IMEC INPUTS ON BLANK DEFECTIVITY

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@ IEUVI MASK TWG 16OCT2011

ACKNOWLEDGEMENTS TO

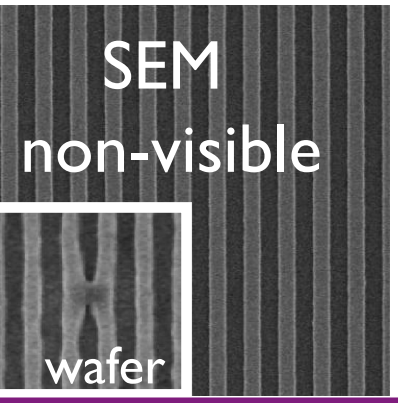
ZEISS intel

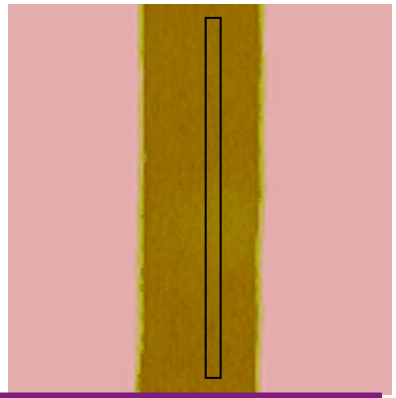
imec

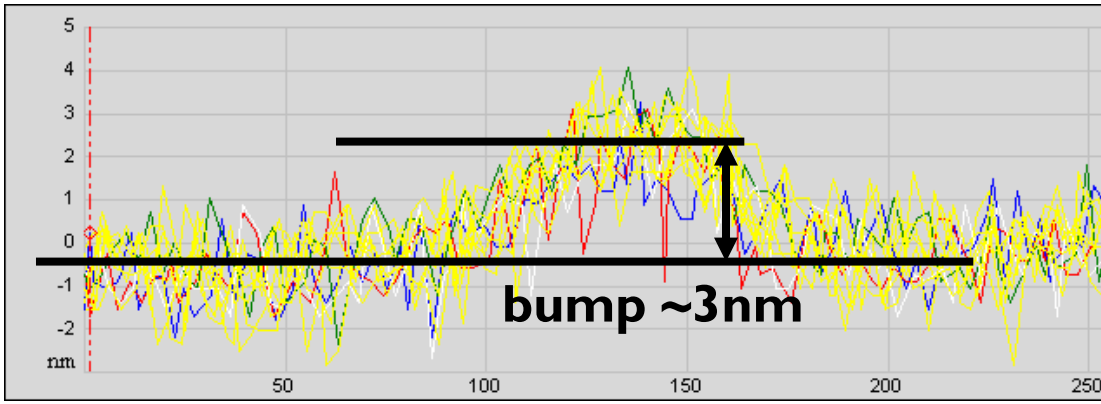
WE INCREASINGLY *FIND* MORE, SMALLER, SHALLOWER PRINTING, NATURAL ML-DEFECTS

→ *CHECK IF DETECTED BY BLANK INSPECTION*

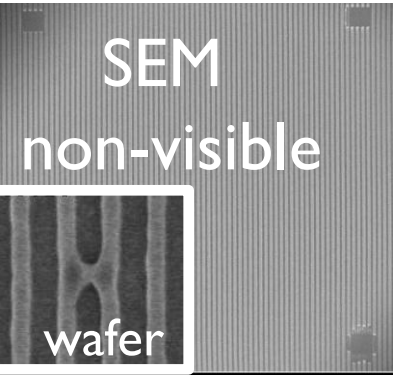
→ *VISUALIZE BY MASK REVIEW (SEM AND AFM)*

