



Accelerating the next technology revolution

EUVL Image Placement Error Analysis with a Rotatable Reticle

TIS and Overlay Results

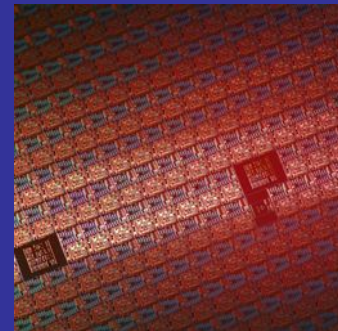
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²ASML Inc.

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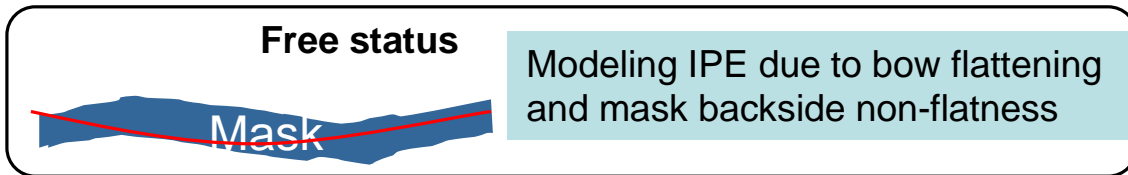
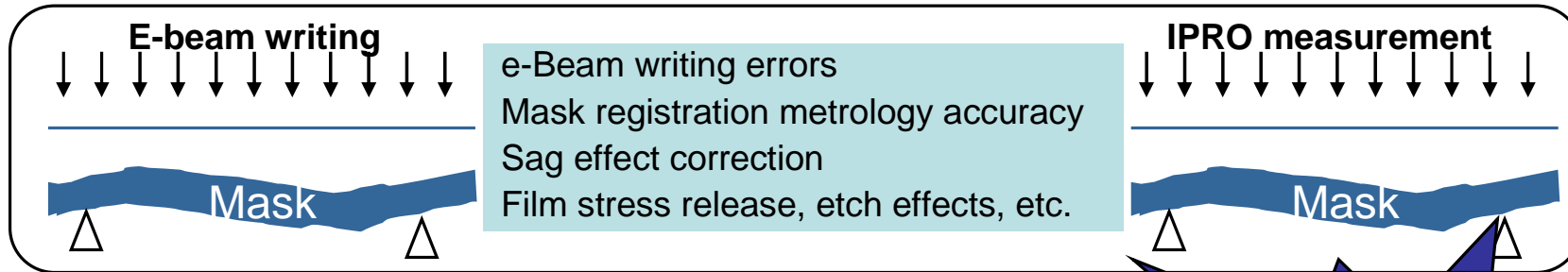
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Introduction

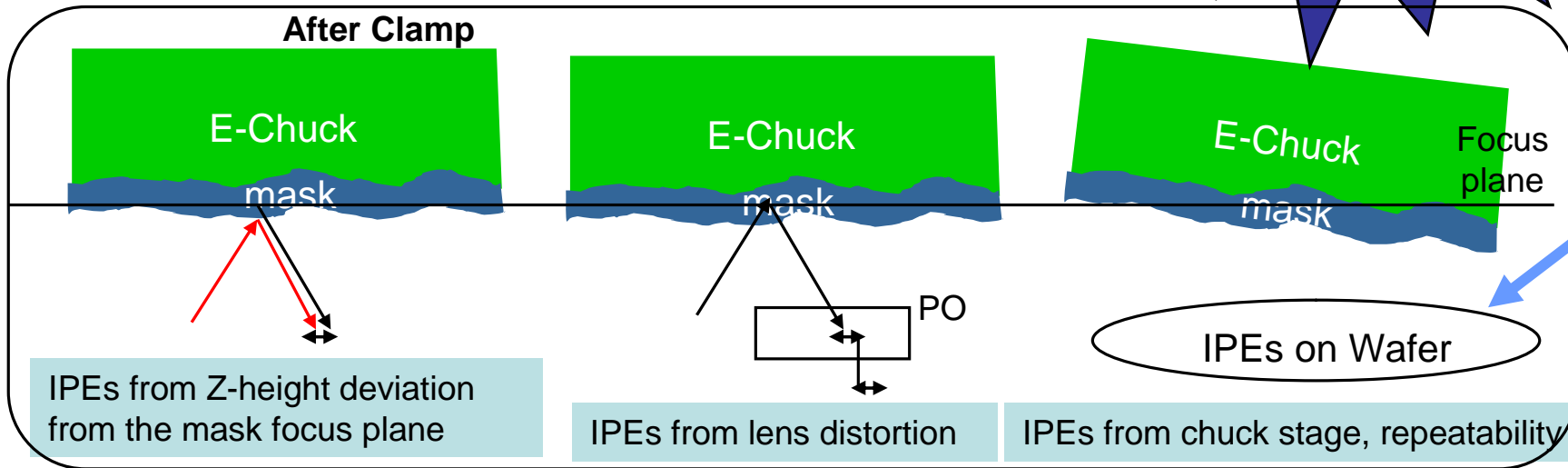


- In EUV lithography, non-telecentric illumination on the mask side causes extra overlay errors from any deviation of mask surface non-flatness.
- Distinguishing the overlay errors caused by mask non-flatness from others is the first step in efficiently mitigating them.
- The unique mask, which contains 468 transmission imaging sensor (TIS) marks, can be used to measure focus and X and Y offsets with the ADT. The mask can be loaded in all 4 different orientations on the ASML alpha demo tool (ADT).
- All mask registration errors, overlay errors from lens distortion, and mask/chuck non-flatness were investigated with this special mask.

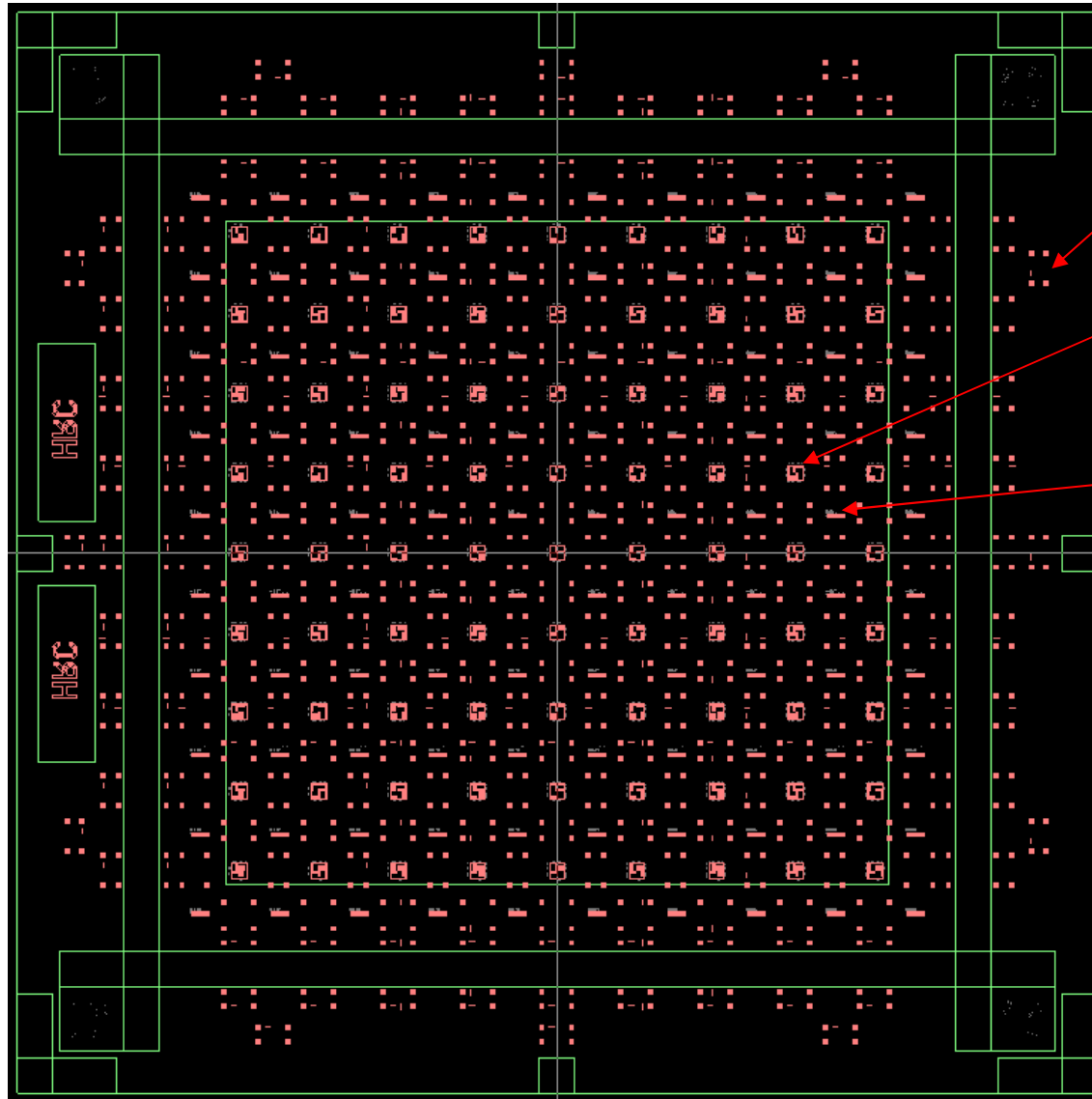
Introduction – Image Placement Errors (IPE) on Wafer



