A YEAR OF NEW MASK DEFECTIVITY INSIGHTS IN IMEC'S EUVL PROGRAM

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imec

OUTLINE

Introduction

- Blank defectivity viewpoint
- Infrastructure for clean handling of NXE reticles @imec

Monitoring NXE3100 reticles (in "clean handling" mode) with focus on added particles

- Front-side (FS) adders
- Back-side (BS) adders
- EUV pod shipping tests
- Present role of cleaning

Conclusions

ML DEFECTS (IMEC STANDPOINT)

Imec continues with its way-of-working

Blank inspection (BI)

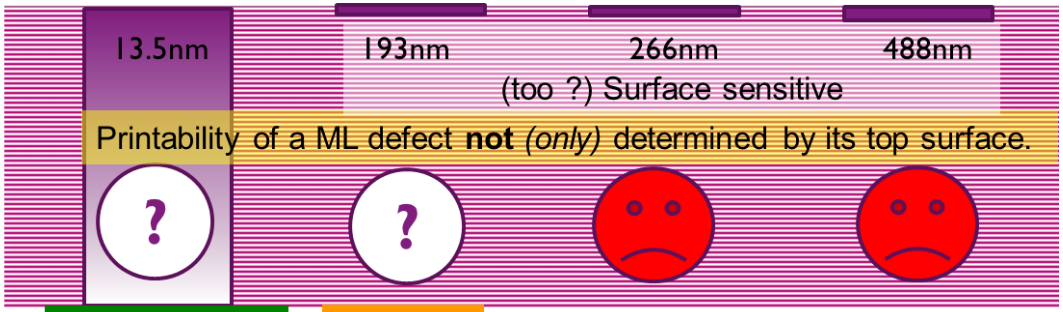
Patterned mask inspection (PMI)

Wafer inspection (WI) incl. repeater analysis

Forward correlation
+
backward correlation

Checking satisfactory performance of blank inspection techniques

Does BI detect all printing ML-defects ?

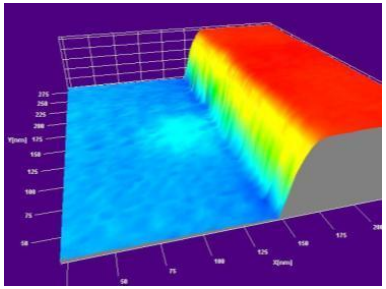


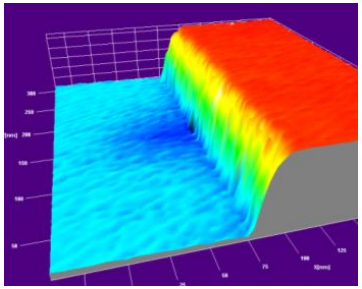
Actinic is most secure choice

Not sure (no data)

NO, evidence of missers !
(ref. SPIE 8166-3, 2011)

Examples found by WI, missed by 266nm BI, visualized by AFM (pictures from Zeiss *@SPIE 8322-11, 2012)*





Actinic BI will be a vital enabler for the EUVL community. IMEC offers to contribute to the confirmation that it detects all printing ML defects.

REMINDER: AVAILABLE INFRASTRUCTURE INTEGRATING CLEANING, BACK-SIDE INSPECTION AND AUTOMATED HANDLING OF NXE3100 RETICLES

BASELINE WAY-OF-WORKING

New NXE3100 reticles

- The reticle is received from the mask shop in ...
  - ... shipping box: manual load into RSP200, auto transfer into EUV pod on InSync
  - ... RSP200: auto transfer into EUV pod on InSync
  - **... EUV pod: only exceptionally used for shipping so far** *(see further)*
- Reticle back-side is checked on SPARK: OK or not for NXE use ? *(see further)*
- Reticle mates with fixed EUV pod, stored in EUV pod stocker between uses on NXE
- Establishing cleaning by default before use *(see further)*

Reticles in use on NXE3100

- Routine back-side monitoring on SPARK interfacing via EUV pod + clean when needed *(see further)*

All via fully automated handling within MT *Pro* + InSync

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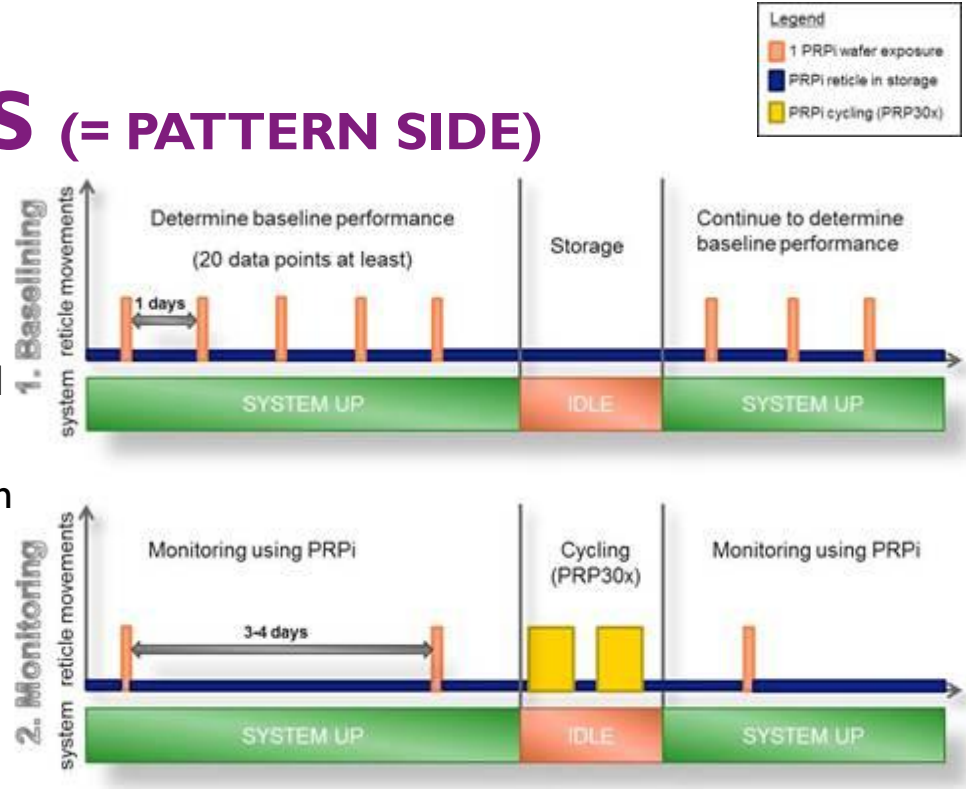
- Front-side adders
- Back-side adders
  - Monitoring
  - Review
- EUV pod shipping tests
- Present role of cleaning

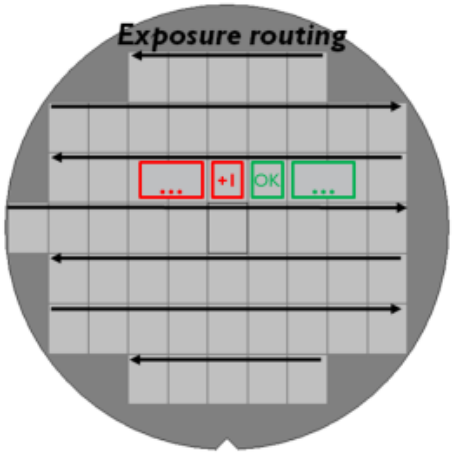
Conclusions

FRONT-SIDE ADDERS (= PATTERN SIDE)



Specifics of way-of-working for FS adders

- Defectivity monitor in place **by wafer printing**.
- Particle adders monitored as **new repeaters** in **wafer inspection** results for a newly exposed wafer, compared to a previous one (reference).
- Unloading reticle from scanner is avoided as much as possible (kept in vacuum library of scanner between exposures).
- Outside the scanner the reticle is in its EUV pod in the stocker, except for back-side monitoring on Süss MT-Pro (yet minimized).



Results and Discussion

- Long term monitoring via WI allows to detect particle issues on reticle FS.
- Monitoring performed on IMEC NXE3100 in collaboration with ASML reveals intermittent particle adders, both during exposure *(see left)* and in between wafer exposures (with reticle in the scanner).
- Issue being addressed by partitioning tests to identify particle root cause and hence to define solutions.

- The real target must remain 0 adders, to assure no yield loss is caused by printing particle adders.
- In parallel to continuous scanner improvement, ASML is investigating feasibility of a pellicle solution.