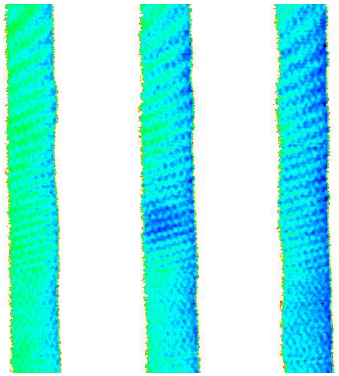


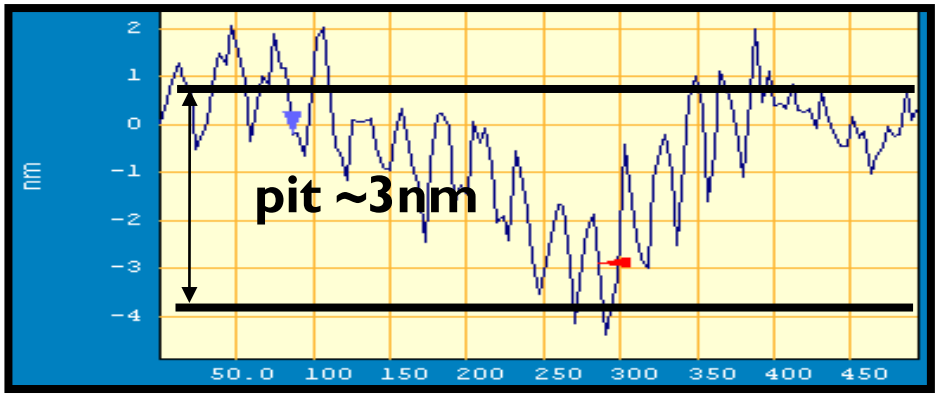




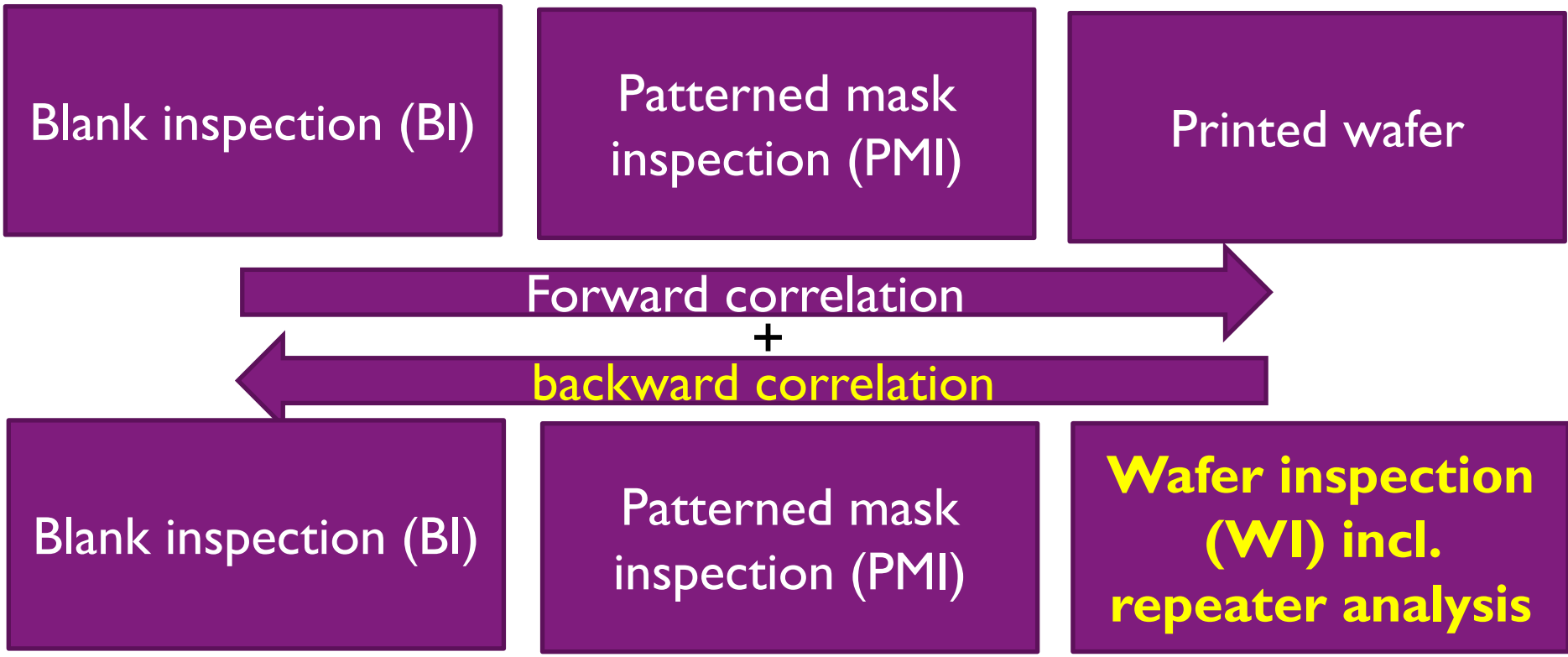
Missers on 1st Gen BI tool







WAY OF WORKING

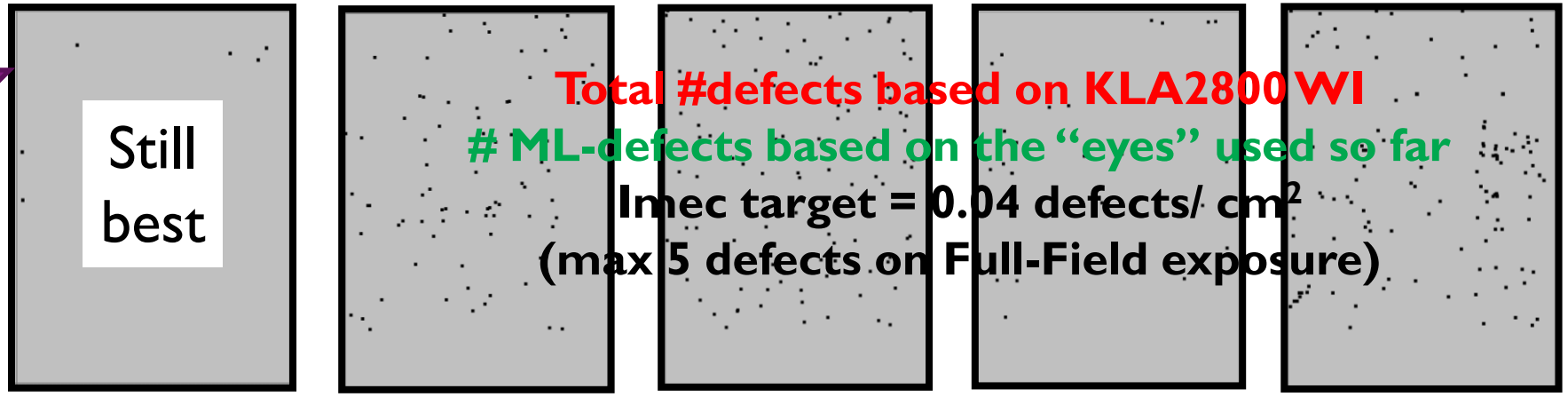


IMEC has evaluated multiple EUV reticles in terms of defectivity in this way

BUT we all need more of such analysis (statistics of defect density !!!)

DO WE SEE IMPROVEMENT IN DEFECT DENSITY ?

Our reticles prior to 2009 typically a high count of absorber type defects, severely obscuring the search for natural defects



DEFECT32	DEFECT40-1	DEFECT40-2	DEFECT40-3	DEFECT32-2
0.21 def/cm²	0.68 def/cm²	0.83 def/cm²	0.21 def/cm²	0.67 def/cm²
0.39 ML-def/cm²		0.69 ML-def/cm²	0.30 ML-def/cm²	

- **In practice we <u>still</u> often see high numbers of absorber type defects and/or particle contamination**
(although better capability assumed resp. known solution).
- **#ML-defects needs to be further decreased.**

EUVL Symposium 2011

MITIGATING ML-DEFECTS

1. **Assure defect-free blank manufacturing ...**
2. Pattern shift method ...
3. Compensation repair for ML defects

1 and 2 **limited to those defects found by BI !!**

Unless there is a "good enough" BI tool, we do not yet know how many printing ML-defects are on a given mask.

