HMI IBM

E-Beam Inspection of EUV Mask Defects on Patterned Wafers by Die:Database Methodology

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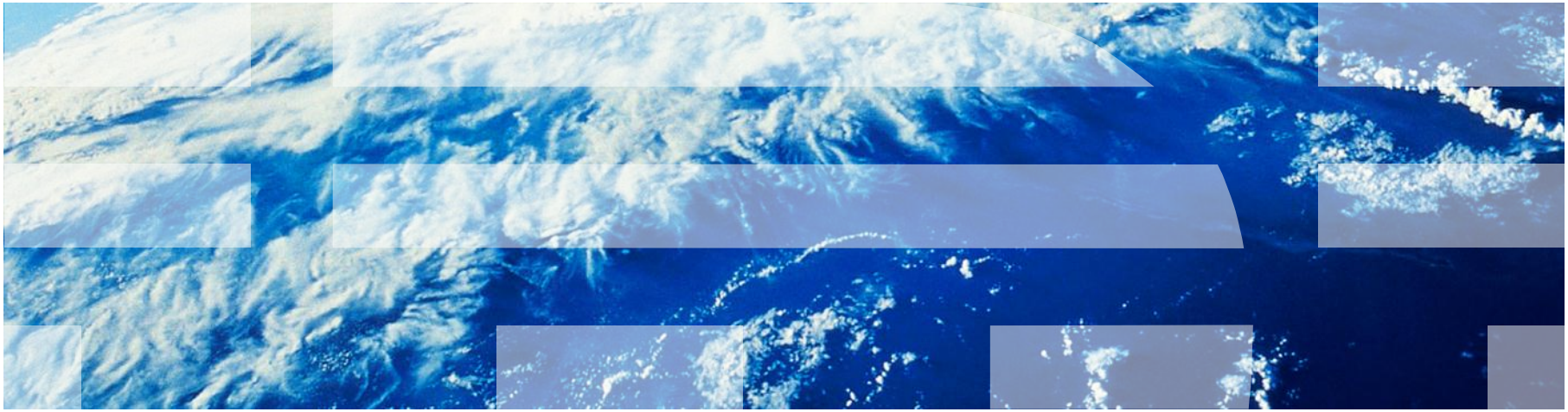
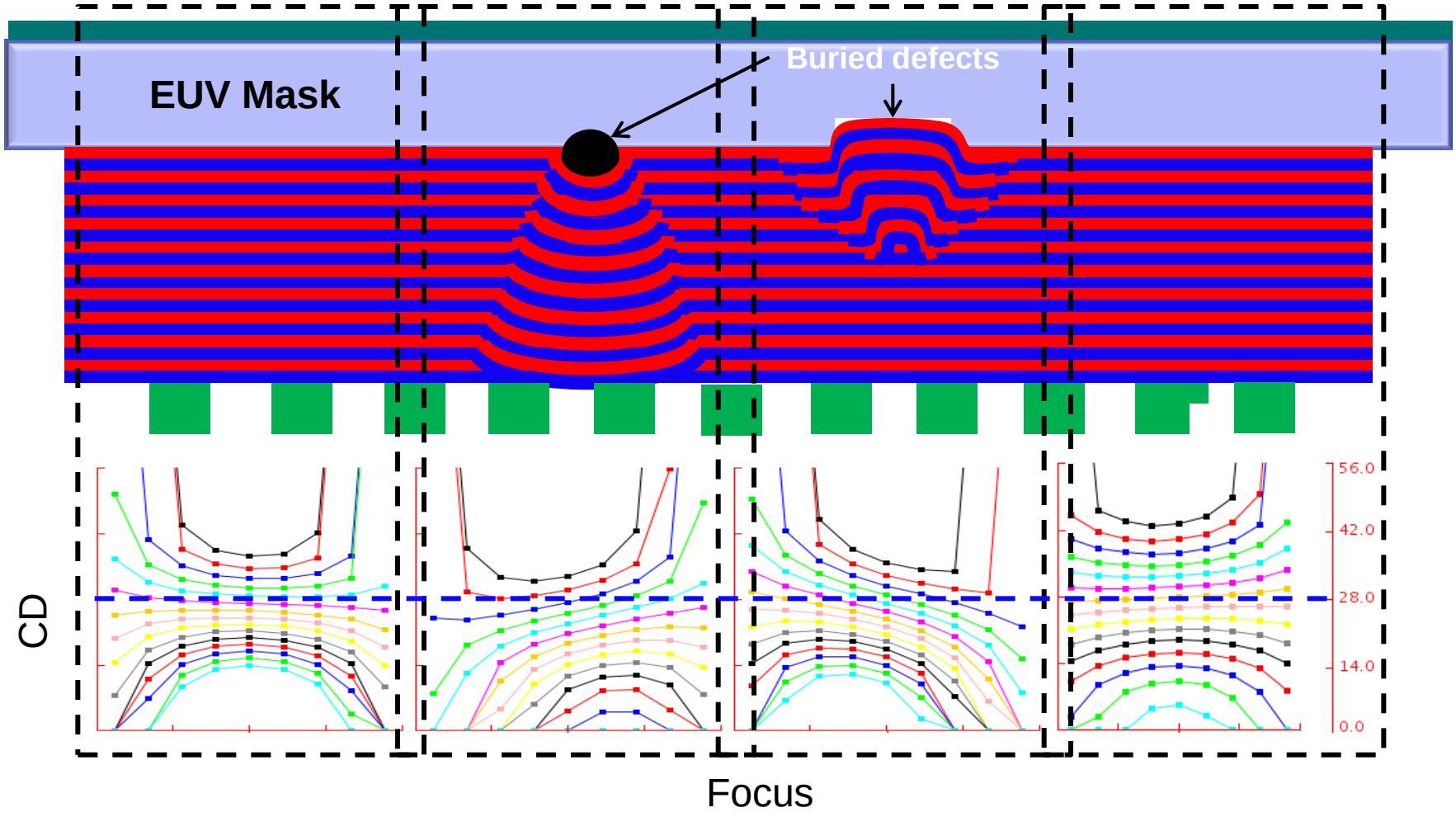
Alfred Wagner and Daniel Corliss