BACK SIDE PARTICLES
(= CLAMPING SIDE)

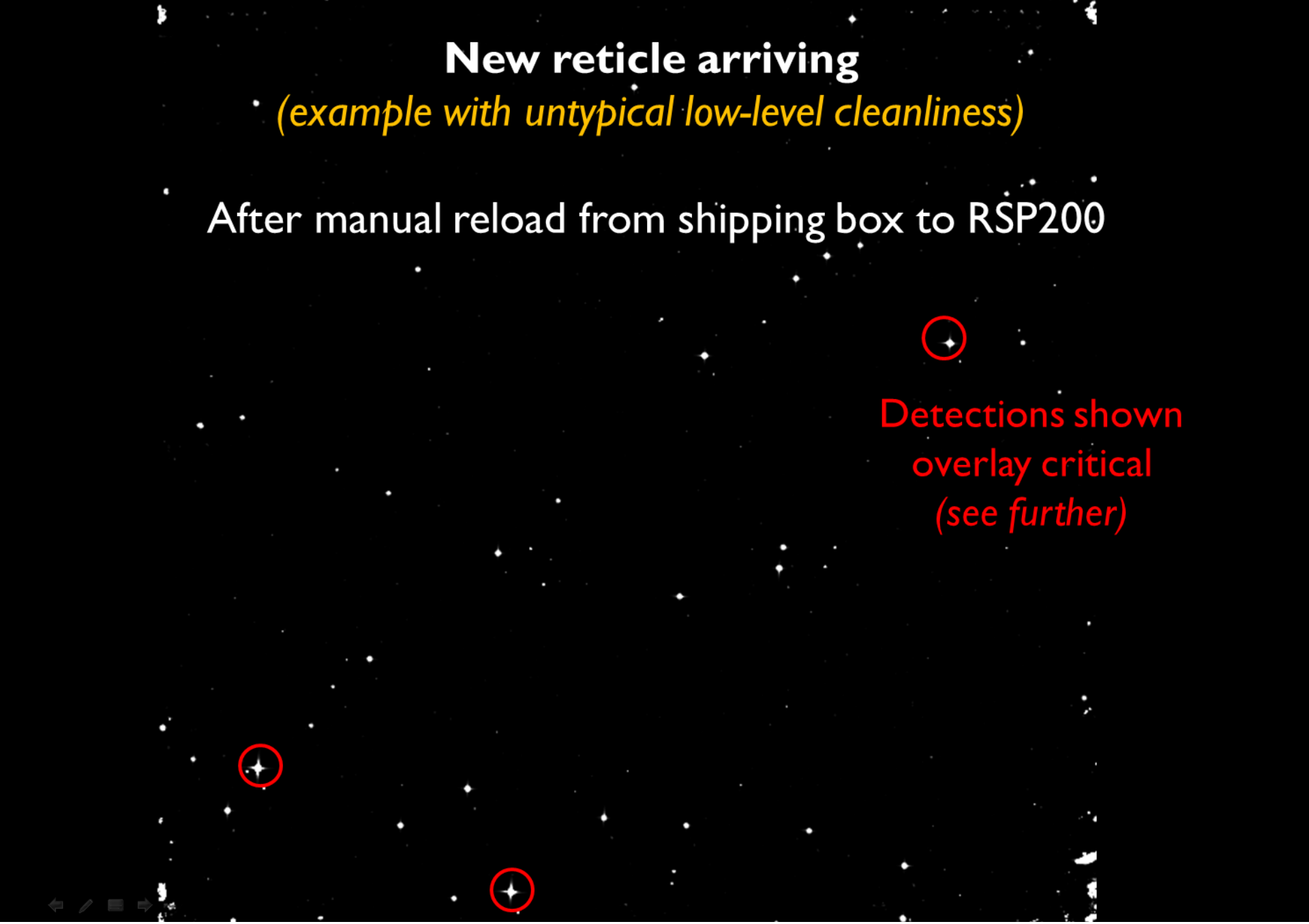
"Movie" time ...

FROM RETICLE ARRIVAL TO FIRST EXPOSURES DONE ON NXE

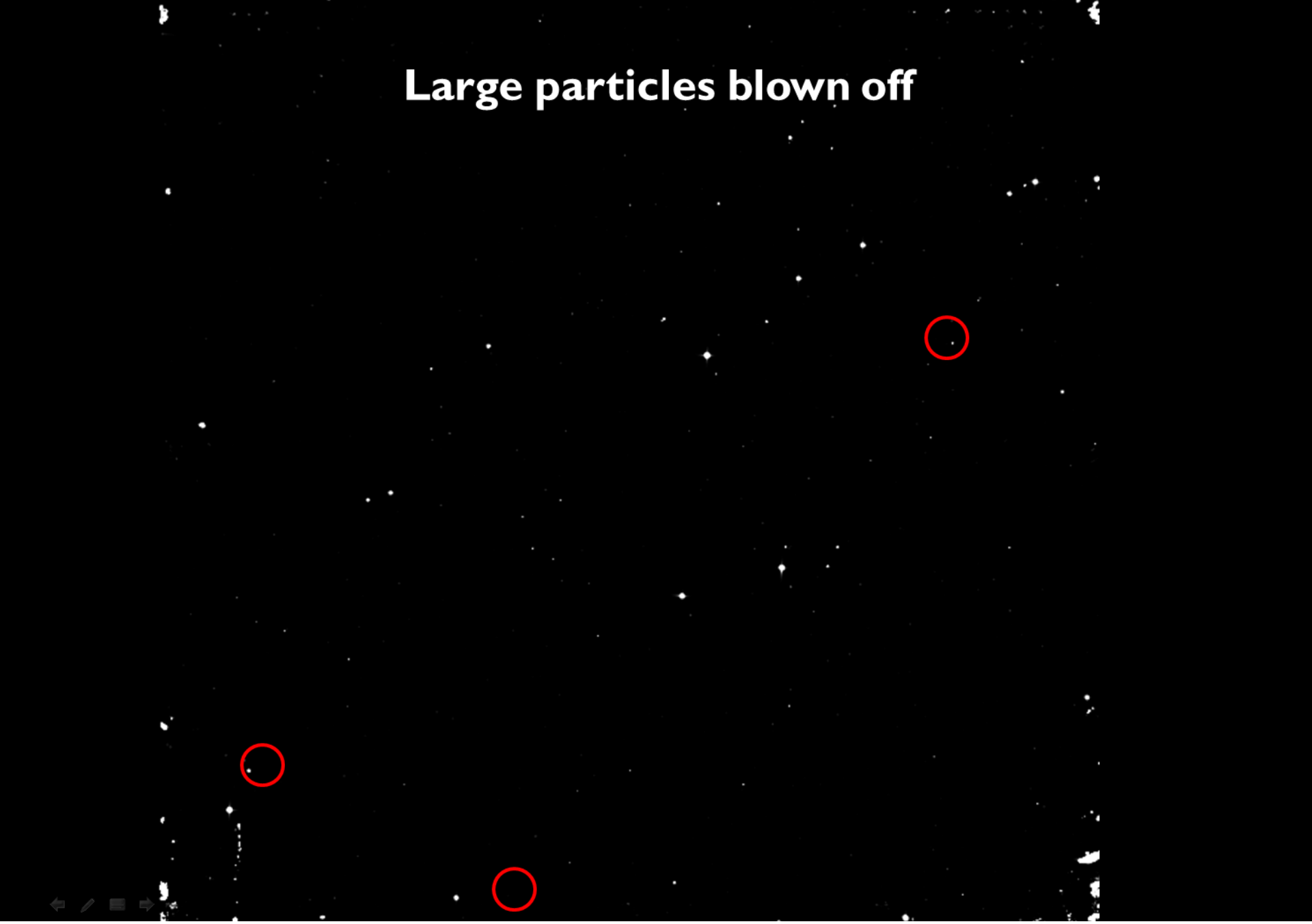
New reticle arriving

(example with untypical low-level cleanliness)

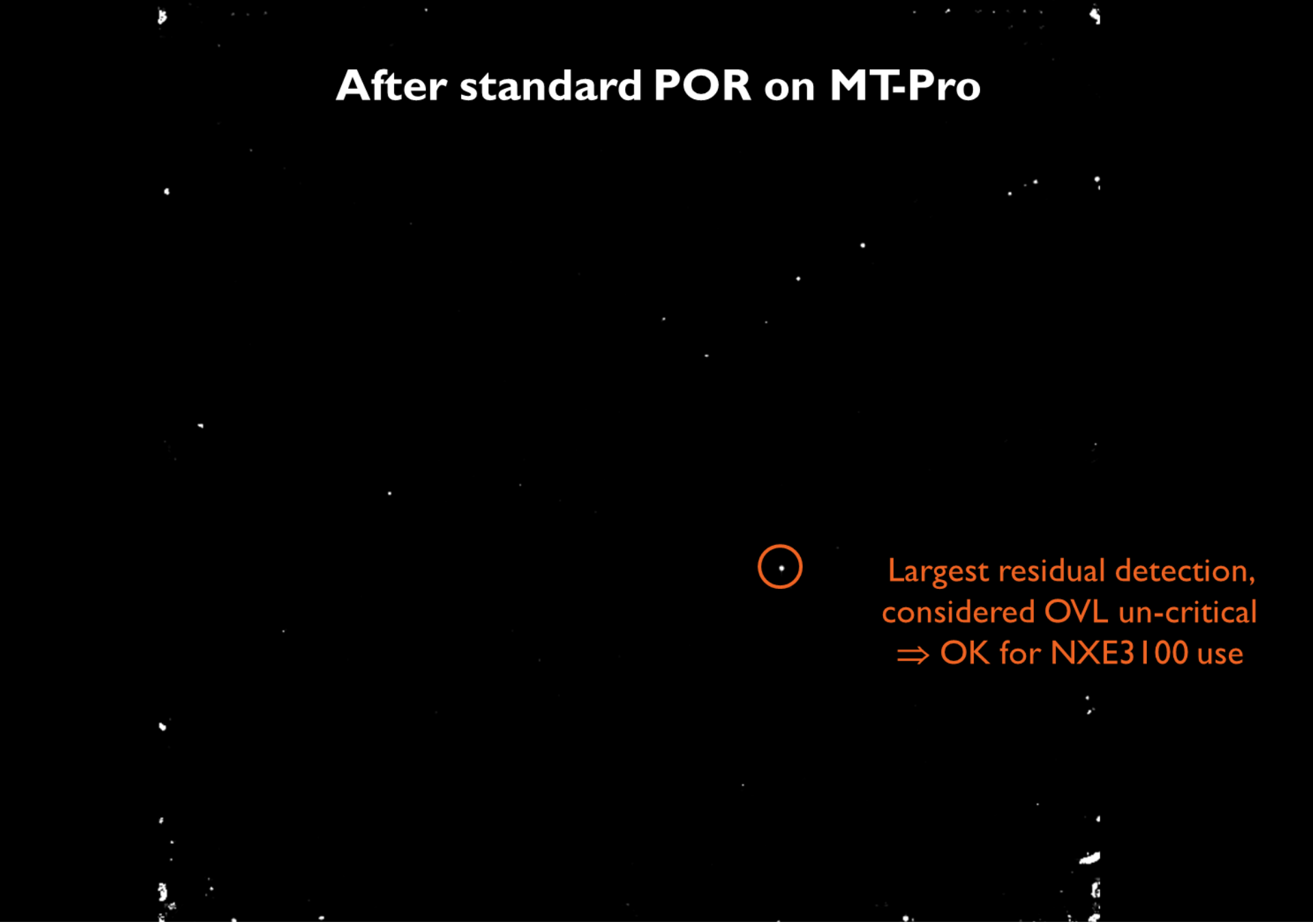
After manual reload from shipping box to RSP200