How good is state-of-the-art BI ?

Imec's work so far:

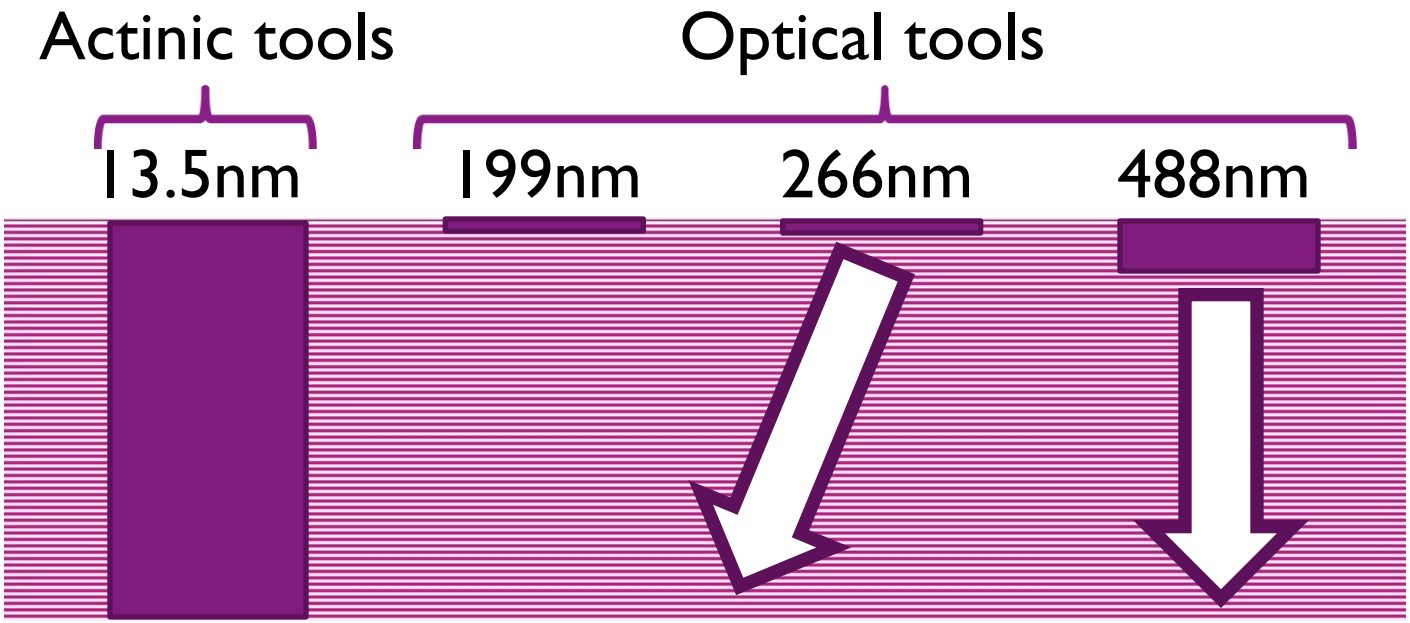
Do BI tools find all ML-defects that matter ?

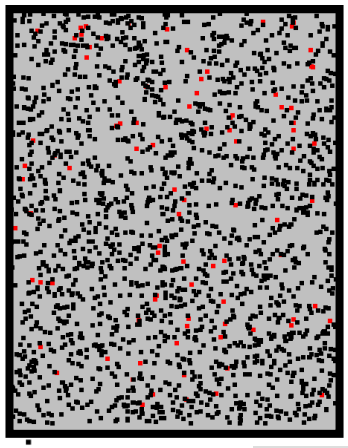
"Can we find evidence of printing ML-defects that were missed by BI tools ?"

How well does it relate to printability ? Nuisance rate ?

+ experimental assessment of compensation repair

BLANK INSPECTION TECHNIQUES PENETRATION DEPTH





2nd Gen. BI tool

(e.g., in use at Intel)

ALSO evidence of printing ML-defects missed (# is 6 now) *(BACUS 2011)*

despite of high nuisance rate

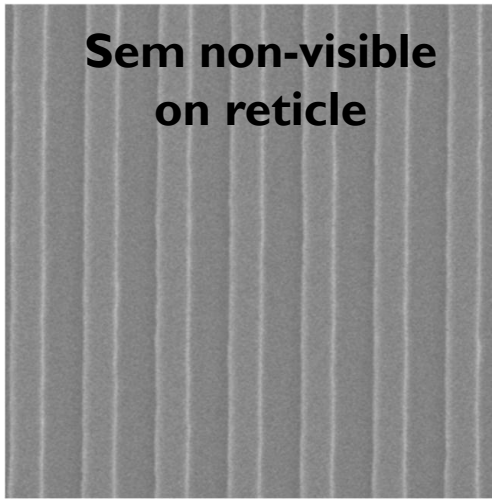
1st Gen BI tool

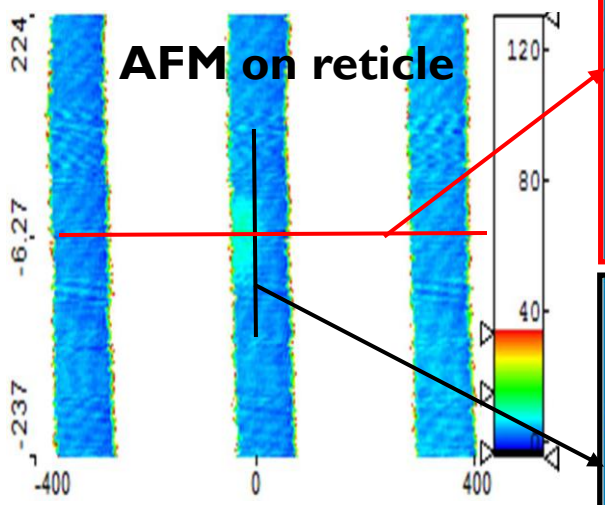
(in use by blank vendors)