*Hermes-Microvision Inc

Motivation

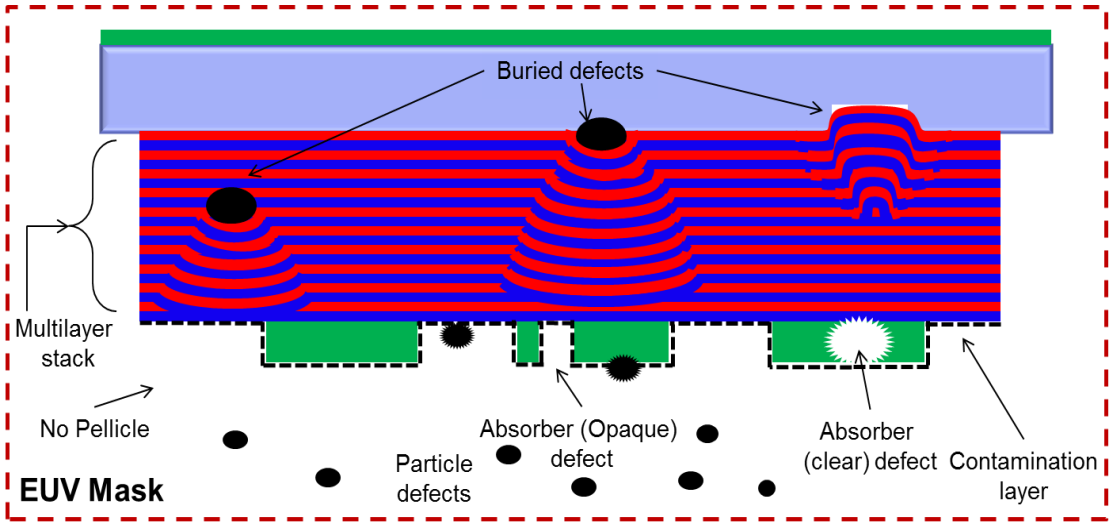


Buried defects in EUV masks have unique print behavior through focus

G. McIntyre et. al. Through-focus EUV multilayer defect repair with nanomachining

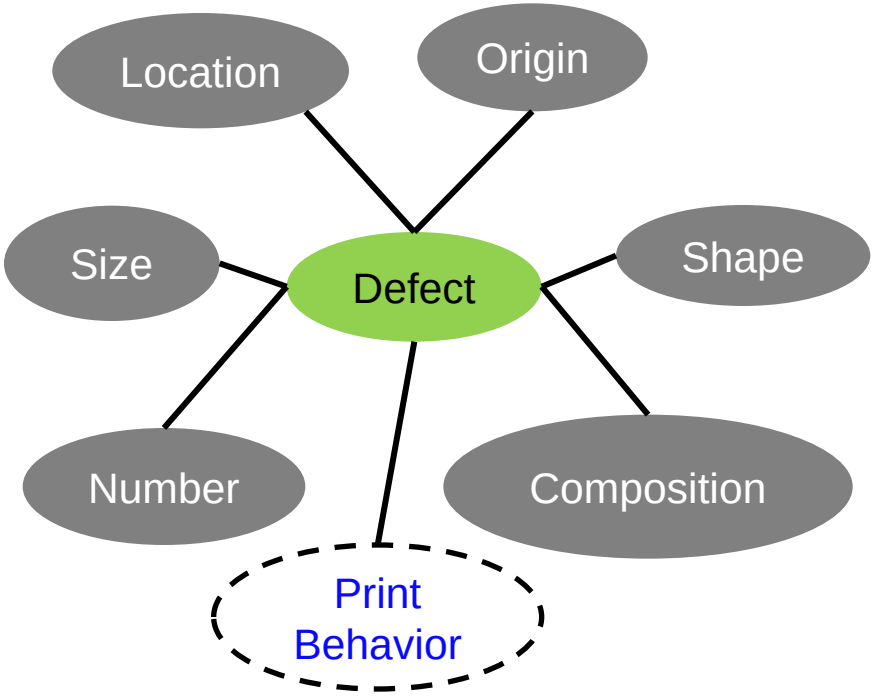
E-beam Defect Inspection for EUV Lithography