Joint work among mask makers and scanner makers, metrology, and modeling studies are needed



SEMATECH Rotatable IPE Mask (SRIM)



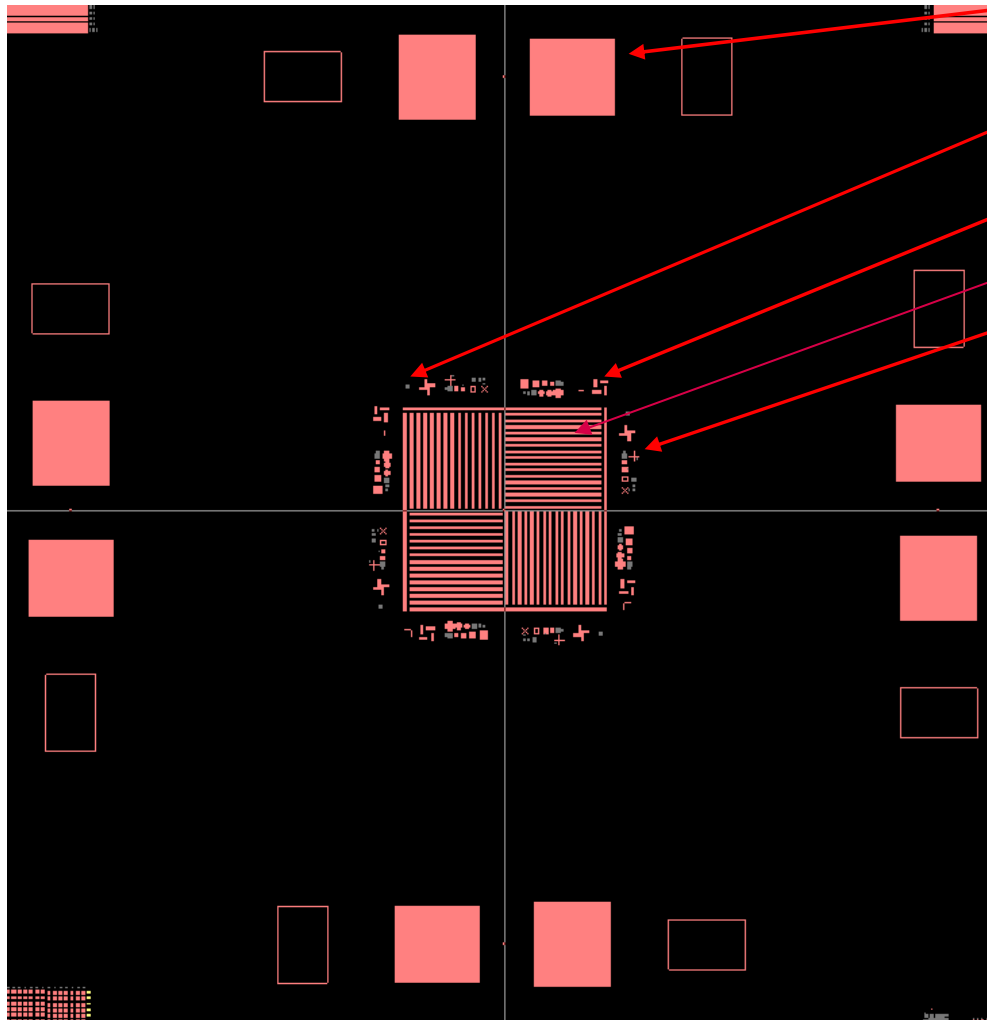
2 pairs of TIS marks on each side

Unit patterns for IPE
XPA mask, AIM, etc., and a
three-bar pattern over the
design area

Unit patterns for imaging
performance

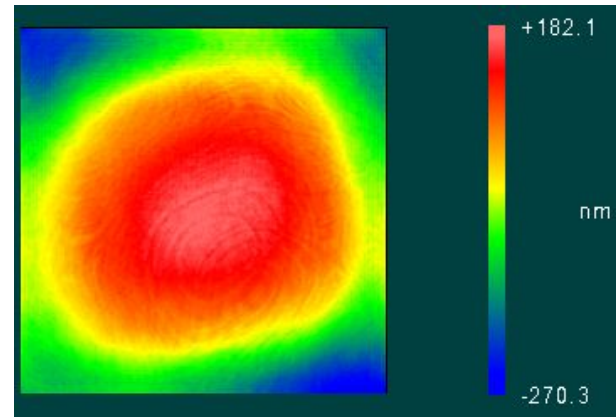
Note: XPA is an overlay
target (eXtended Pattern
Area)