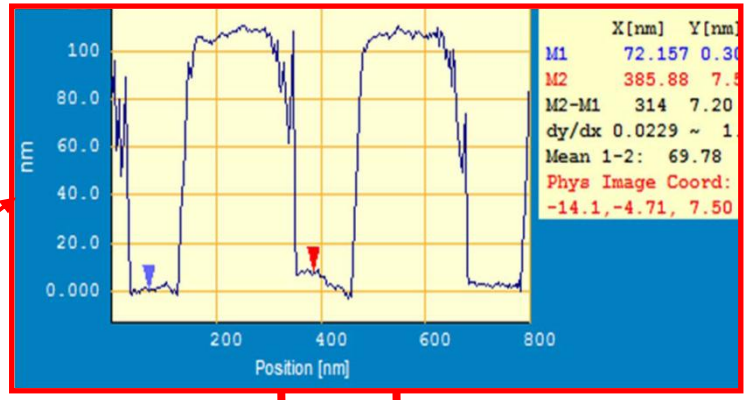
Evidence of printing ML-defects missed

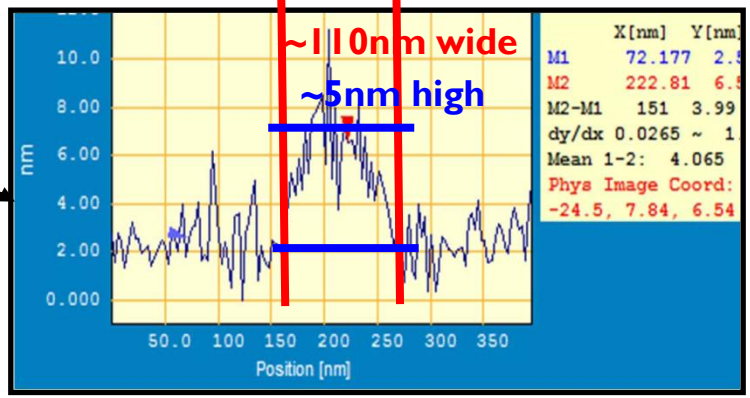
(BACUS 2010)

EXAMPLE 1 OF GEN2 MISSER



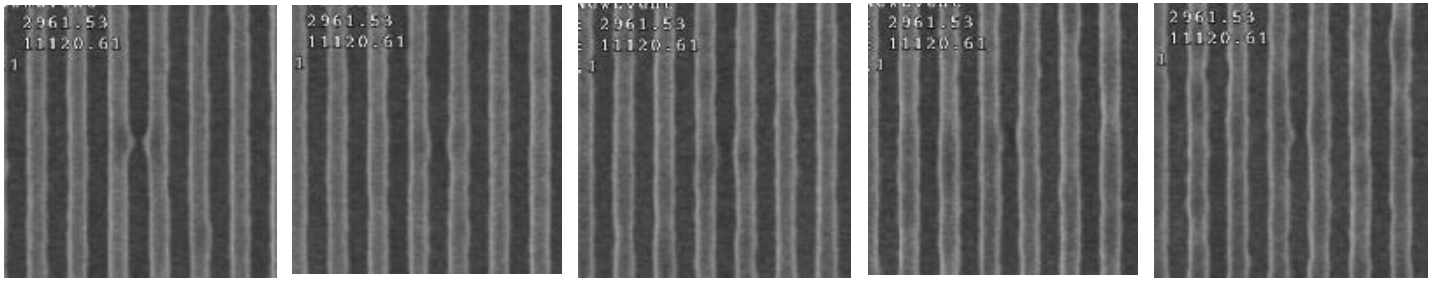




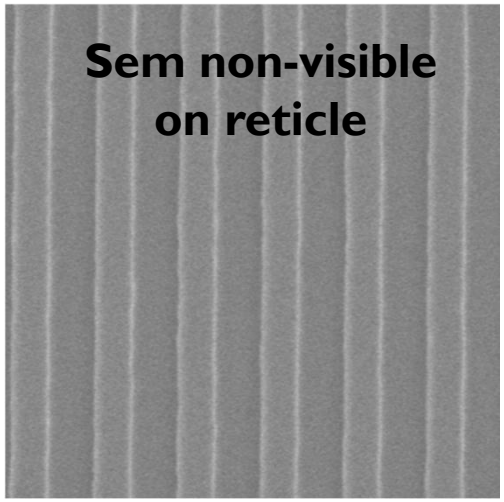


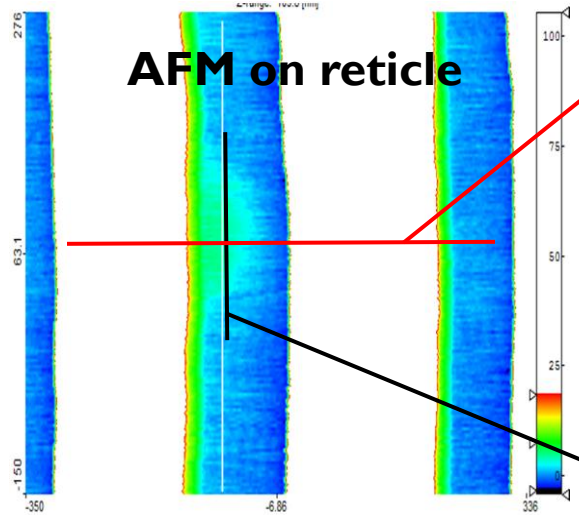
SEM-review on wafer

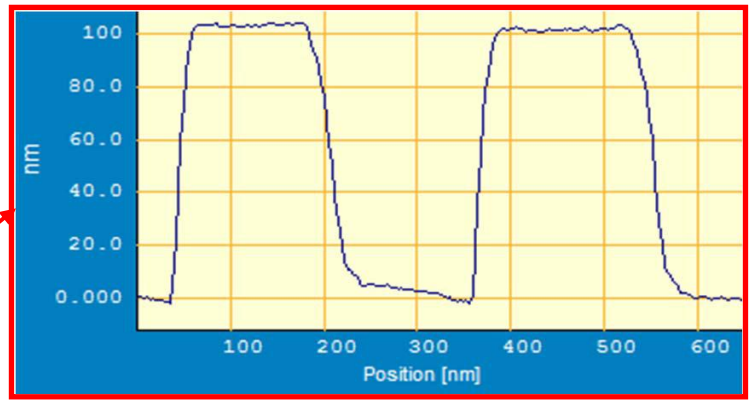
BF-100nm | BF-50nm | BF | BF+50nm | BF+100nm

