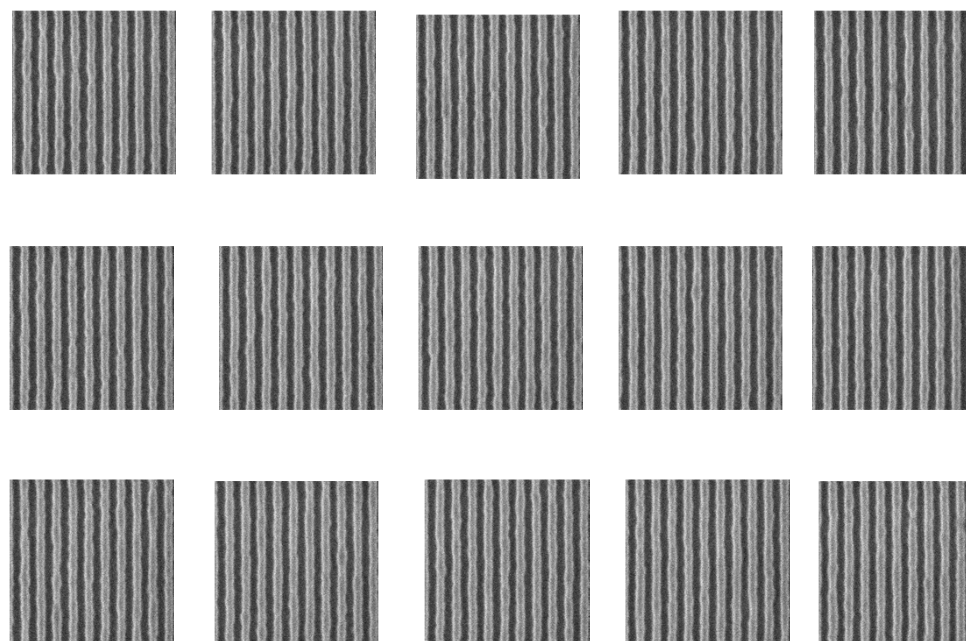
2012 POR TEST ON NXE:3300
22NM LS PROCESS CD UNIFORMITY

- 22nm LS, NXE:3300, conventional illumination
- 2012 POR \ NXE:3100 monitor mask (CDU27_1)