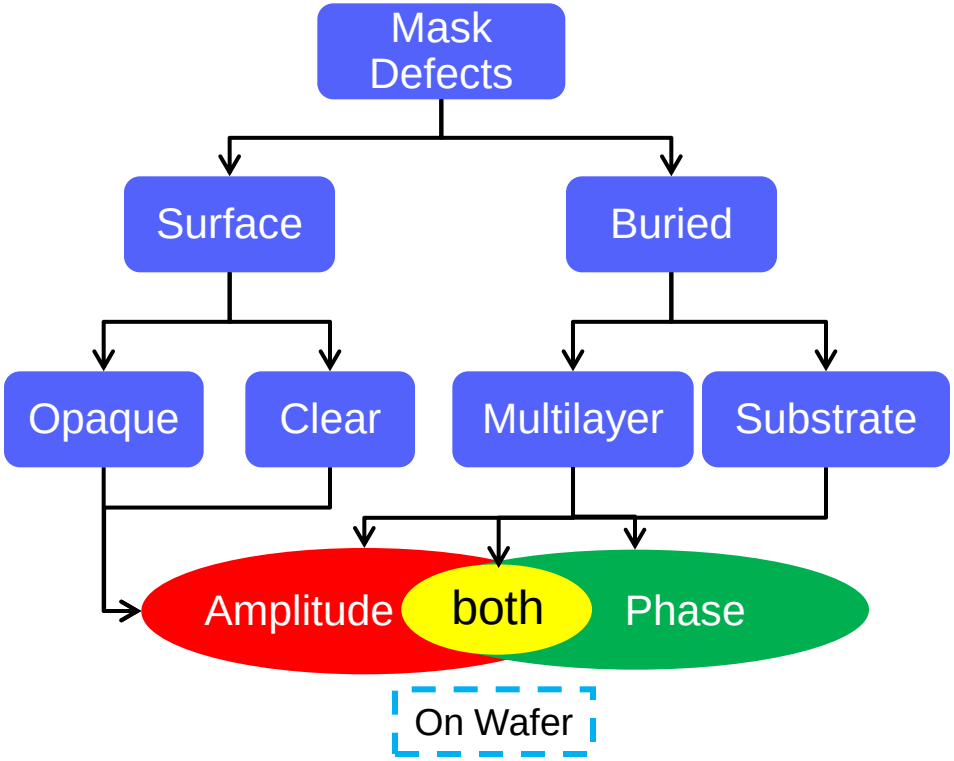
- EUV Lithography Challenge
  - No Actinic Inspection
  - No Pellicle
- e-beam Inspection
  - High sensitivity for defect detection
- e-beam Mask Inspection
  - Surface defects
- e-beam Wafer Inspection
  - Buried Mask Defects
  - Process defects