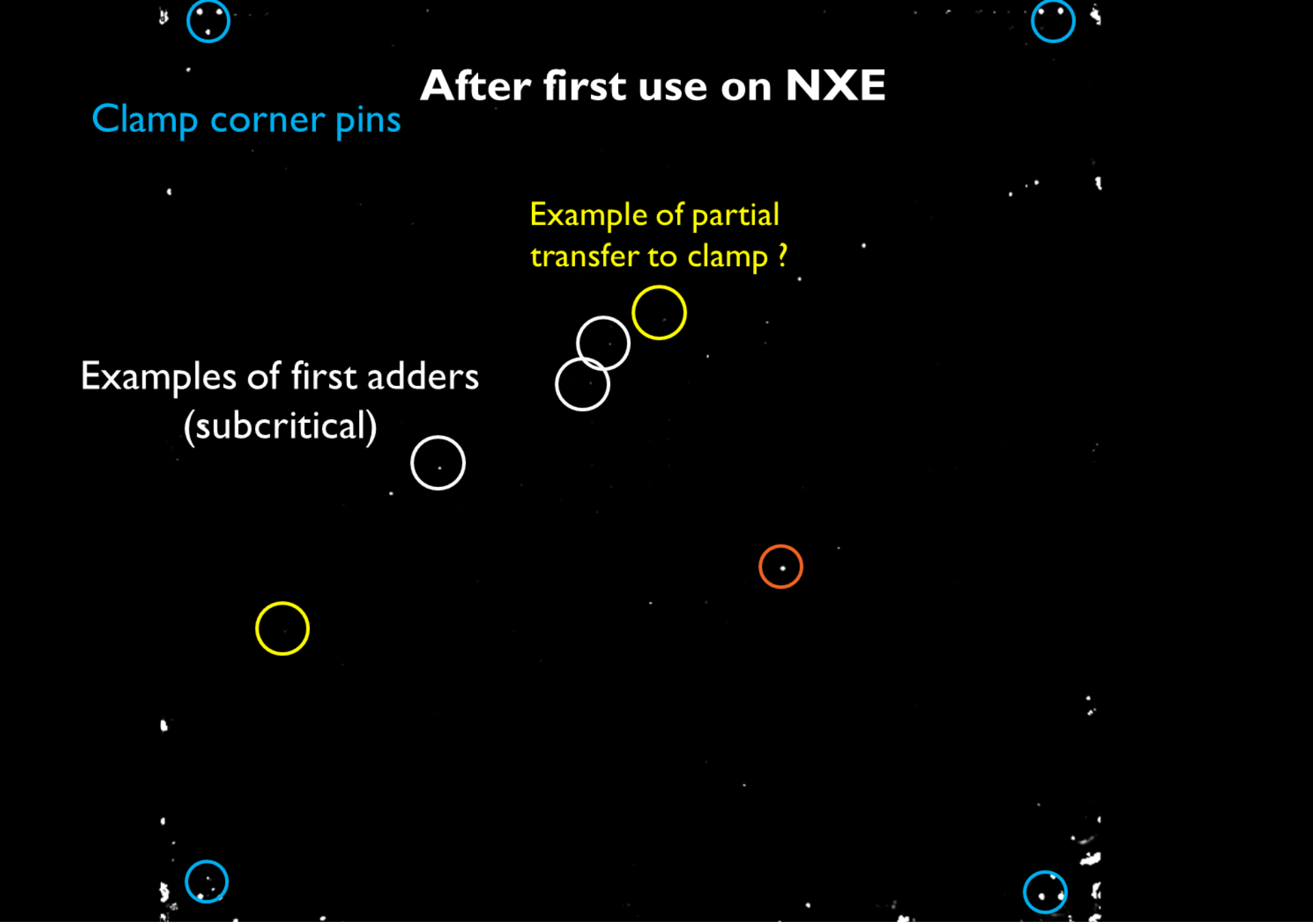
Large particles blown off



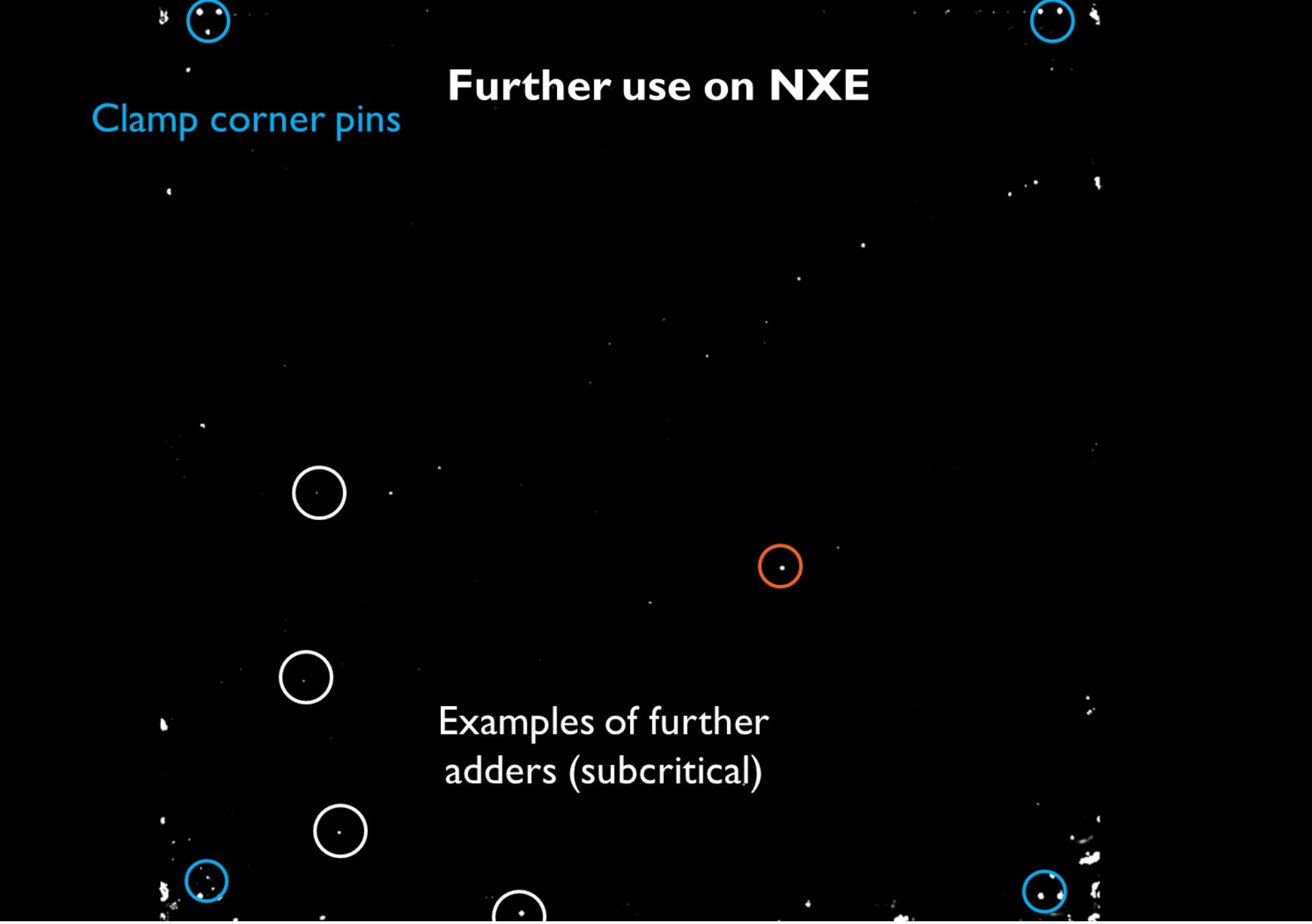
After standard POR on MT-Pro



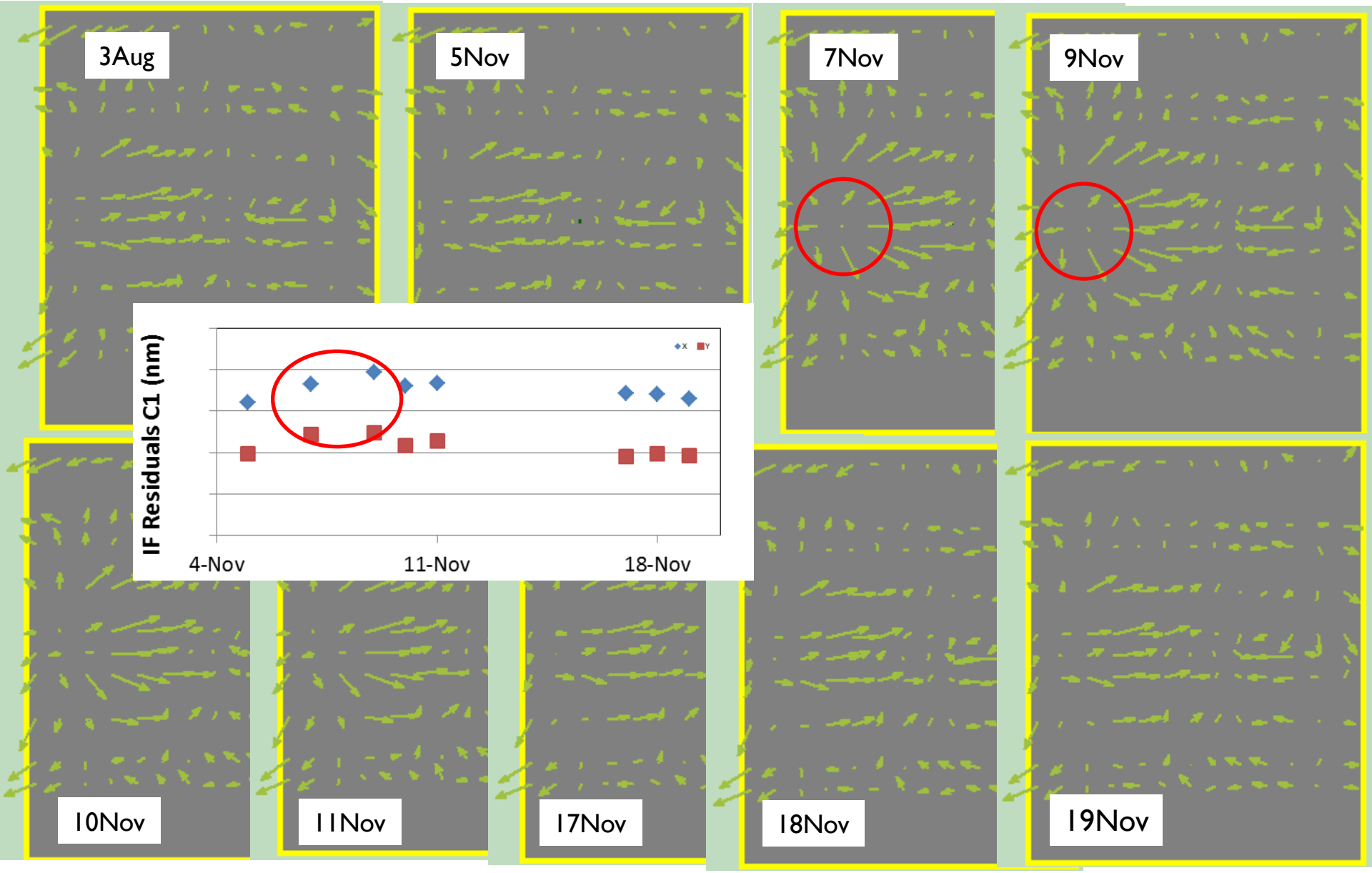
After first use on NXE



Further use on NXE



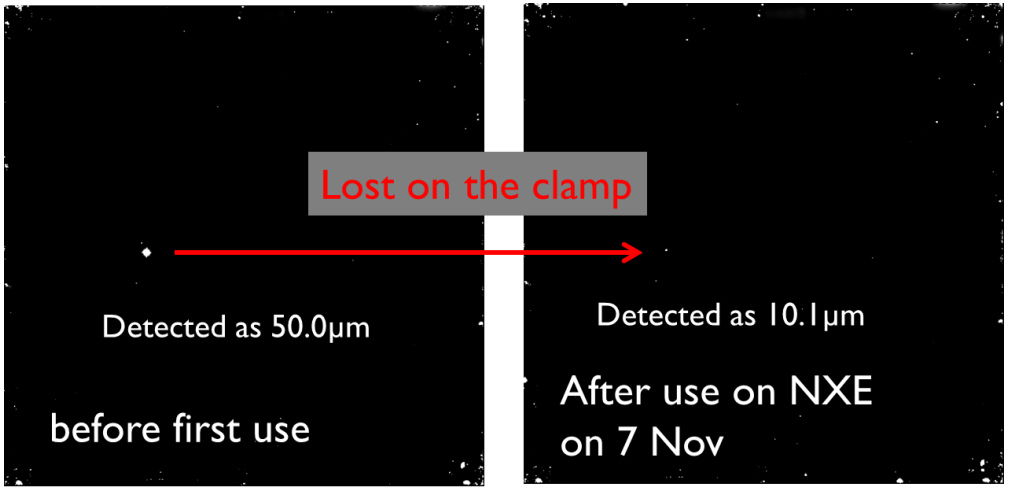
LEARNING FROM OVERLAY EXCURSIONS



BIG PARTICLE ON INCOMING RETICLE

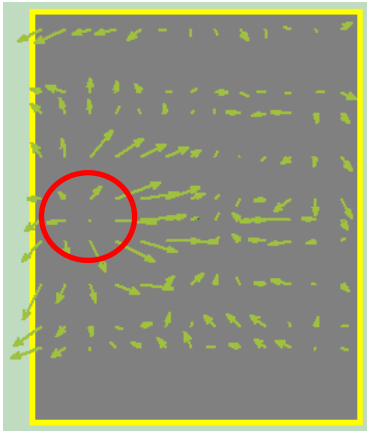
Interpretation:

- First clear example of a big, overlay-critical particle that was CLEARLY brought onto the NXE3100 reticle clamp, by a reticle
- **Clearly correlating to the hot-spot in printed overlay**

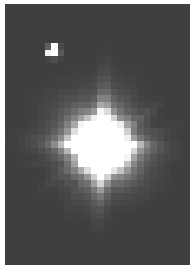