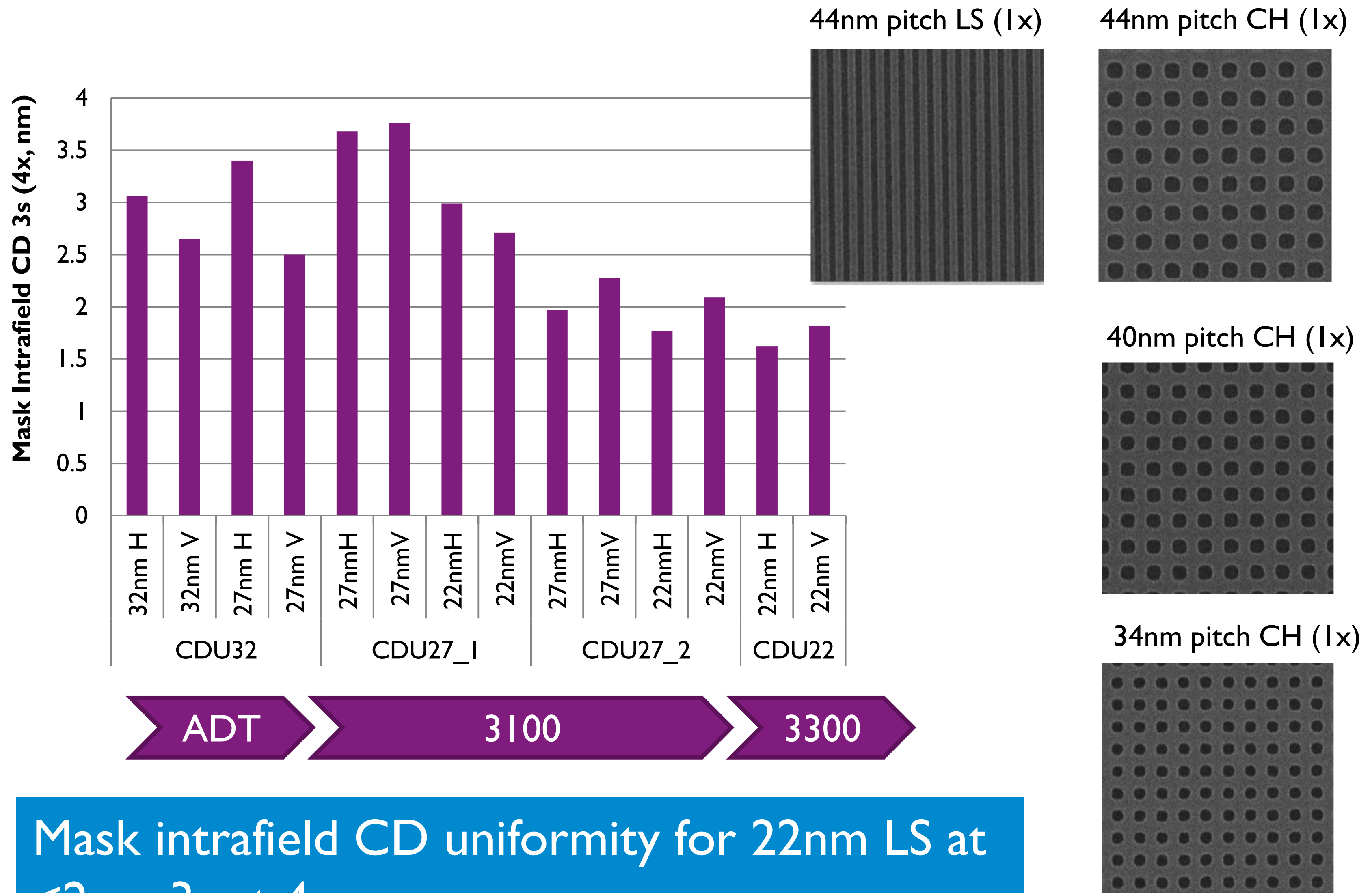




3 x 5 sampling
Raw data – includes mask signature

2012 POR tested on NXE:3300 with 22nm LS on 3100 mask - showed IF signature (mask) and process limits at 22nm LS

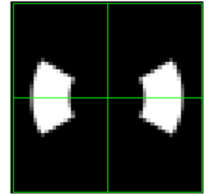
NXE:3300 MONITOR MASK
ABSORBER WIDTH UNIFORMITY ON MASK



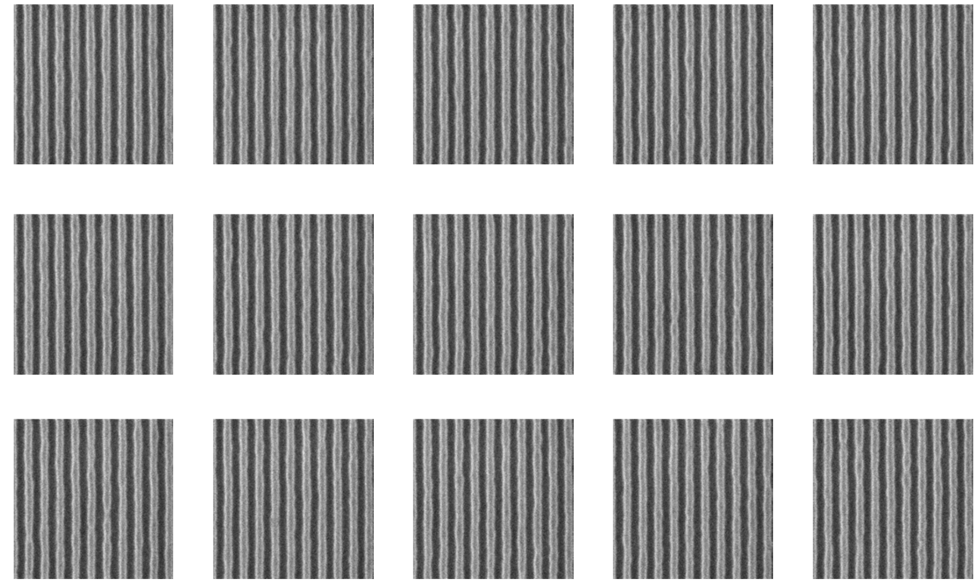
Mask intrafield CD uniformity for 22nm LS at <2nm 3s at 4x