SRIM - Unit Pattern – 9 x 9 Array

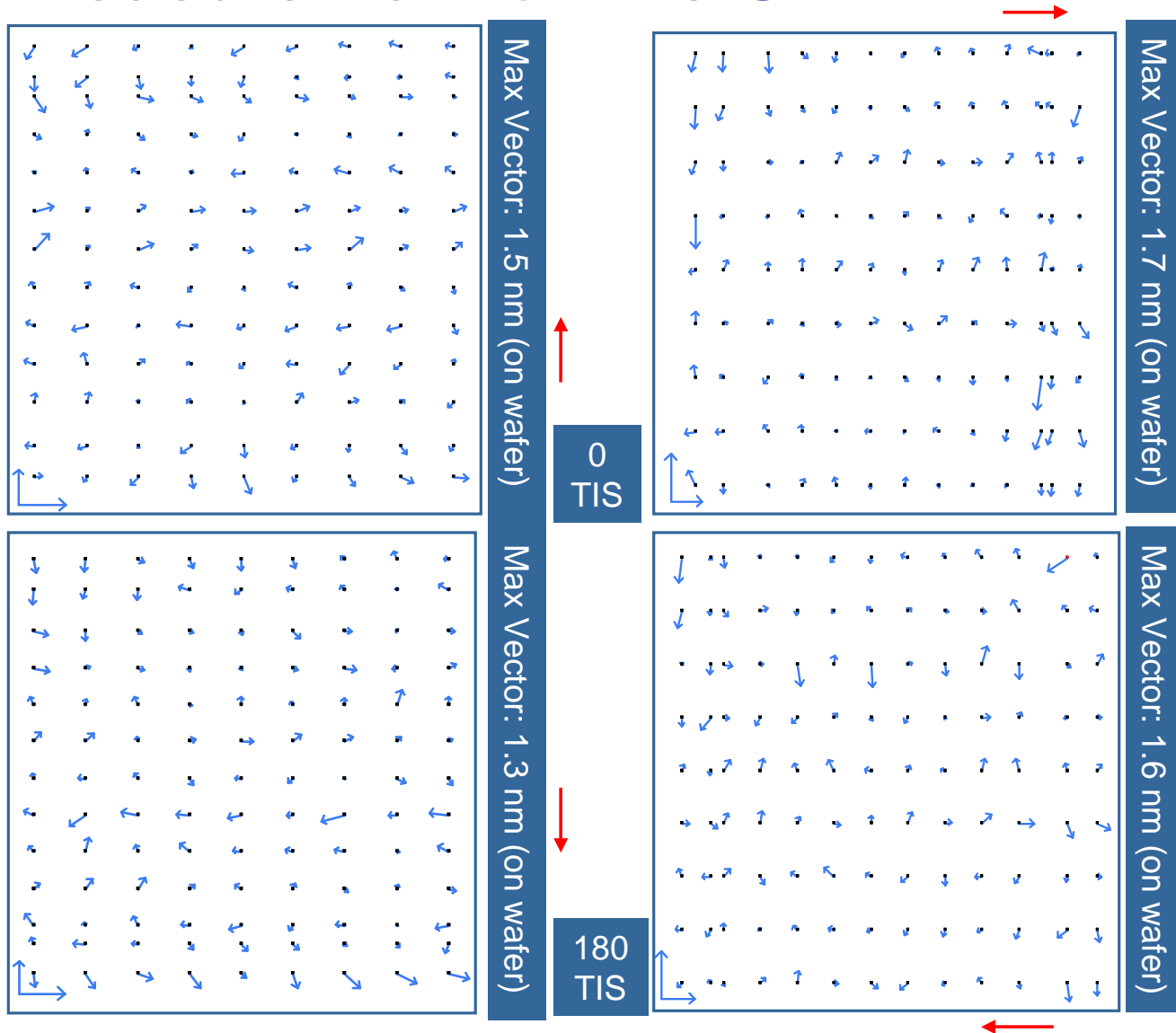


- TIS marks for 4 different orientations
- Box-in-box for overlay metrology
- AIM pattern for overlay metrology
- XPA for ADT in-tool measurement
- 3-bar pattern for CDSEM metrology

SRIM:
TIS marks across the field
Substrate PV ~ 450 nm, 360 nm
in pattern area



Mask Registration Errors from iPro Measurement on the SRIM



Scales in X,Y for all charts are 10nm (mask)

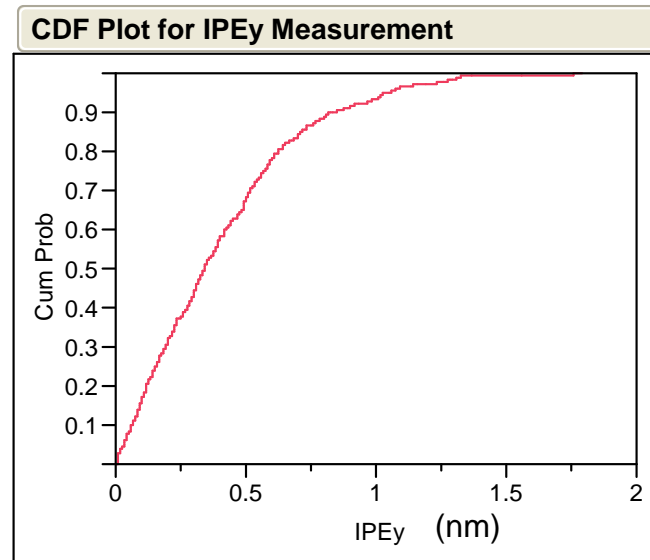
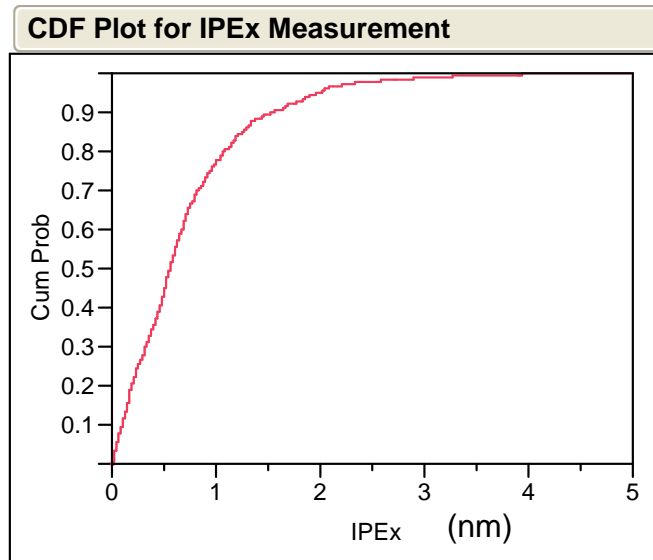
Contributions from mask registration errors on the wafer are randomly distributed across the field

90 TIS
Red arrows are scan directions when wafers are exposed in different orientations

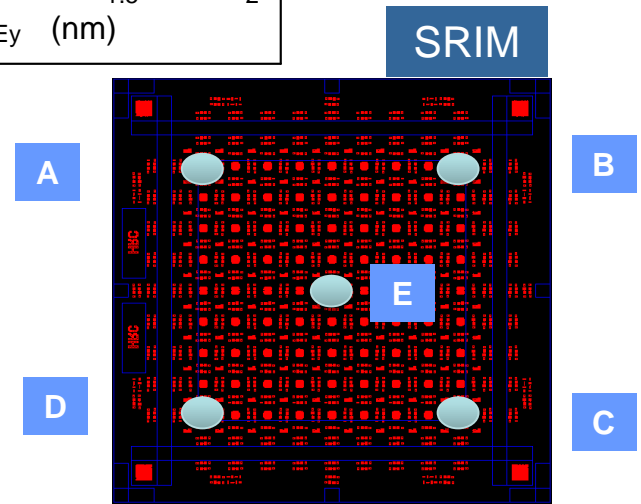
Contributions from mask registration errors on the wafer are less than 1.7 nm in the maximum overlay vector

270 TIS

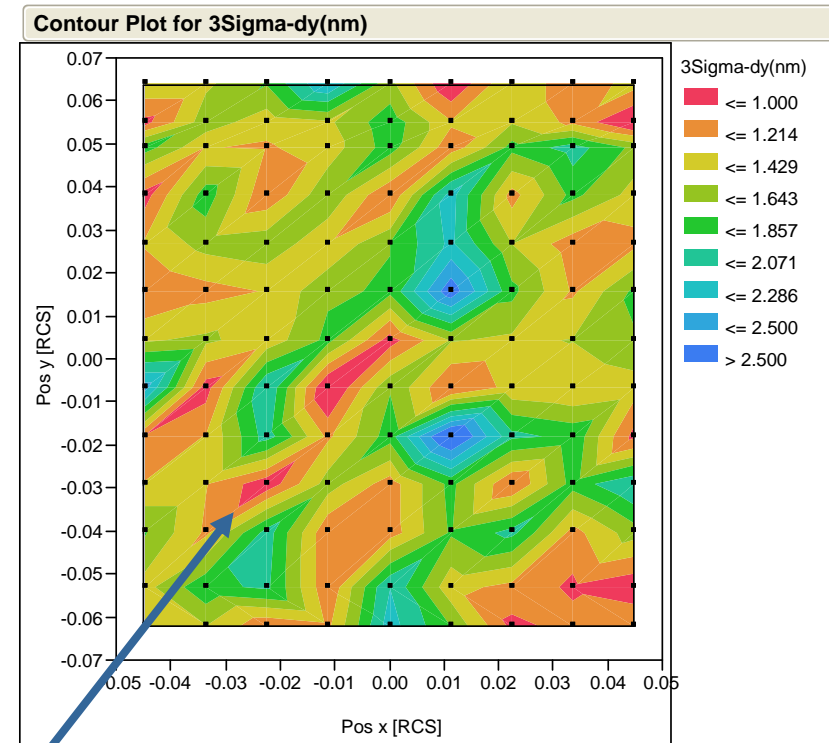
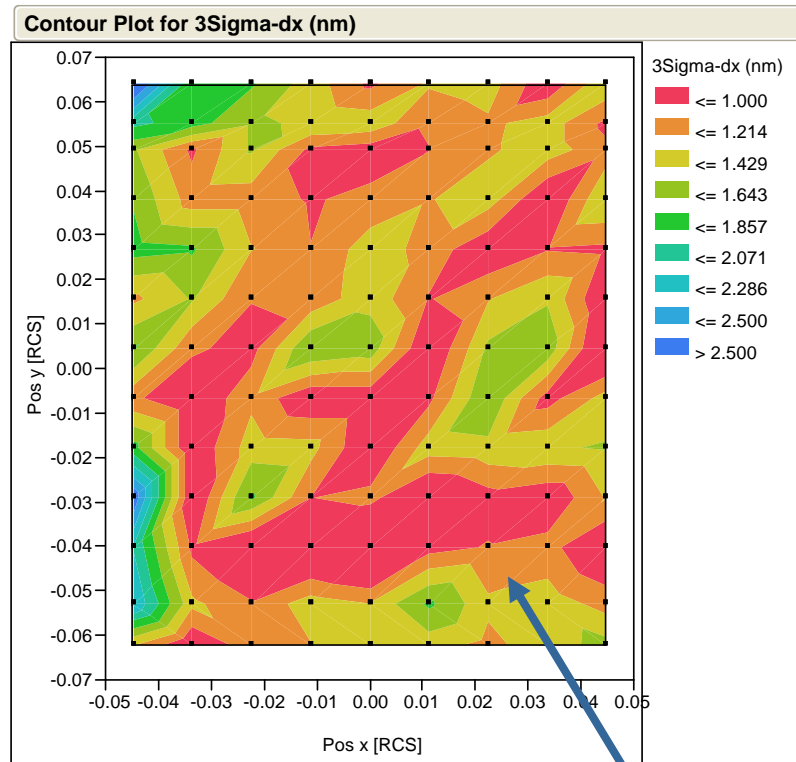
Short-Term Repeatability (100 measurements)