Learning:

- SPARK BS inspection was done (during first load into EUV pod), but **big detection (50µm) was not flagged** (= operator action)
- Reticle was used on NXE anyhow **and caused a clear overlay excursion**
- This triggered us to start **routine back-side monitoring**

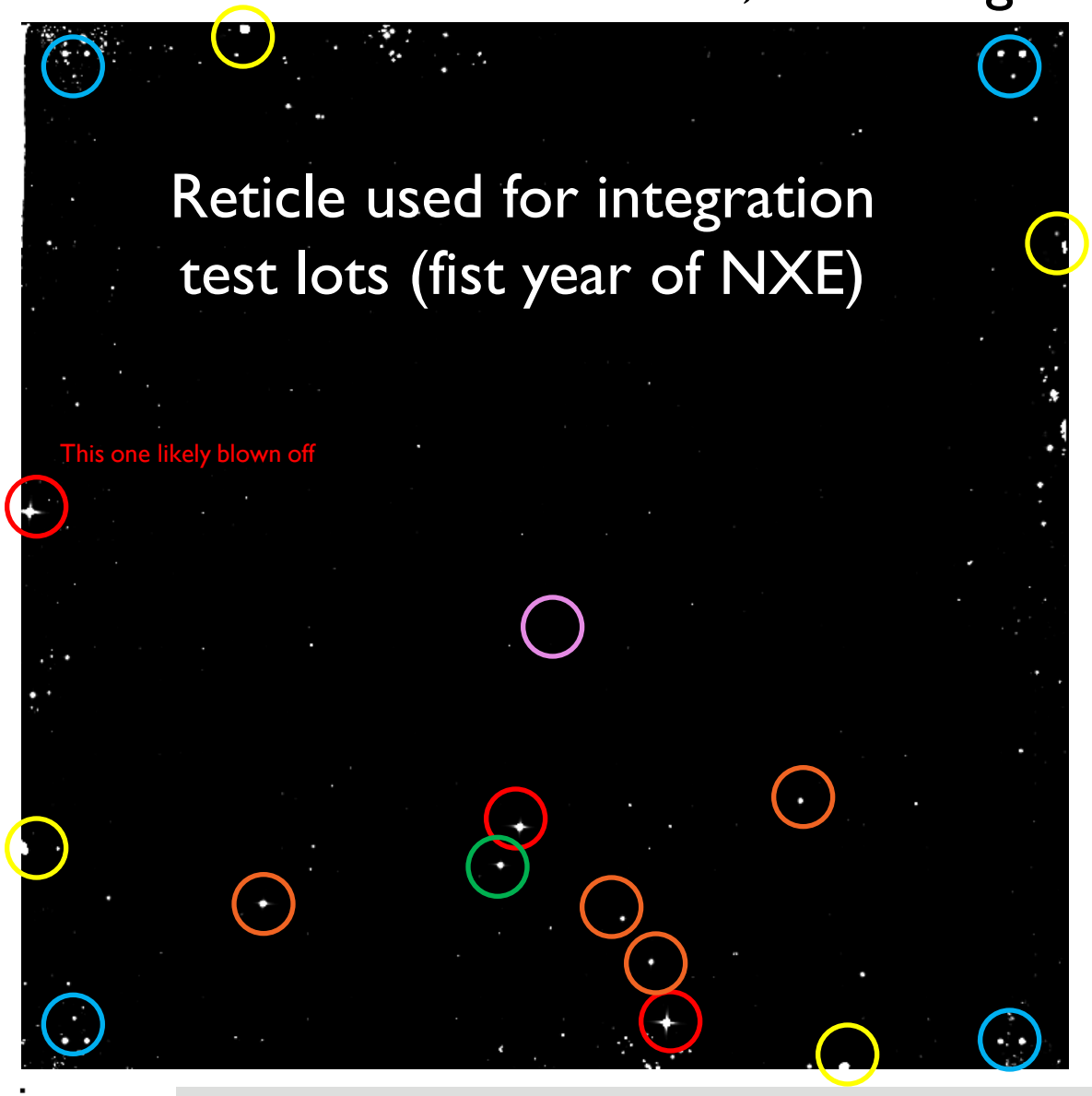


- **(new) SPARK detections of ≥45µm (*) adopted as criterion for prohibiting the use of a reticle on the NXE3100**
  → <u>considered</u> overlay critical particles
  (*) SPARK was calibrated by PSL based on scattered light intensity,
  leaving the requirement to interpret detections in terms of height.