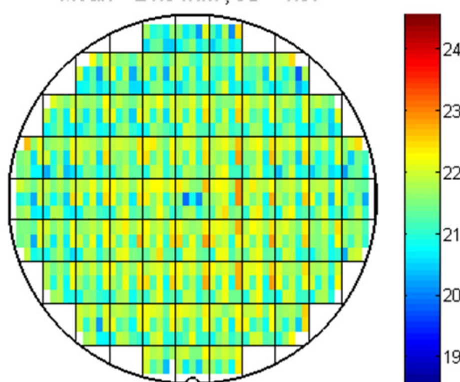
EUV RESIST LS PERFORMANCE

22nm LS CDU – RESIST C

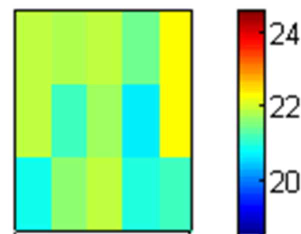


- NXE:3100 exposure
- Wafer coated on TEL Lithius Pro
- Dipole 60-X illumination, 20.5 mJ/cm^2
- Full wafer and full field exposure
- CD measured in 3 x 5 field positions, including field edges
- Raw data reported – split up in IF and across wafer signature

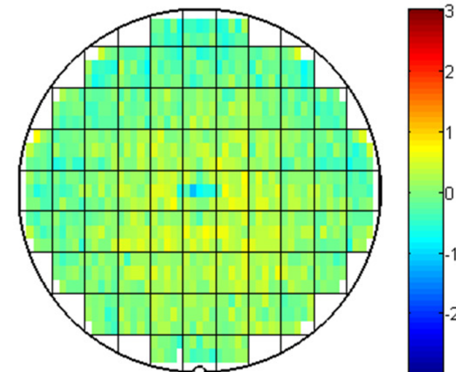




Total
1.67nm 3s



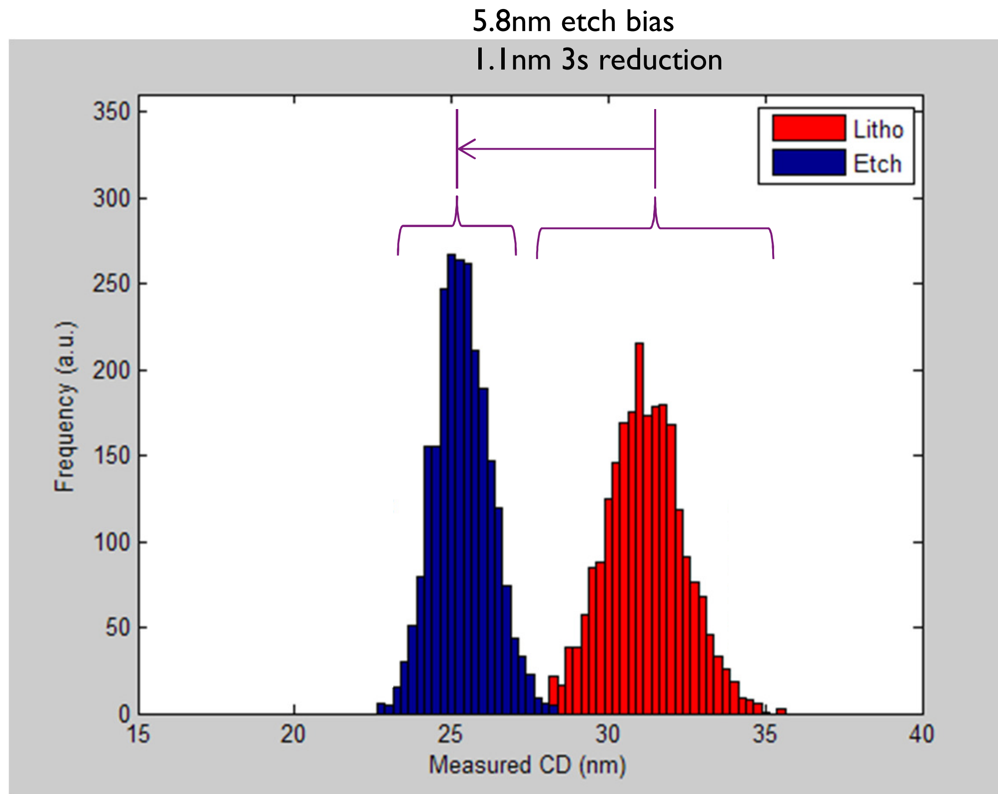
Intrafield
1.50nm 3s

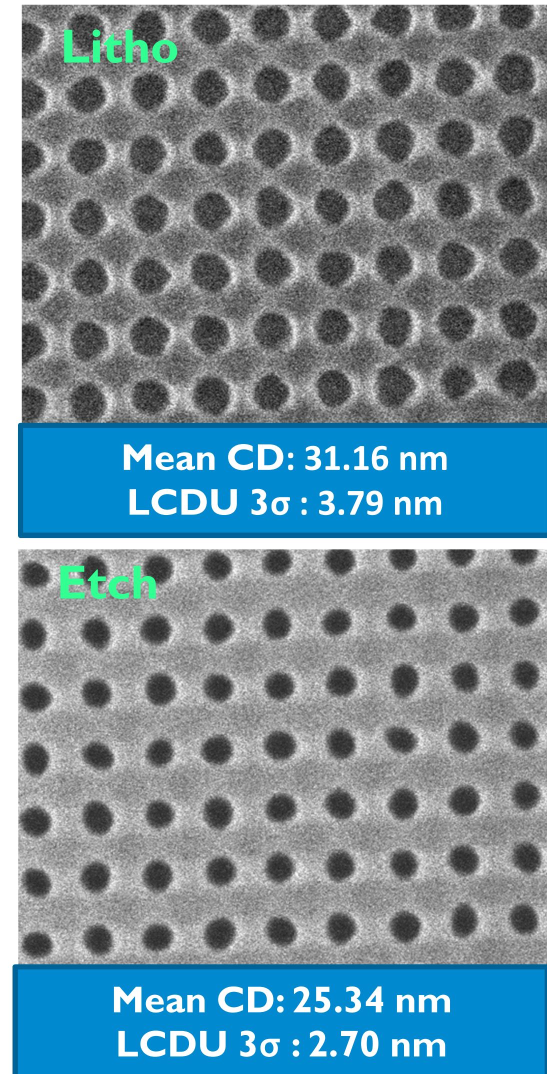


Intrafield subtracted
0.82nm 3s

NXE:3300 PROCESS NEW CANDIDATE
52NM PITCH CH CD UNIFORMITY AFTER LITHO-ETCH

5.8nm etch bias
1.1nm 3s reduction





Contact hole uniformity 3s across wafer improves to 2.70nm 3s through resist etch

31nm CH at 52nm pitch printed to 31nm after litho
CD distribution over 32 fields, 75 CH per field, 27.25 mJ/cm2

Ming Mao et al, 2013 MNE

CONCLUSIONS

NXE:3100	
Throughput	More than 6000 wafers exposed Collector mirror influences power level ~6 months collector mirror lifetime
CD control	Stable CD and CD map
OVL control	Grid and IF residuals are stable, but can be impacted by particles on mask and wafer BS Best demonstrated is ~6nm (matched to XT1900i)

NXE:3300	
Resist	Candidate resist tested on NXE:3100 – 22nm VLS 1.67nm 3s
Mask	New mask fabricated with improved uniformity
Track	Accepted TEL Lithius Pro-Z track (09/2013)

NXE:3100 has sufficient CD and overlay control to enable pre-production device fabrication in wafer batch mode
NXE:3300 preparation for track, resist, and mask ongoing

ACKNOWLEDGEMENTS

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- Mircea Dusa
- Timon Fliervoet

TEL

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