100 TIS measurements for each TIS mark, a total of 5 marks were measured over the mask field as shown on the left; short-term repeatability is shown for imaging placement errors (x and y) from TIS

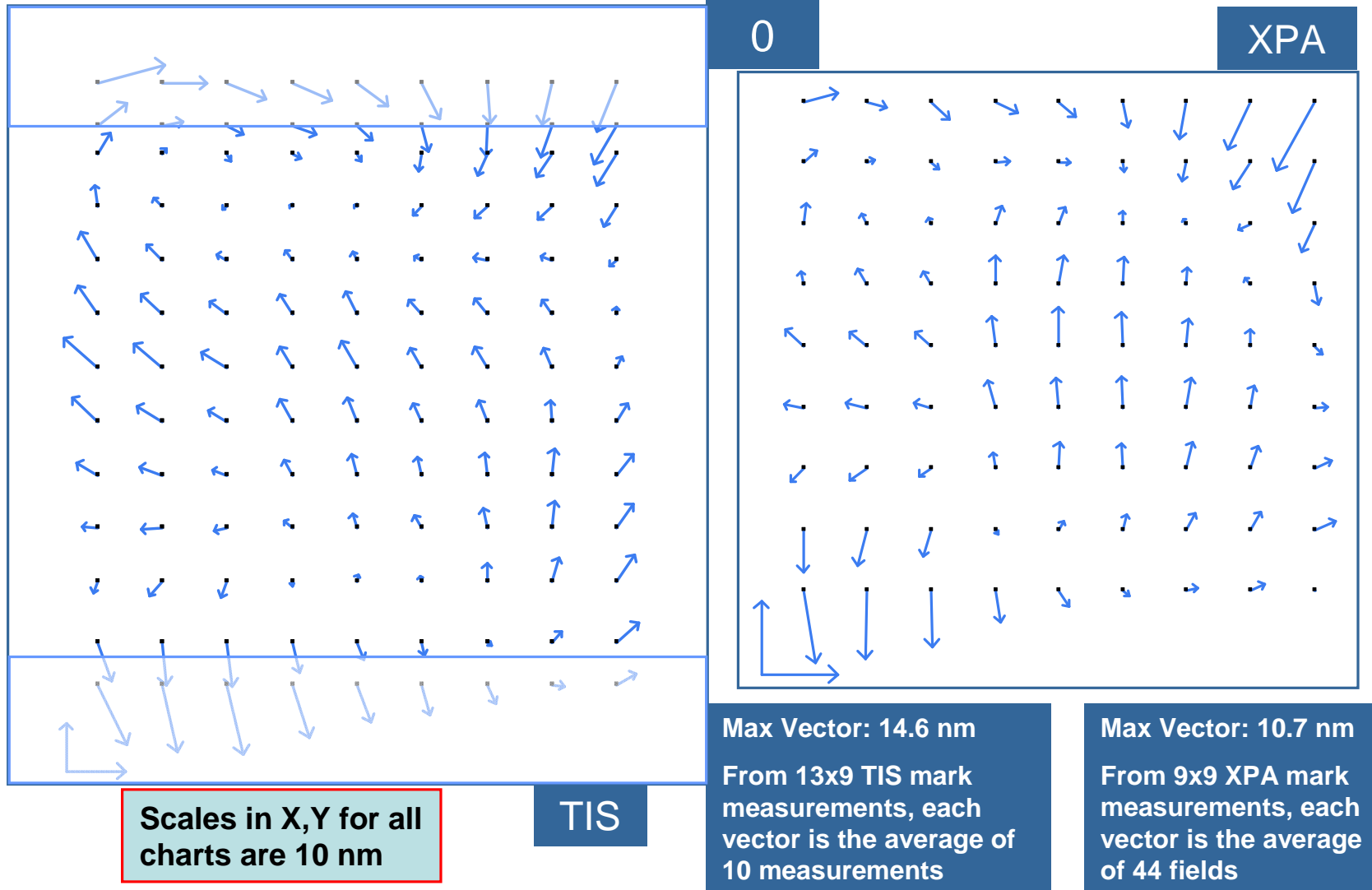


Measurement Accuracy at Each Site for Full Mask TIS Measurements

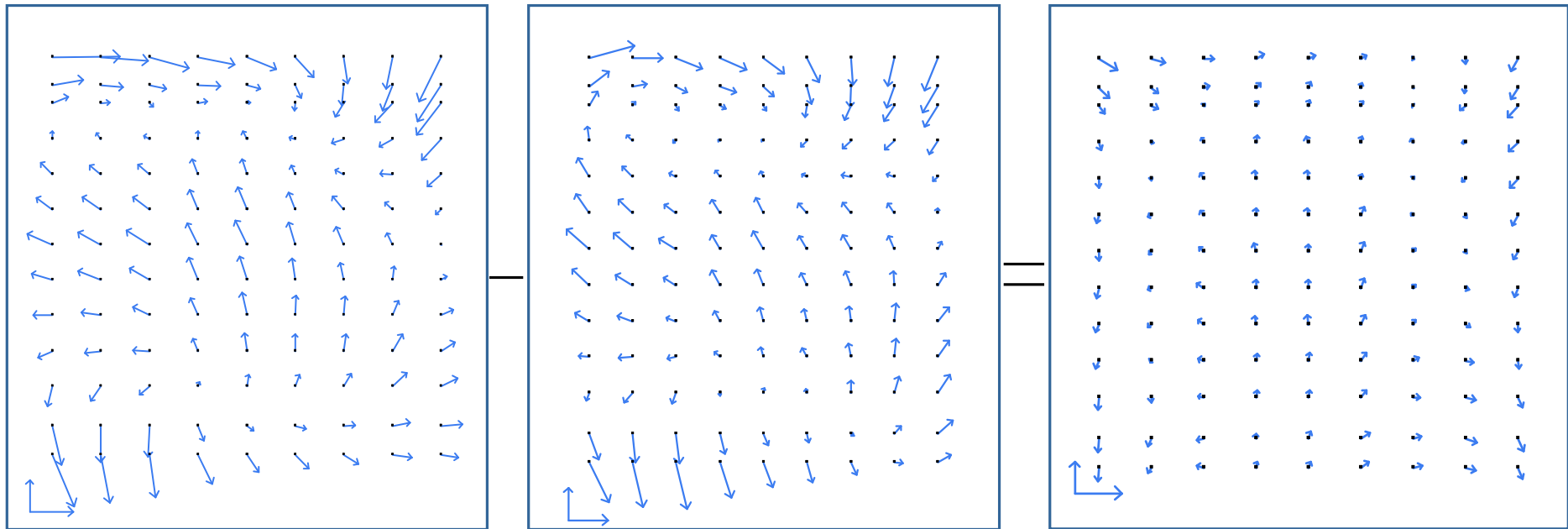


3-sigma of 10 measurements of each TIS mark across the mask — most measurements are less than 2 nm — 0 orientation TIS, 1st measurement