ON-RETICLE REVIEW OF ANOTHER NXE3100 RETICLE

Locations of interest, according to **imec classification**

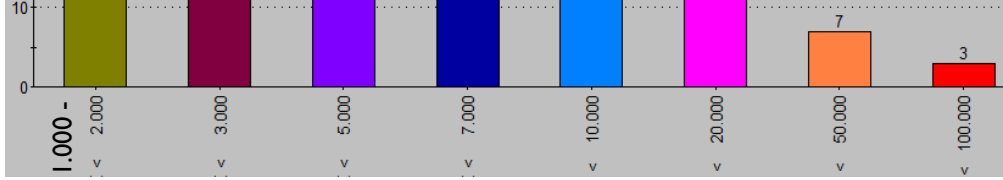


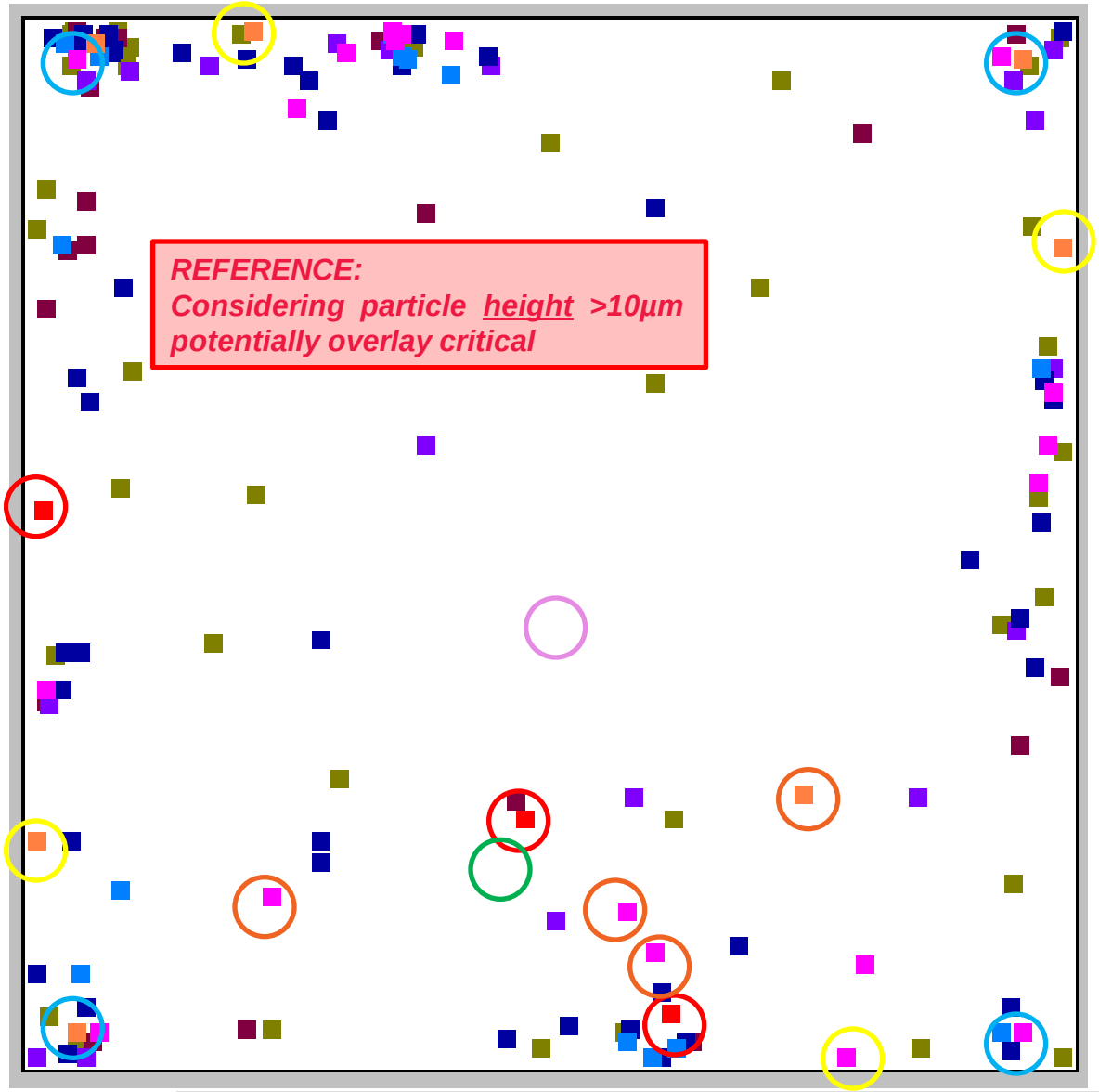
Intention: Determine HEIGHT

- Detections considered OVL critical(*)
- Contact point EIP
- Clamp corner pins
- Adders since latest exposure
- Detections lost over time
- Historical medium-size detections (OVL un-critical ?)

(*) yet no printed overlay data for this reticle

DETECTIONS >1µM





Note 2 color codes used:

- **Detection size**
- **Imec classification**

Detections considered OVL critical(*)