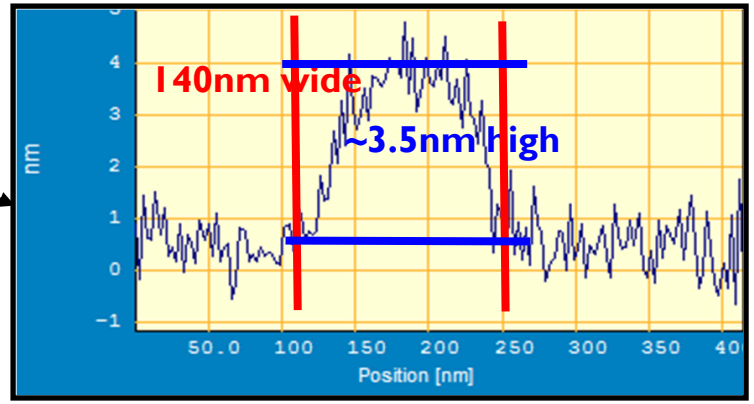


EXAMPLE 2 OF GEN2 MISSER



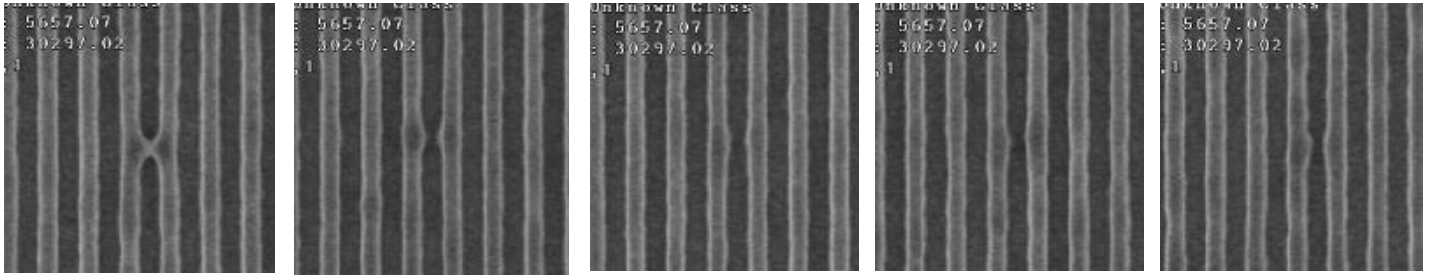




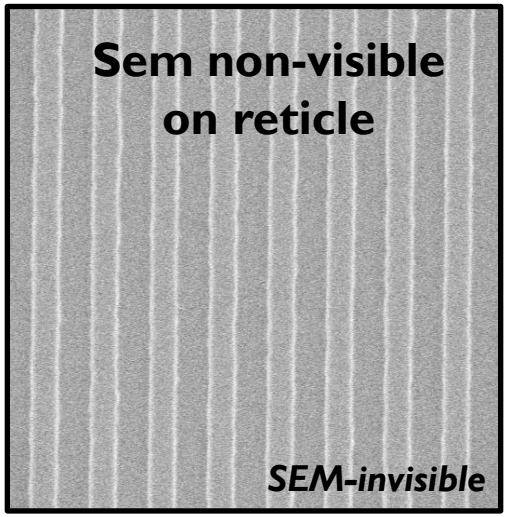


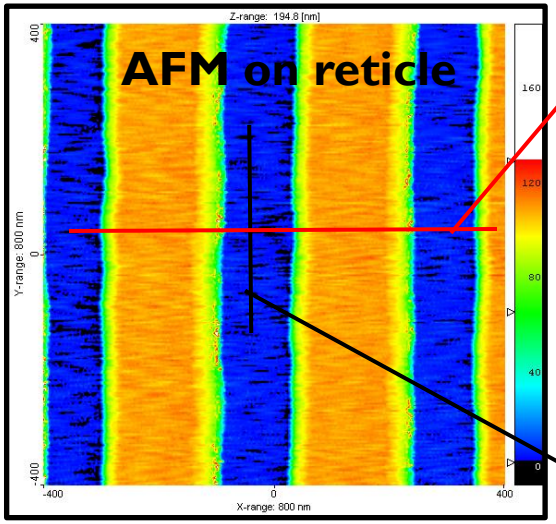
SEM-review on wafer

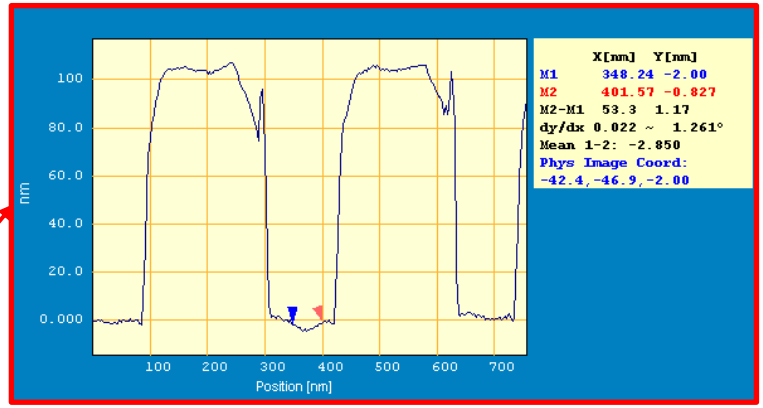
BF-100nm | BF-50nm | BF | BF+50nm | BF+100nm