Residual Vector Map Comparison at 0 Orientation of SRIM (TIS vs. XPA)



ADT Mask Chucking Repeatability



2nd TIS measurement
Max Vector: 17.15 nm

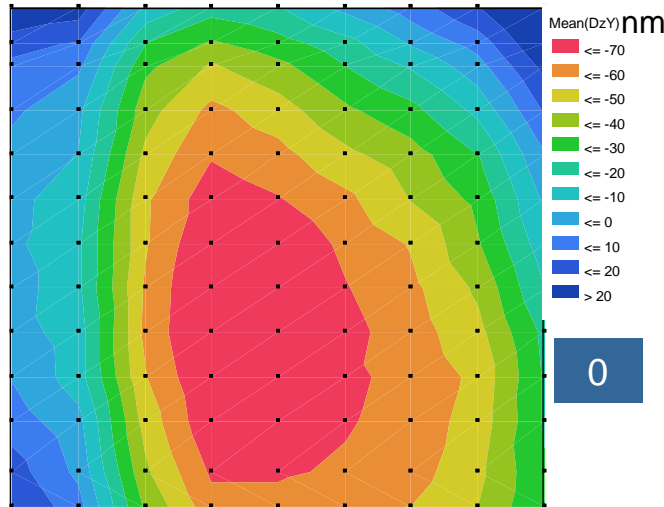
1st TIS measurement
Max Vector: 14.6 nm

Difference between 2nd
and 1st measurement
Max Vector: 5 nm

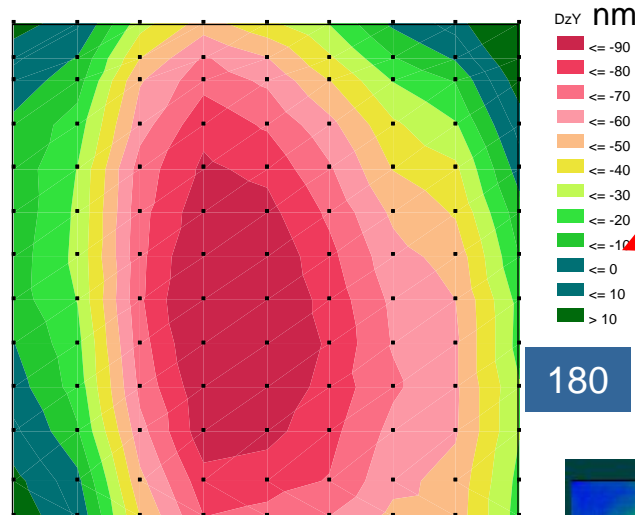
**Scales in X,Y for all
charts are 10 nm**

Chuck repeatability (including measurement errors):
3-sigma of X difference: 1.9 nm
3-sigma of Y difference: 1.9 nm

Focus Map After Chucking on the ADT at 0, 90, and 180 Orientations

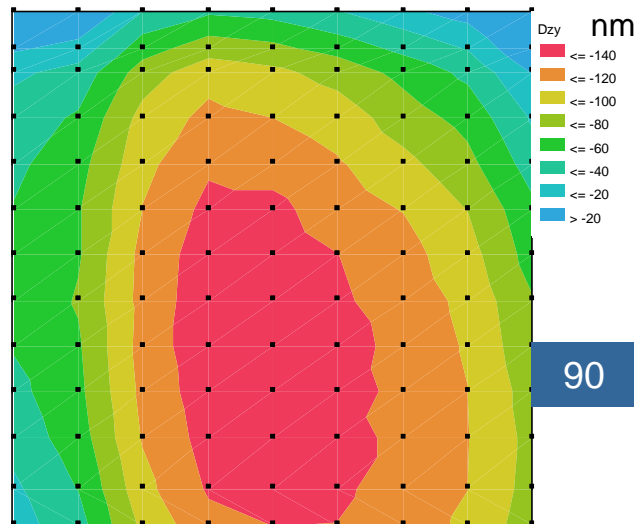


0

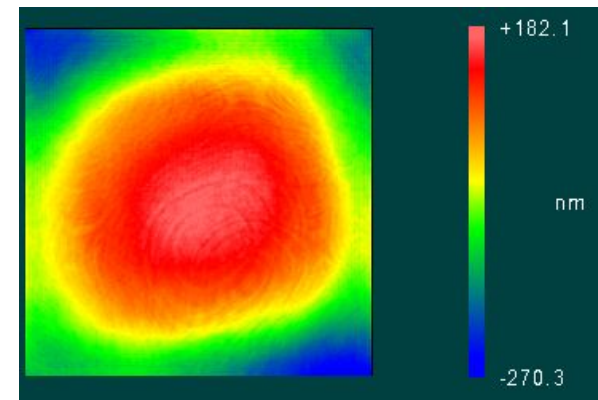


180

ADT in-tool measurement (DZy analysis)
Area: 89.6(X) x 126 (Y) mm

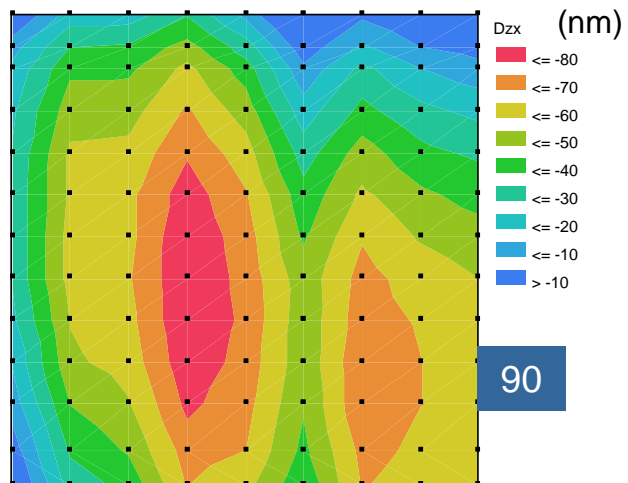
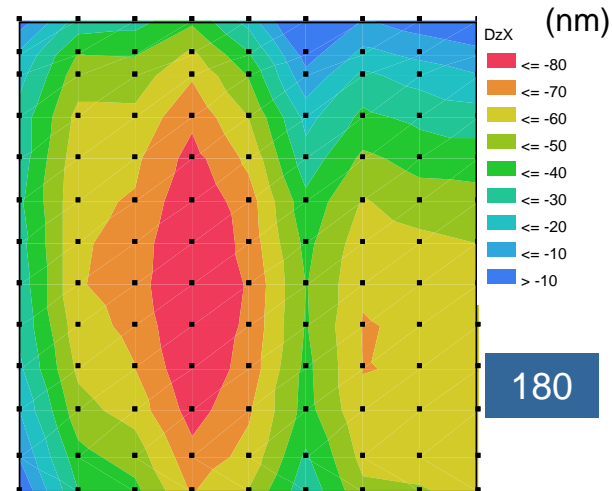
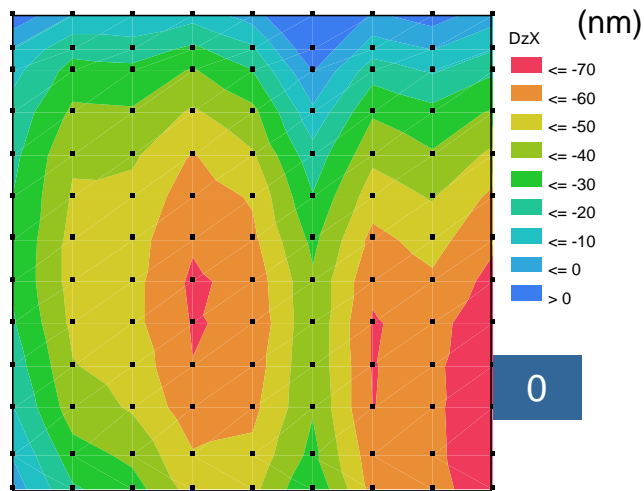