Contact point EIP

Clamp corner pins

Adders since latest exposure

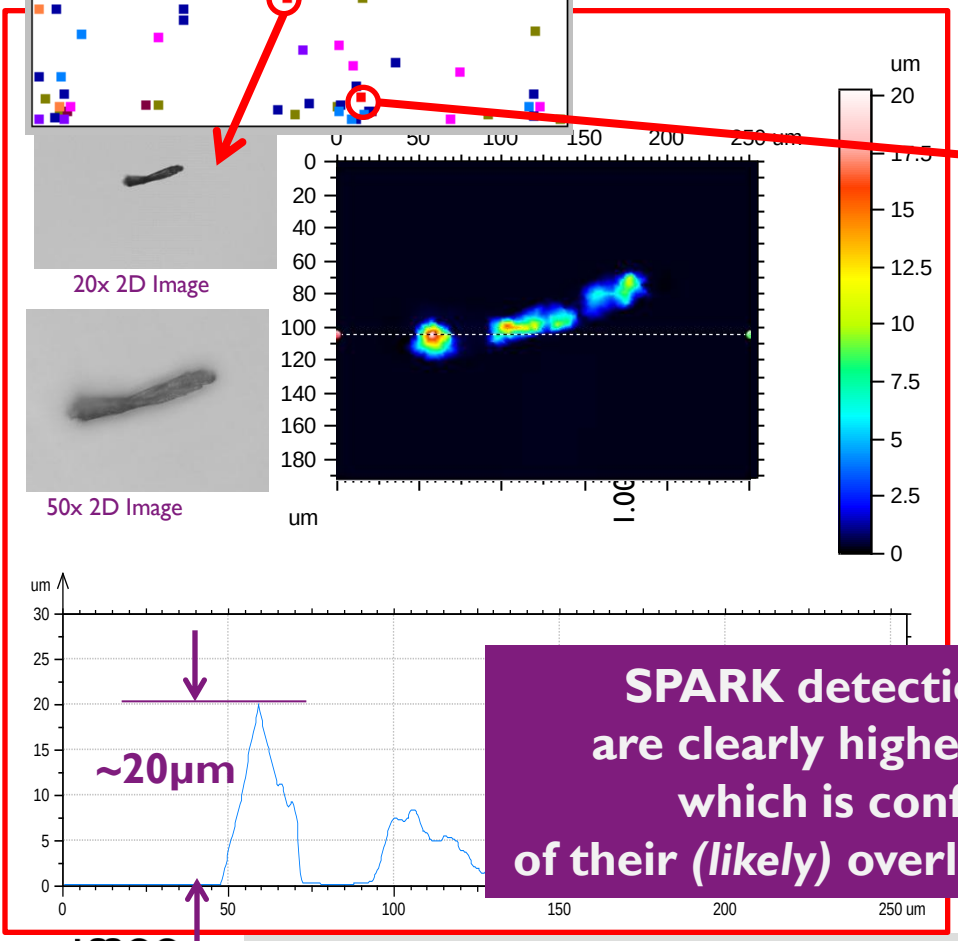
Detections lost over time

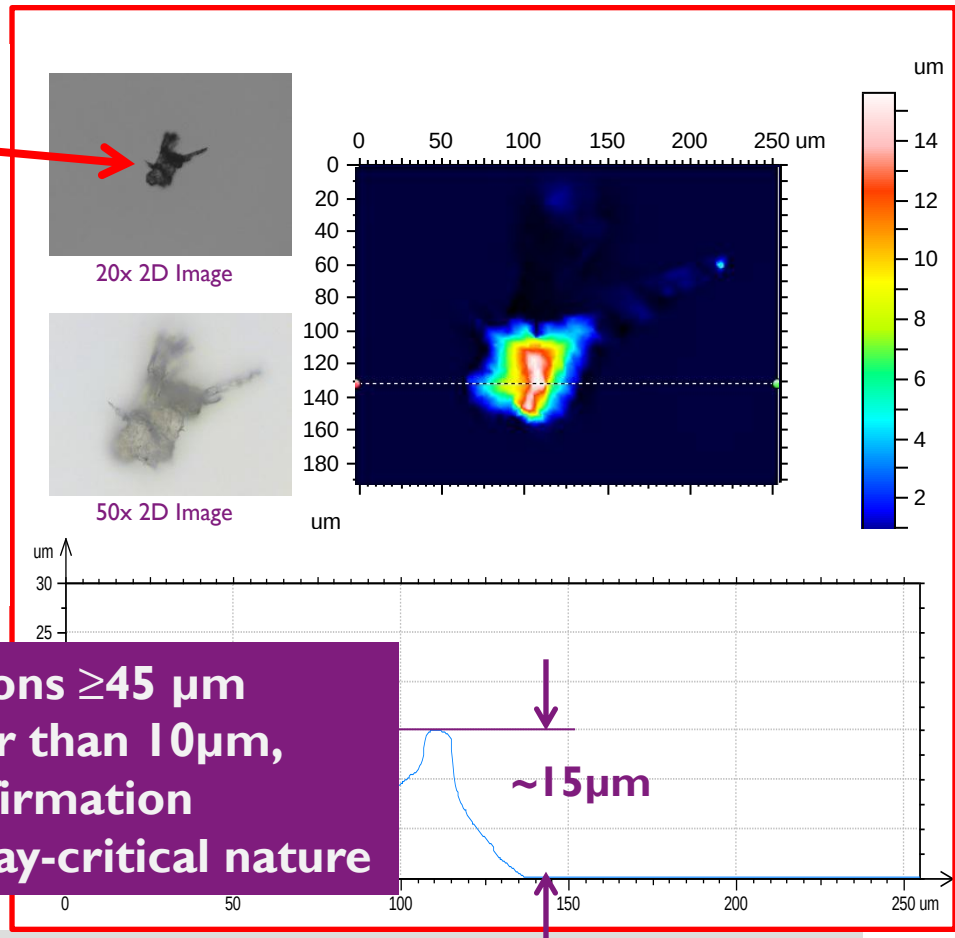
Historical medium-size detections (OVL un-critical ?)

(*) yet no printed overlay data for this reticle

CONFOCAL MICROSCOPE REVIEW AT ASML

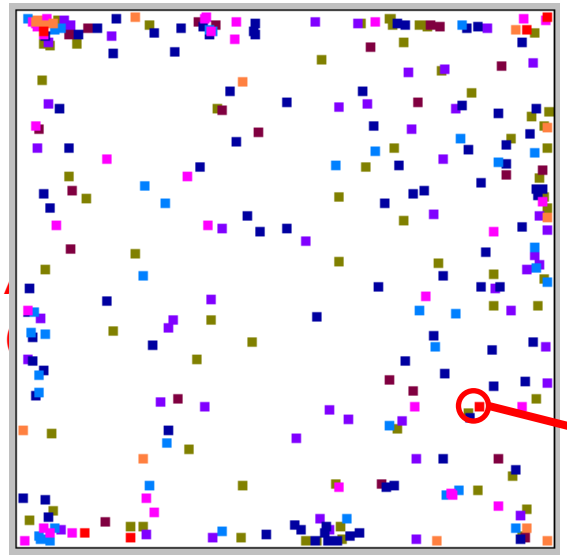
Detections considered OVL critical



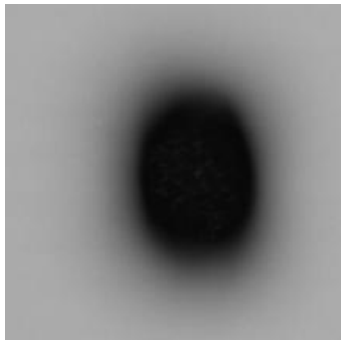


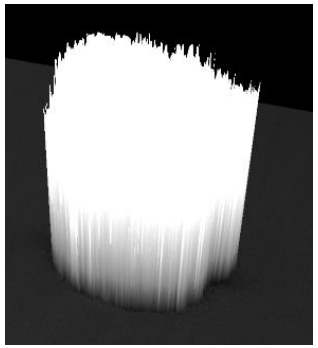
SPARK detections ≥45 µm are clearly higher than 10µm, which is confirmation of their (*likely*) overlay-critical nature

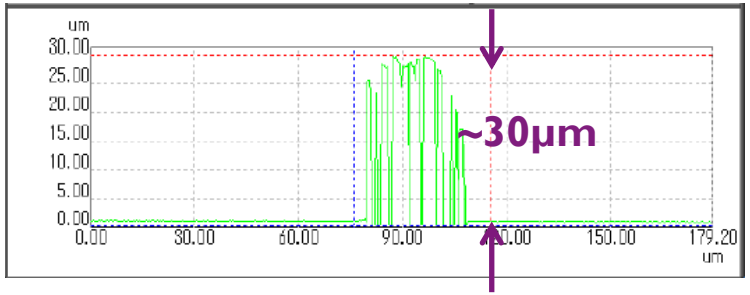
REVIEW ON BI100 Lasertec



Spark-detected as 50.0 µm







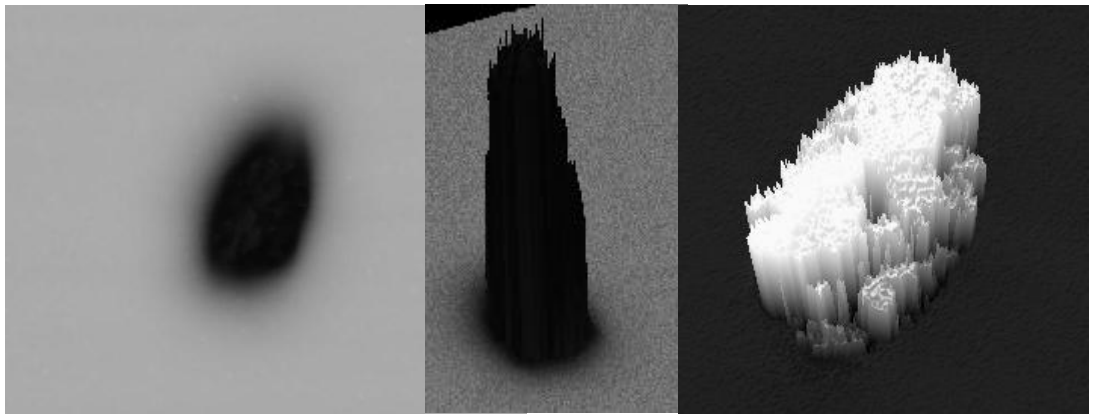
Same reticle
after manual handling and shipping in shipping box
on different detection (in time and location):

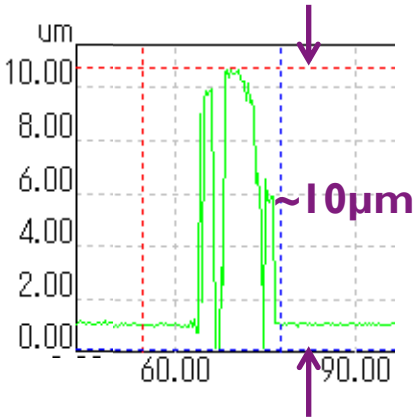
for sure un-crunched
(= added after latest use on scanner)

Also exceeds 10µm, which is a second confirmation of the *(likely)* overlay-critical nature of such ≥45µm SPARK detection

ON MASK REVIEW ON BI100 INTERMEDIATE DETECTIONS

Spark-detected as 26 µm





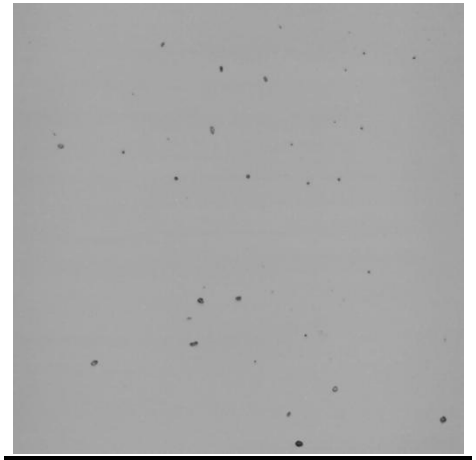
Considered overlay uncritical *(based on above mentioned experience)*

Such cases have heights up to 10 µm

Such detections must over time be avoided
→ calling for more frequent cleaning

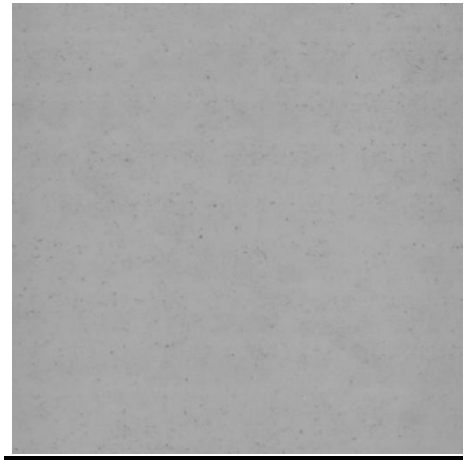
REVIEW RESULTS OF OTHER DETECTIONS

Lasertec



Contact point EIP

Spark-detected as ~28 µm



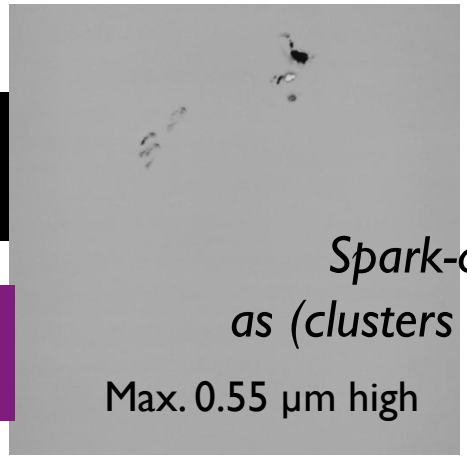
Clamp corner pins

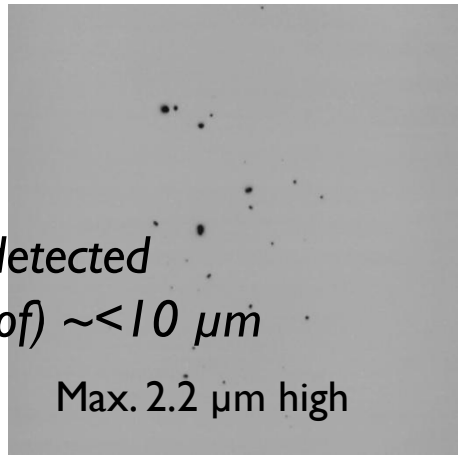
Spark-detected as ~18 µm

These 2 types have negligible height, hence are considered overlay-<u>un</u>critical.