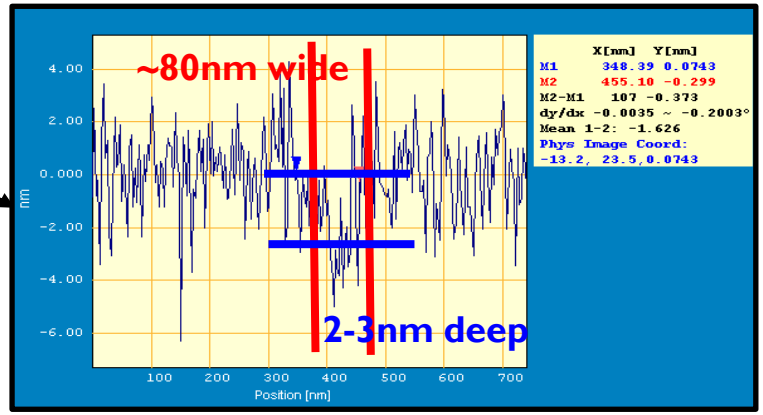


EXAMPLE 3 OF GEN2 MISSER





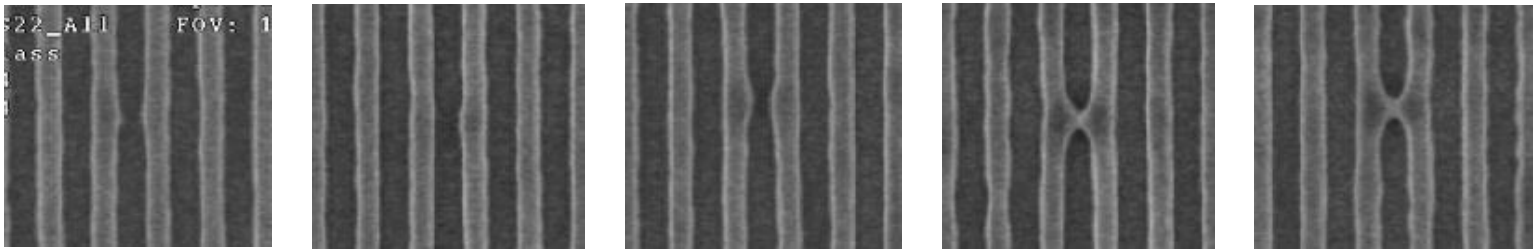




Noise level starts to limits visualization for shallow defects

SEM-review on wafer

BF-100nm | BF-50nm | BF | BF+50nm | BF+100nm

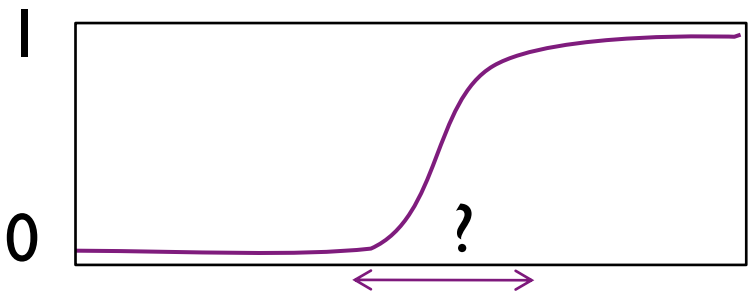


ANALYSIS OF M7360 MISSERS

- M7360 detections visualized typically start from SEVD = 35~40nm, equally for ML bumps and pits
- The **6 defects missed** have resp.
  - On reticle A: SEVD = 27, 27, 23, 37nm
  - On reticle B: SEVD = 55, 49nm
    (estimated error flag ±10%)

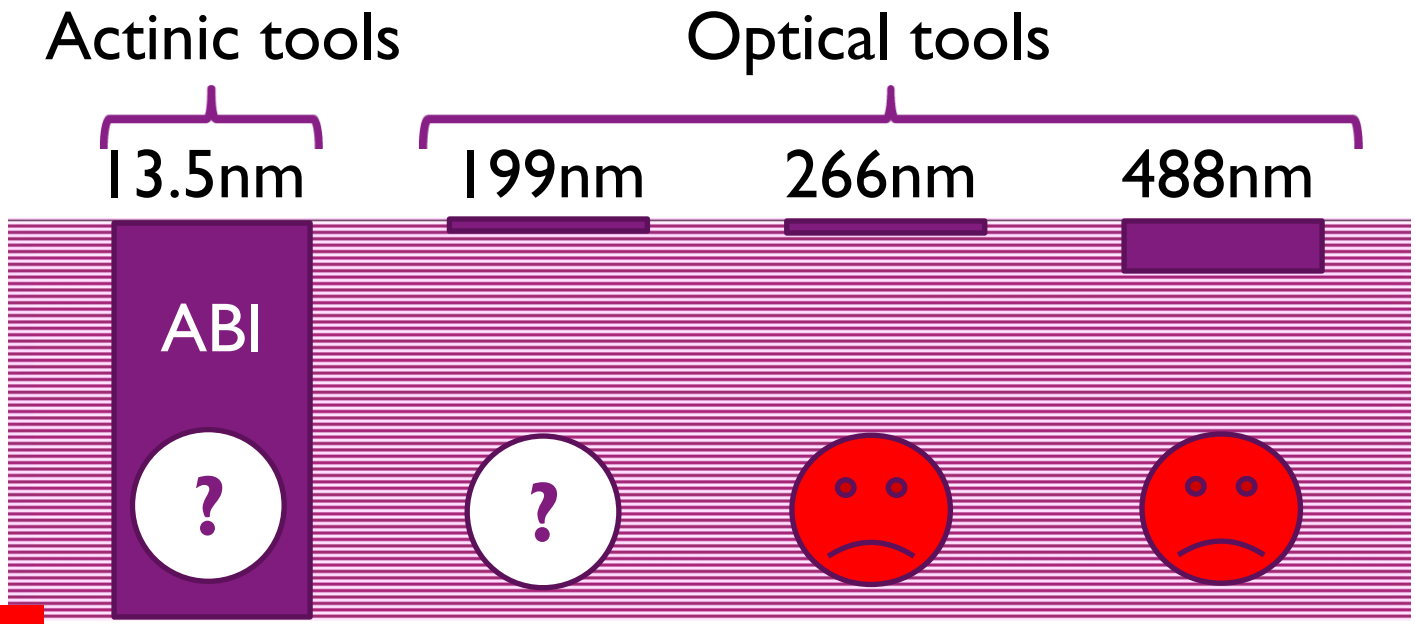
SEVD derived cfr Kang@SPIE2010

- Assumed related to capture rate = f(SEVD)
  - Typically ...