90



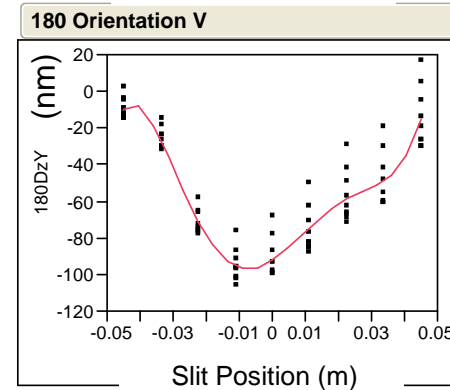
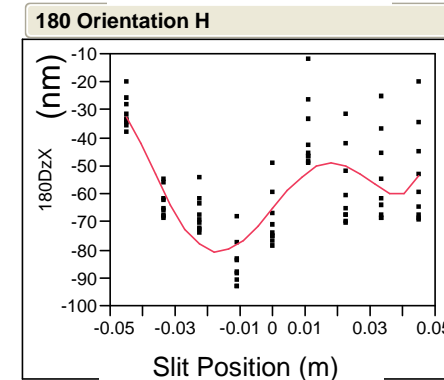
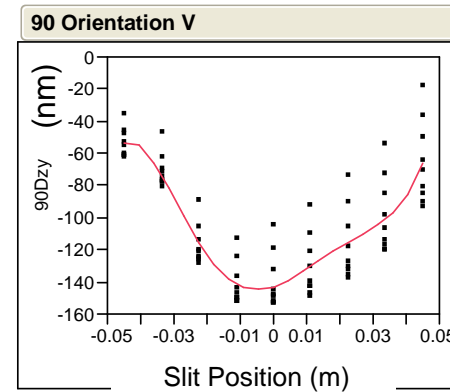
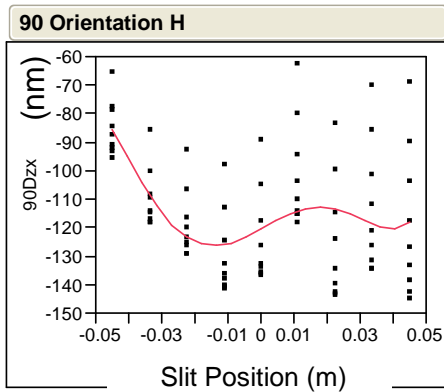
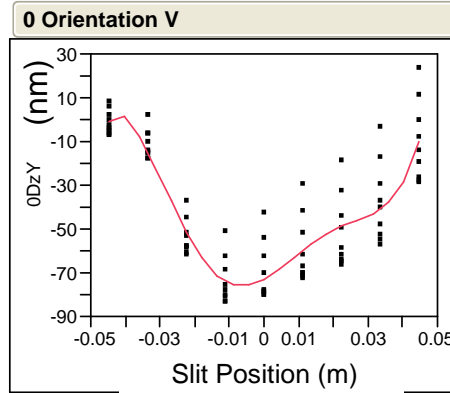
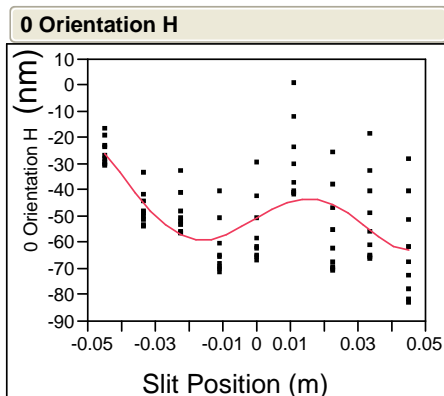
Mask blank Z-height measurement
Area: 142(X) x 142 (Y) mm

Focus Map After Chucking on the ADT at 0, 90, and 180 Orientations



ADT in-tool measurement
(DZx analysis)
Area: 89.6(X) x 126 (Y) mm

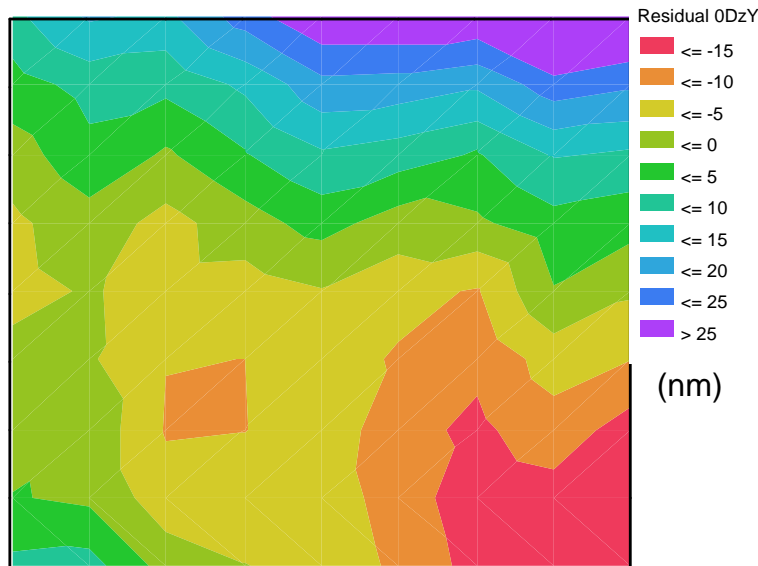
Lens Contributions to Focus Errors



ASML Tool Monitor

IPD (image plane deviation) ~ 80 nm
Astigmatism ~ 50 nm

Mask Non-flatness (chuck, mask, and potential stage tilt during scan)

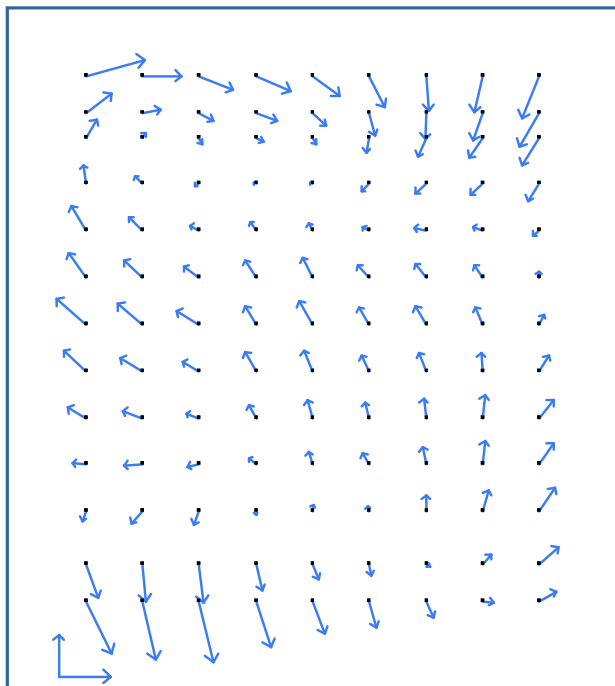


Chuck and mask non-flatness: about $50 \times 16 = 800$ nm

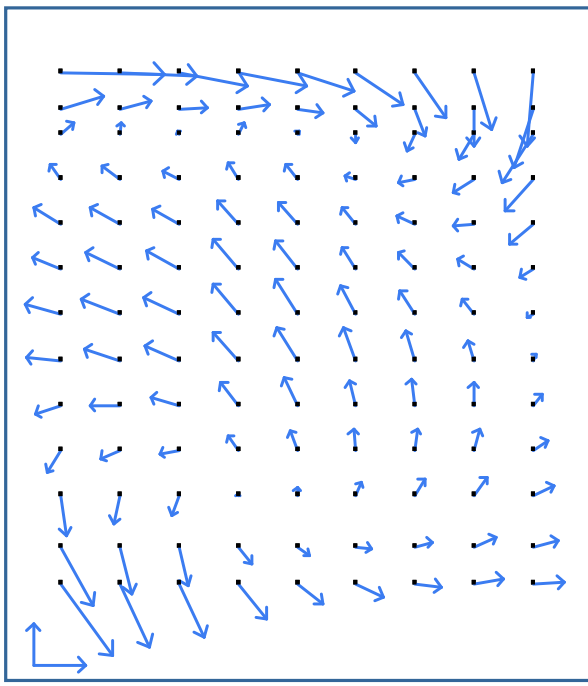
- 1.Mask PV: 360 nm
- 2.Chuck non-flatness: 50 nm
- 3.Stage rolling estimate: 390 nm (it can be corrected by tool)