There is no evidence that these backside detections shed small particles that can move to the FS and become printable, however this is difficult to prove.

Further adders over time





Spark-detected as (clusters of) ~<10 µm

Max. 0.55 µm high

Max. 2.2 µm high

<u>Avoid</u> by more frequent cleaning before they become non-cleanable

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- EUV pod shipping tests
- Present role of cleaning

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Analysis based on QA 144mm

EUV POD SHIPPING TESTS WITH BLANKS

pod type	do what	Adders FS		<---- Adders BS ------>		
	imec-Entegris-imec	>0.5µm	<0.5µm	>20µm	5 - 20µm	≤5µm
1005A in use	round trip shipment	0	1	0	3	6
1005A in use	round trip shipment	0	0	0	3	6
new 1007A	round trip shipment	0	0	0	6	3
new 1007A	round trip shipment	0	0	0	0	3
new 1007A	round trip shipment	0	2	0	0	3
new 1007A	ship + ISTA-3A protocol	0	1	0	3	12
new 1007A	ship + ISTA-3A protocol	1	0	0	0	3
new 1007A	ship + ISTA-3A protocol	0	0	1	2	5
new 1007A	control kept at imec	0	0	0	0	2
new 1007A	control kept at imec	0	3	0	1	5
new 1005A	round trip shipment	0	1	0	0	2
new 1005A	round trip shipment	0	2	0	0	5

ISTA = International Safe Transit Association

- Front-side adders: **max 3 adders** >200nm, but 1 large one near QA edge (*)
- Back-side adders: Typically largest detection is ~10µm, yet once it is >20µm (*), but **no overlay critical adder** (*)

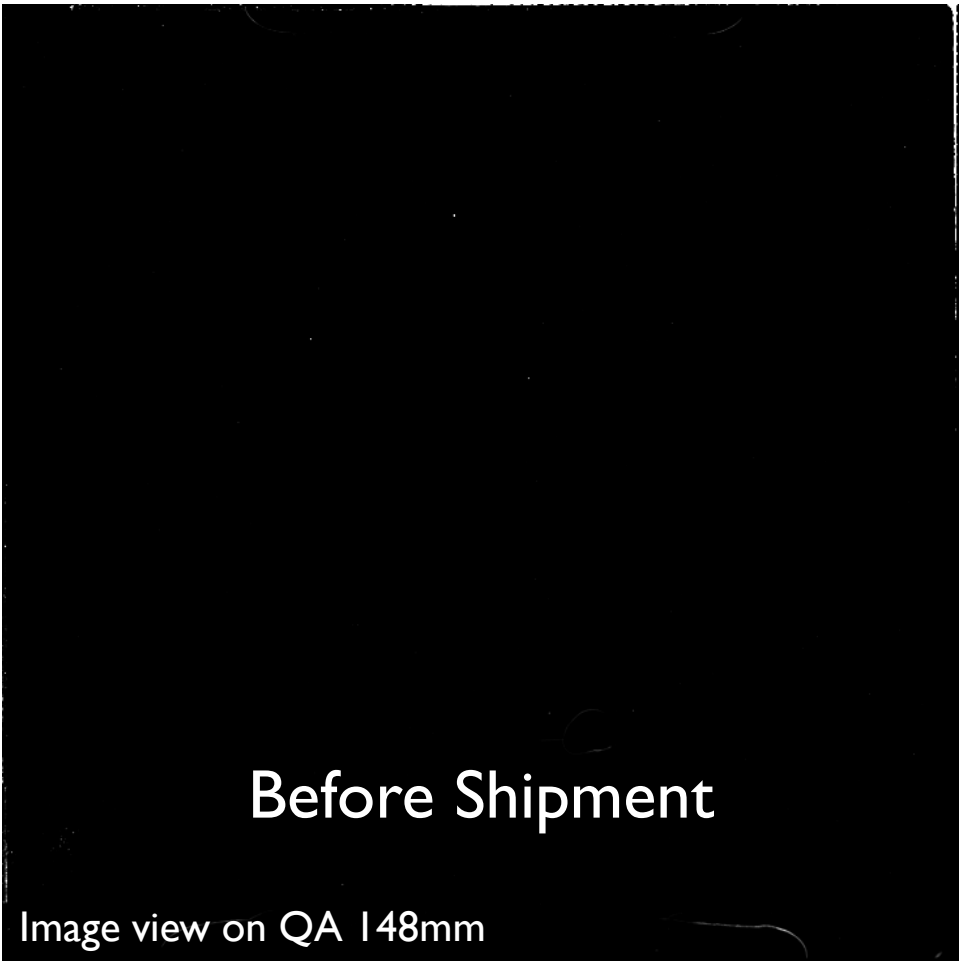
(*) Based on SPARK, see above explanation for BS, 150nm sensitivity. For FS actually no dedicated calibration.

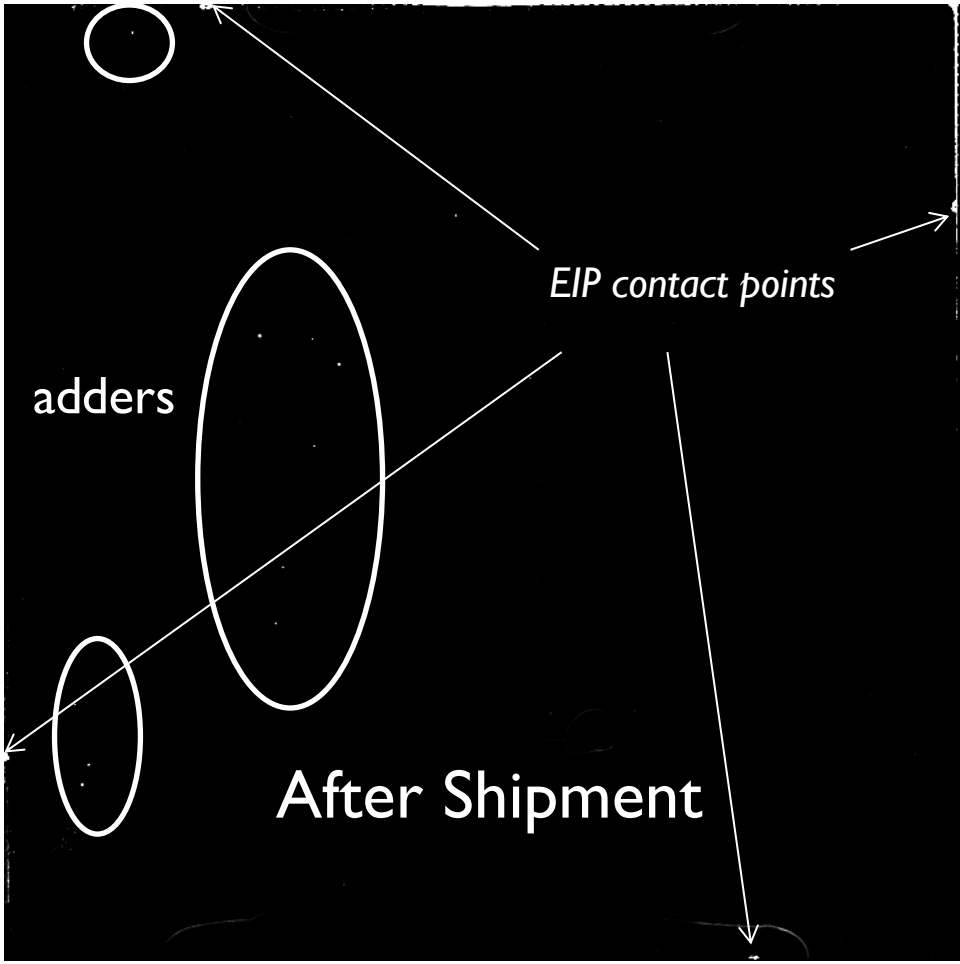
Very encouraging results → found OK to use for shipping, but recommending cleaning upon arrival to cope with few residual adders *(see further)*

Worst case

EUV POD SHIPPING RESULTS

pod type	do what		<---- Adders BS ------>		
	imec-Entegris-imec	BACK-SIDE	>20µm	5 - 20µm	≤5µm
new 1007A	ship + ISTA-3A protocol		0	3	12