(1 inspection on M7360 used)

CONCLUSIONS
BLANK INSPECTION TECHNIQUES



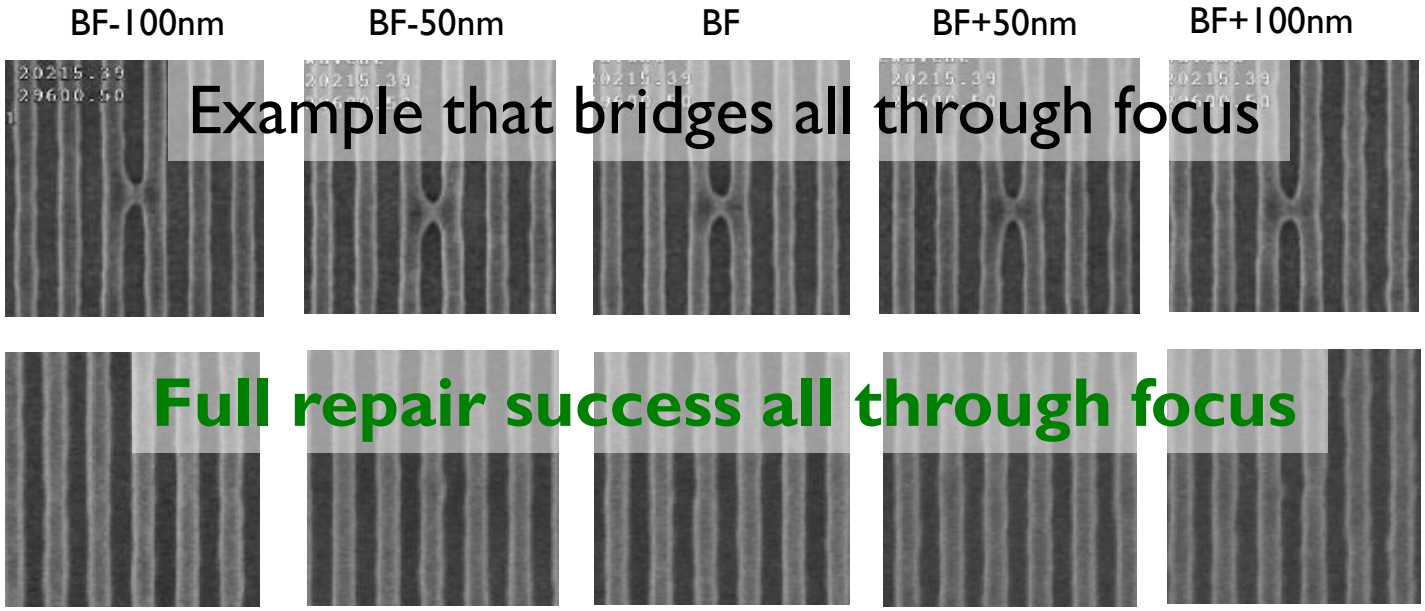
Printability of a ML defect **not** *(only)* determined by its top surface.

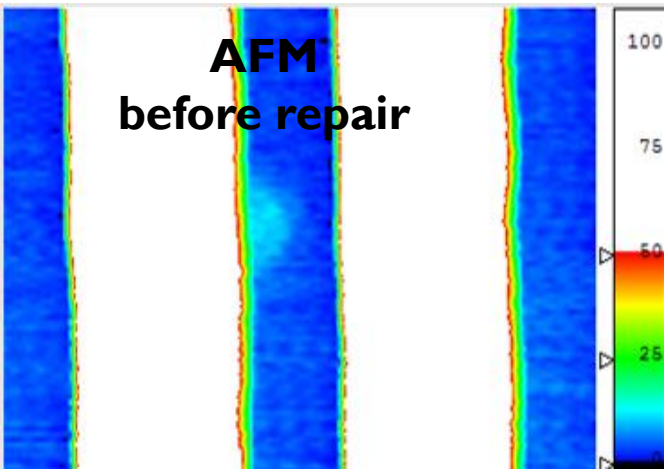
This may be an indication for the **likelihood of missers** of **blank** inspection tools to detect printing **blank** defects.

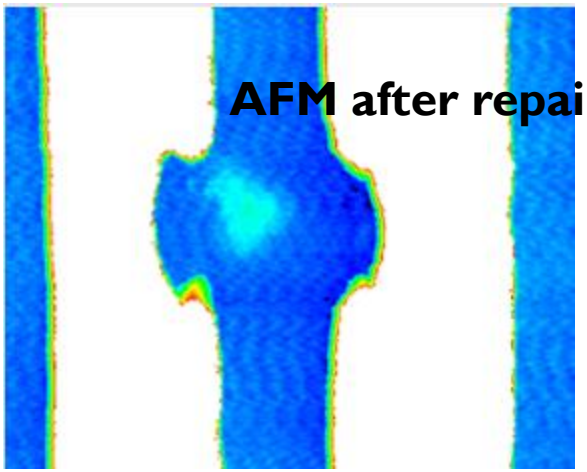
EXAMPLE OF SUCCESSFUL COMPENSATION REPAIR