0 orientation Z-height map after removing all lens contributions

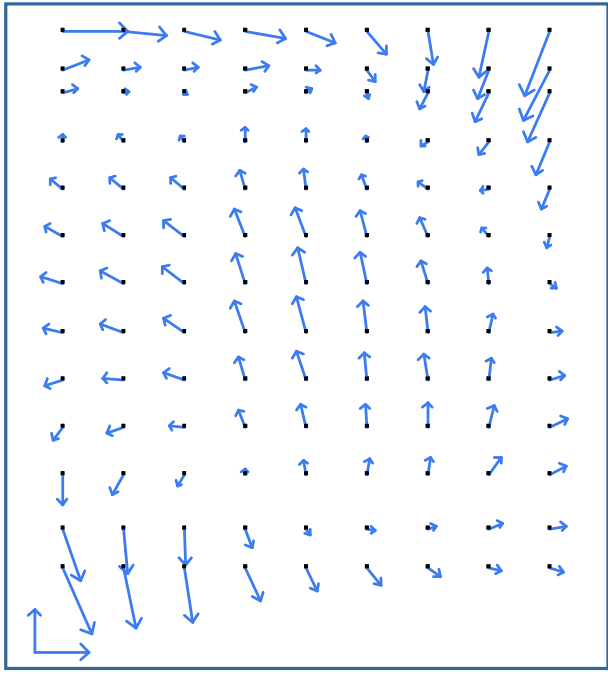
Full Reticle TIS Measurement and Comparison at 0, 90, and 180 Orientations



0 Max vector: 14.6 nm



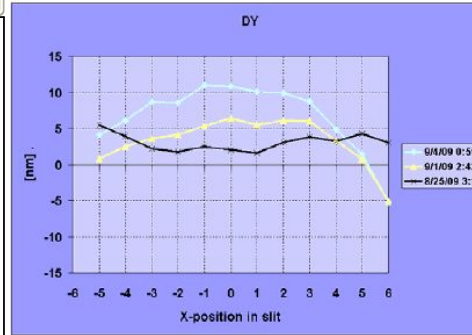
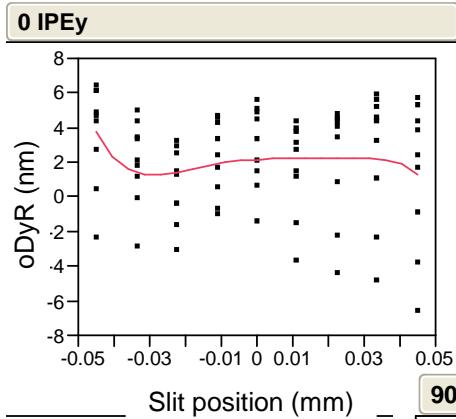
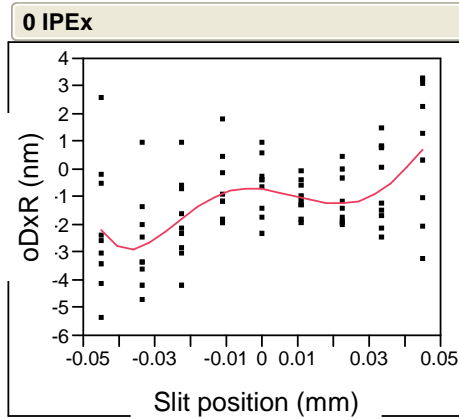
90 Max vector: 20.3 nm



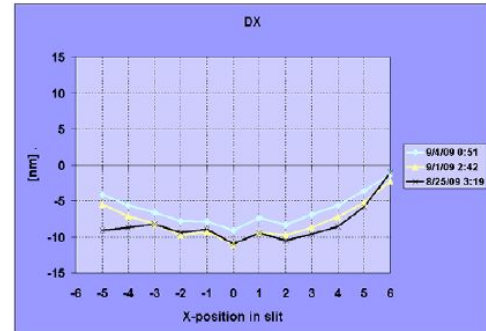
180 Max vector: 16.5 nm

Scales in X,Y for all charts are 10 nm

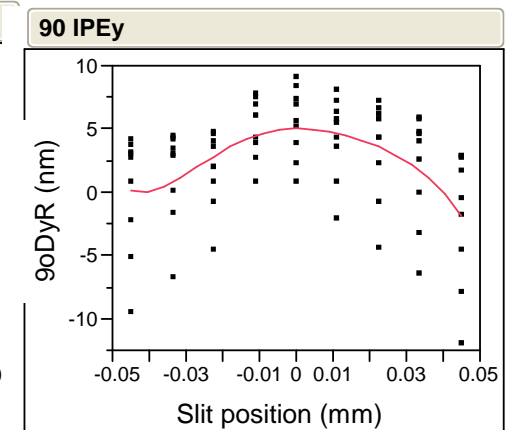
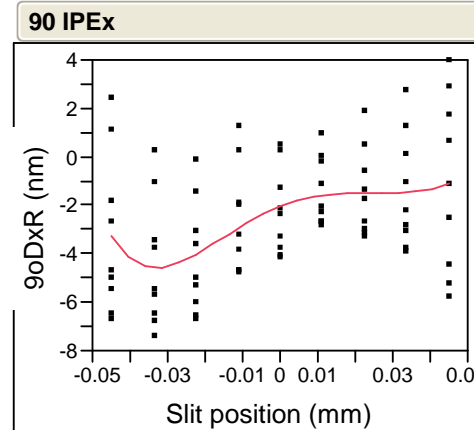
Lens Contribution on IPEs



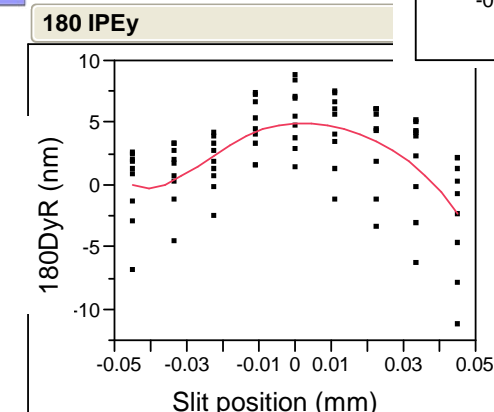
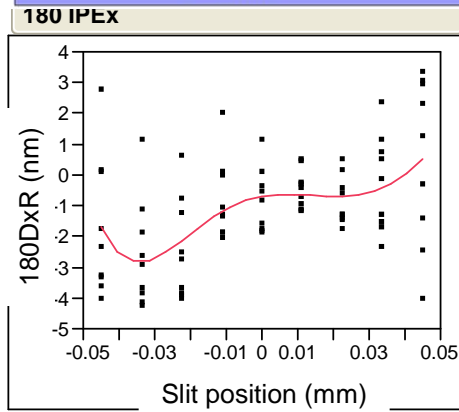
ASML IPE_y monitor data