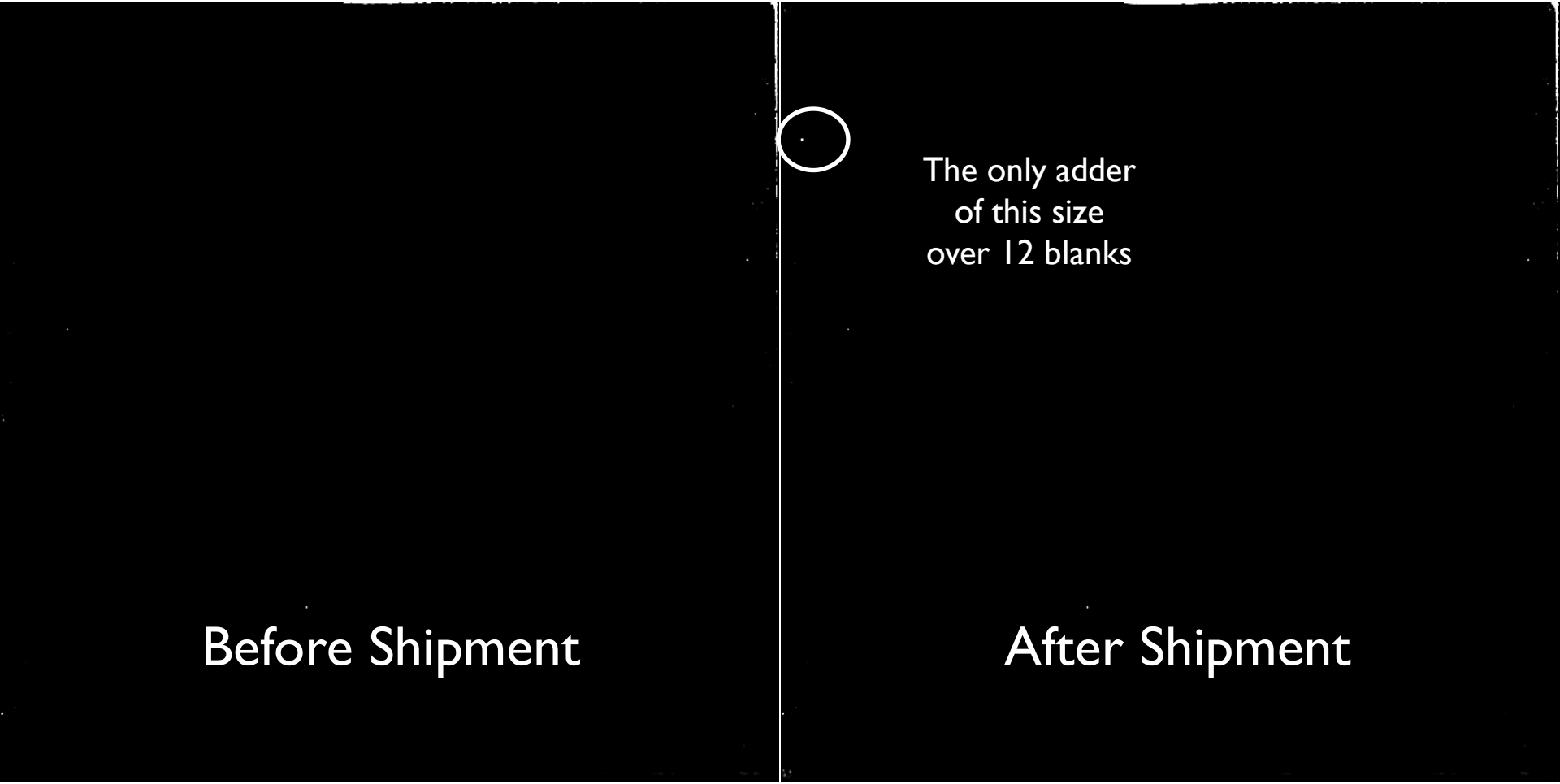


Worst case

EUV POD SHIPPING RESULTS

pod type	do what	Adders FS	
	imec-Entegris-imec	>0.5µm	<0.5µm
new 1007A	ship + ISTA-3A protocol	1	0

FRONT-SIDE

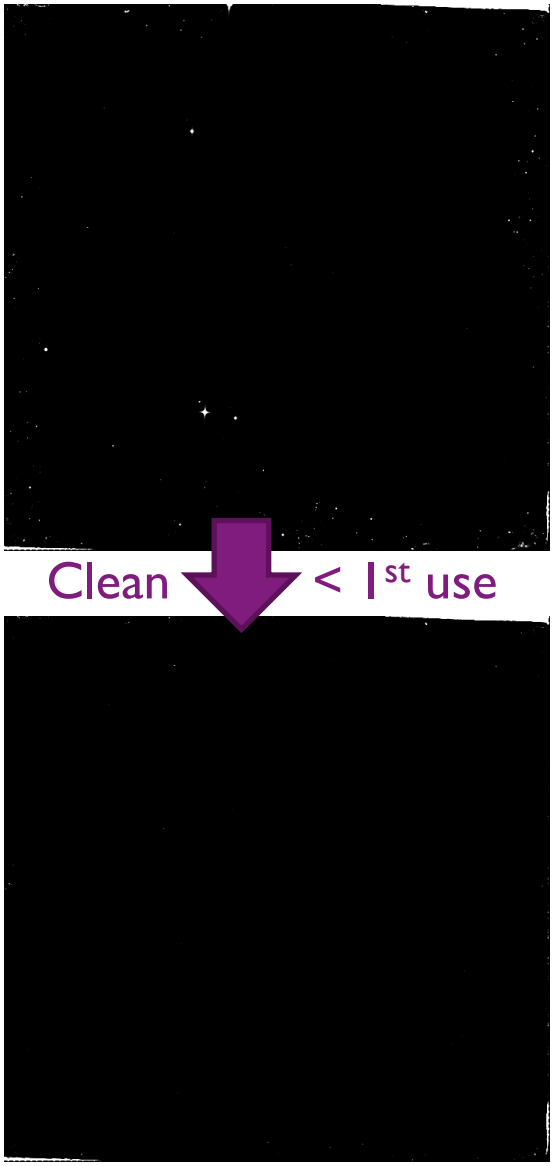


TUNED CLEANING RECIPE

Historically used POR is still to aggressive for the FS.
Best result we reported so far (*EUVL 2011*)
showed printed CD stable up to 15 cleans.

Focused the purpose to back-side particle removal

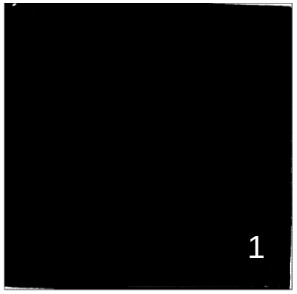
- **Clean-by-default of newly received reticles** →
- Avoid "clamp traveling" particles (by frequent clean)

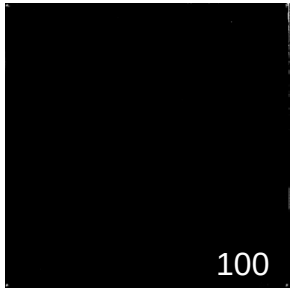


4 phases to implementation:

- Prove 100 cleans on blank, without SPARK-detectable FS degradation, and with acceptable PRE for FS

Achieved





Ongoing:

- Prove 50 cleans on NXE reticle by stability of printed CD
- Extend to reticles with ML-etched black border
- Implement as new POR

CONCLUSIONS

The present "clean handling" path, as for now done the best we can, still requires further improvement.

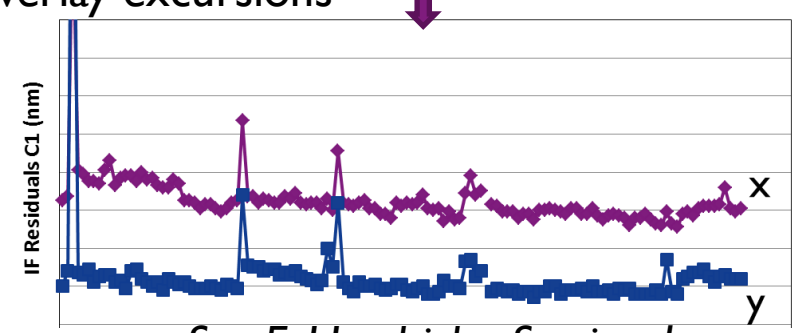
Shipping in EUV pod confirms good FS protection + gives no overlay critical adders

FS particles: Clear evidence of occurrences

- Working with ASML to evaluate performance of mitigation actions
- Additional measures planned for NXE3300

Present **way-of-working for BS particles** is confirmed by **on-mask review** of SPARK detections on a typical NXE3100 reticle, providing **particle height info**

- **≥45µm SPARK-detections shown as particles with effective height >10 µm**
- Back-side monitoring contributed to **limiting the occurrence** of particles on the reticle clamp, shown to cause overlay excursions



See E. Hendrickx, Session 1

Actions towards further improvement

- Solve FS adder issue
- Avoid "reticle clamp traveling" particles
  - More frequent clean + do on new reticle by default
  - Maximize cleanliness of reticle clamp
- Artifacts on backside, while not overlay-critical, need to be assured that any shed debris cannot get to front-side *(yet no such evidence)*

ACKNOWLEDGEMENTS

ASML

Lasertec

Entegris

Süss MicroTec

Nanometrics

Partners in imec's Advanced Lithography Program

ASPIRE
INVENT
ACHIEVE

imec