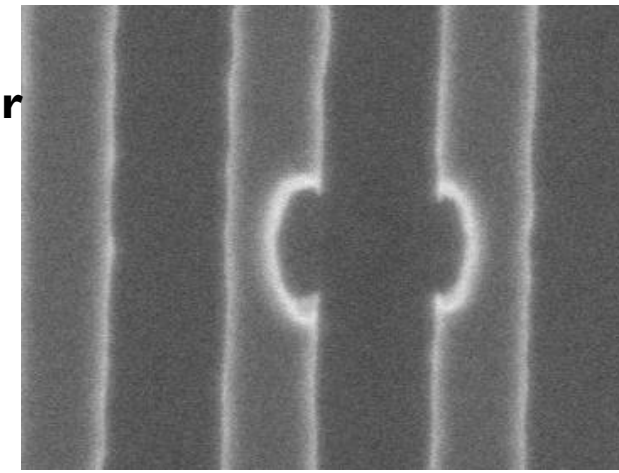
See BACUS2011

7nm bump









SUMMARY COMPENSATION REPAIR

Feasibility of compensation repair is demonstrated experimentally.

- **All experimental results show a clear improvement**

Available examples confirm **constraints** expected from simulation, **but simulation predicted stronger limitation**

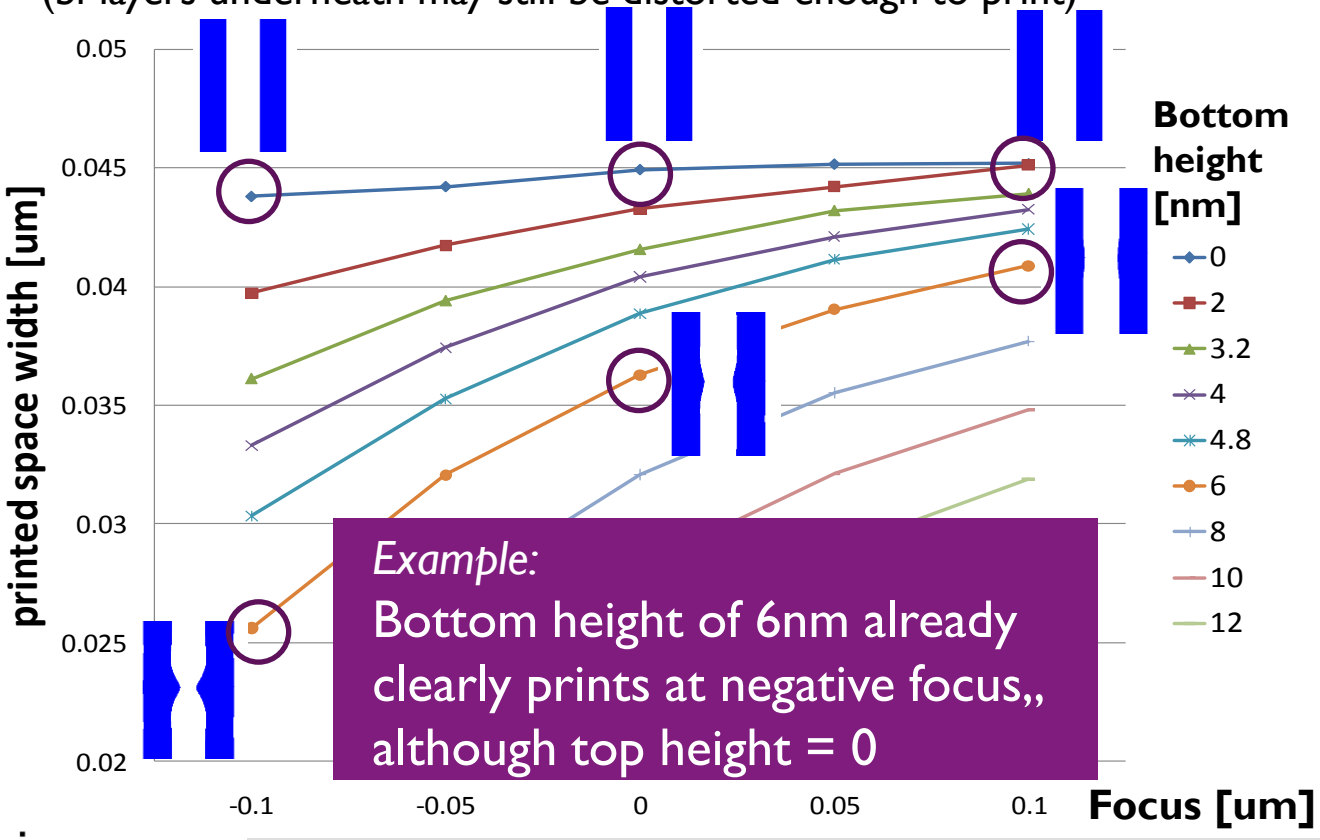
- Success is limited to the less "solid" ML defects
  → avoid by blank quality improvements and/or pattern shift technique
  (BOTH require detection by BI !!)
- Tight placement of compensation relative to defect
  → **integration of AFM in repair tool is an important asset !**
- Limited knowledge of the ML defect propagation inside the ML
  → Such analysis is destructive (TEM), but is very much of interest
  → Benefit of **publicly known smoothing**
  → If not: Printing results help, but **EUV-AIMS is needed**
- Beware for those not known yet (= those not yet found experimentally)
  - What prints at smaller hp, "zero-height" ML defects, et.

ZERO HEIGHT ML DEFECTS ?

No experimental proof yet: (So far) We were 100% successful in visualizing ALL ML-defects by AFM that we found via printing.

But the **concern** about smoothing is:

- if is is not enough ⇒ residual height/dept at top (=printing)
- **If no residual height at top ~~⇏~~ it is enough (i.e., NOT printing)**
  (bi-layers underneath may still be distorted enough to print)



Example 40nm l/S
72nm FWHM fixed
@substrate (& 0 at top)
linear propagation

Thank You

ASPIRE
INVENT
ACHIEVE

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