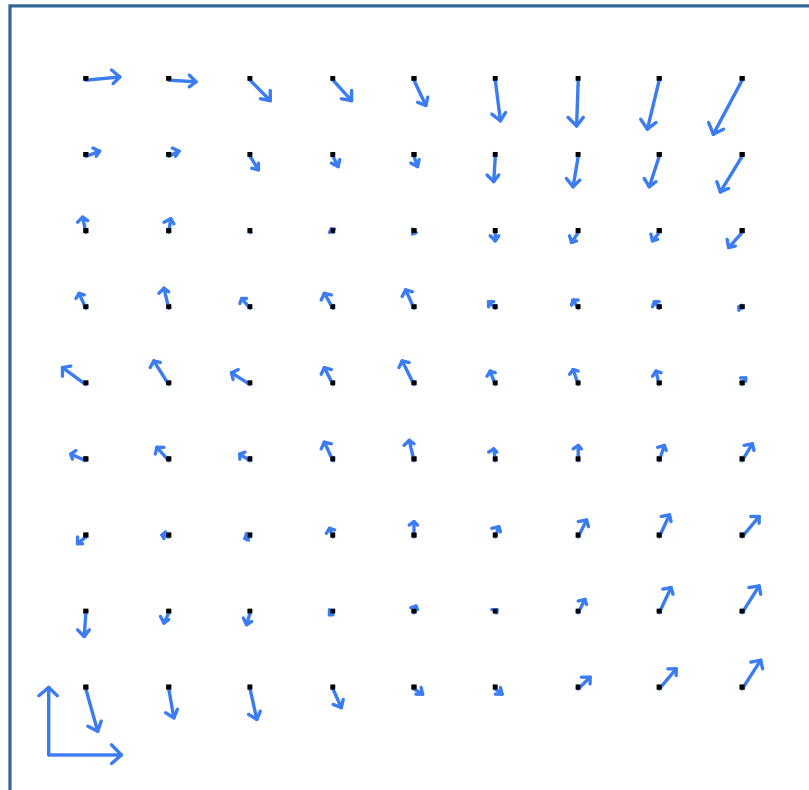
ASML IPE_x monitor data



90 and 180 orientation tests were done after 7 days with a scheduled vacuum downtime

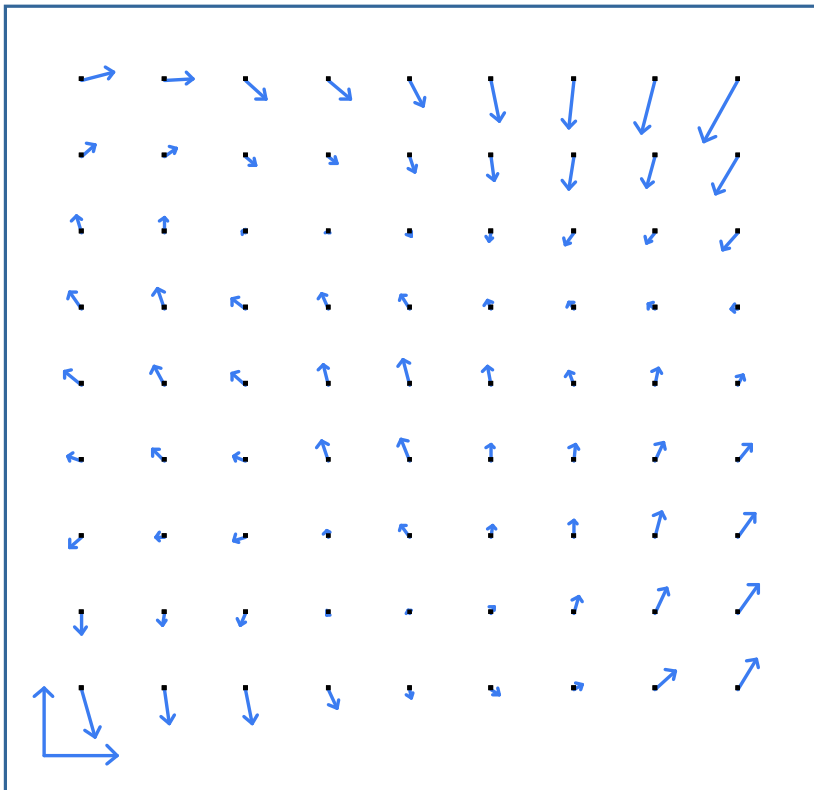


TIS Results at 0 and 180 Orientations After Removing Lens Contributions



0

Max: 8.9 nm

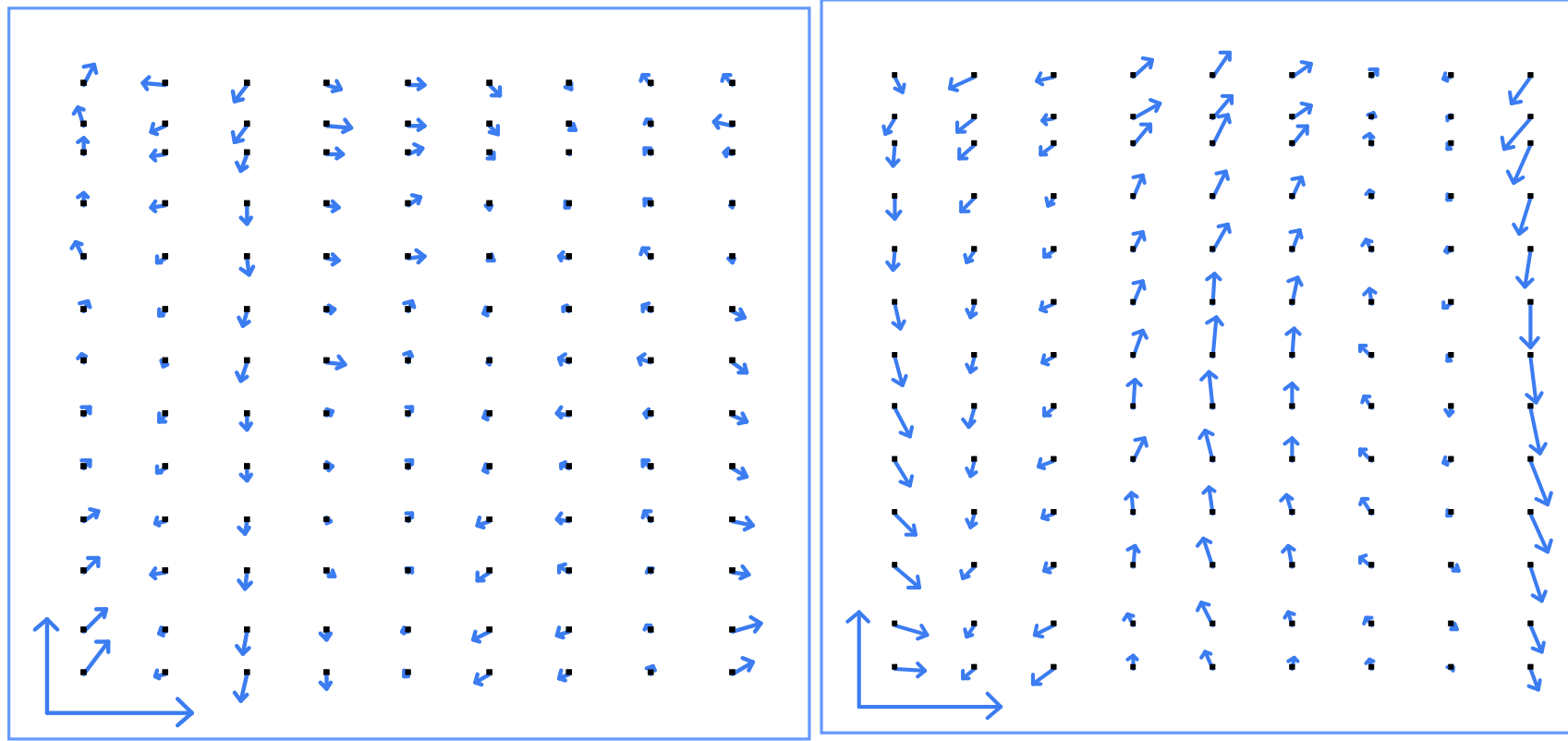


180

Max: 10 nm

Scales in X,Y for all charts are 10 nm

TIS Results at 0 and 180 Orientations After Removing Stage Rolling and Lens effects



0 Max: 3.8 nm

180 Max: 5.0 nm

Scales in X,Y for all charts are 10 nm

Summary



- IPE residual analysis from TIS and exposed XPA mark measurements shows a similar fingerprint across the exposure field.
- TIS can be a good alternative for IPE studies with good accuracy and flexibility.
- The focus and overlay errors caused by lens contributions on the ADT were distinguished, and results show good agreement with ASML ADT monitor data from the same time period.
- ADT mask chucking repeatability over 7 days with a scheduled vacuum downtime was measured and reported to be better than 1.9 nm in 3 sigma for both X and Y IPE, respectively (including measurement errors).
- This poster presents the status report on a current on-going project. Further experiments are needed to confirm ADT mask stage rolling effects, which seem to be a dominant factor in IPEs from Z-heights (tool correction was turned off on purpose for better experimental analysis).

Acknowledgements



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