Defect Inspection is a major challenge for EUV Lithography

Defect Characterization



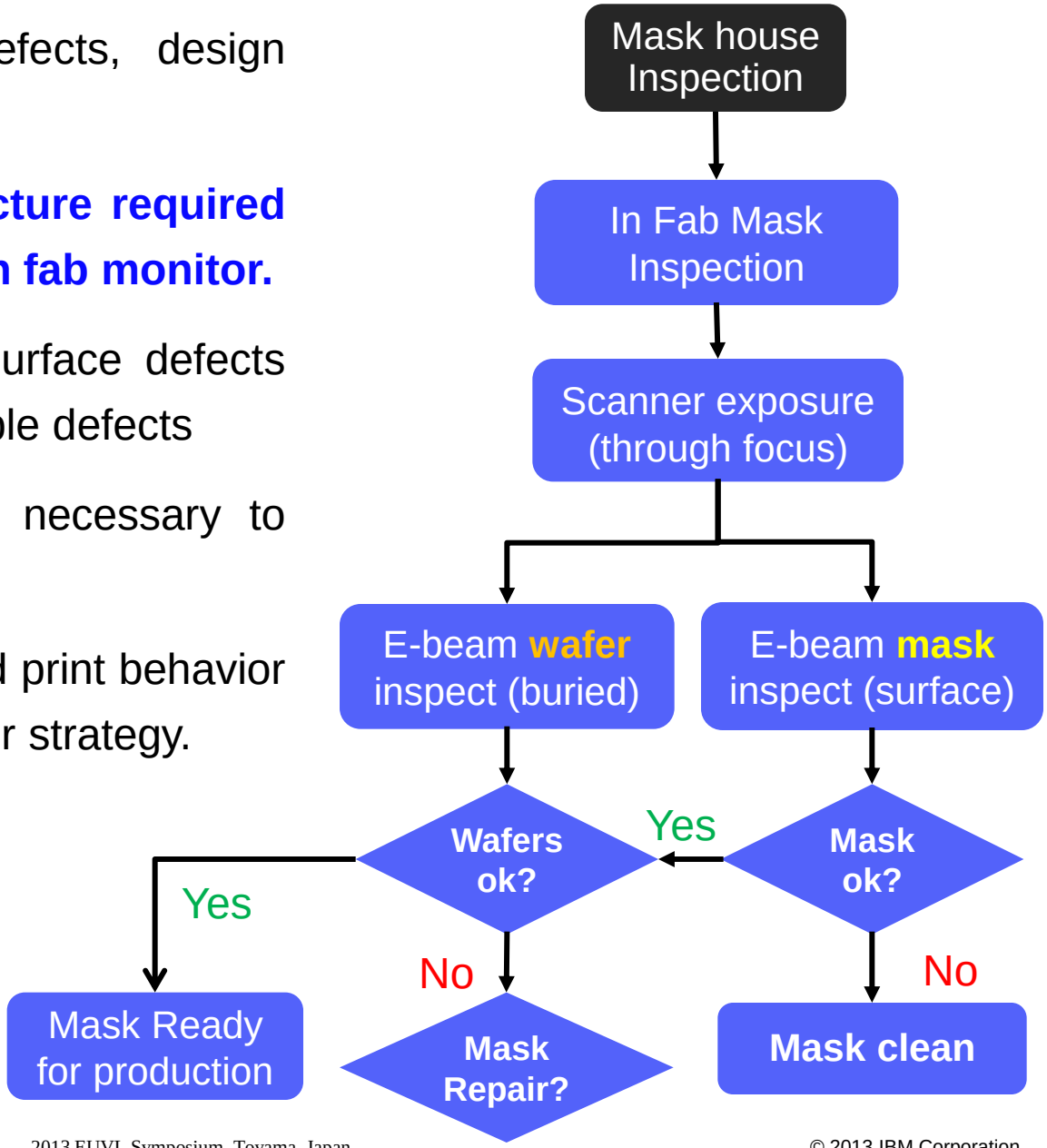


- Mask defect location, size and shape are important to understand its optical manifestation on wafer.
- Buried defects can be classified based on their print behavior.

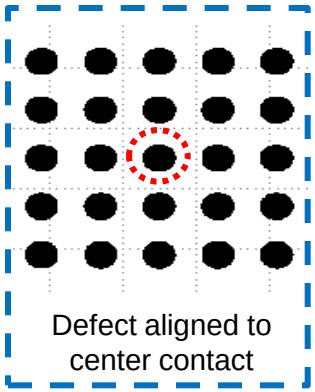
Defect Characterization important for appropriate mitigation strategy

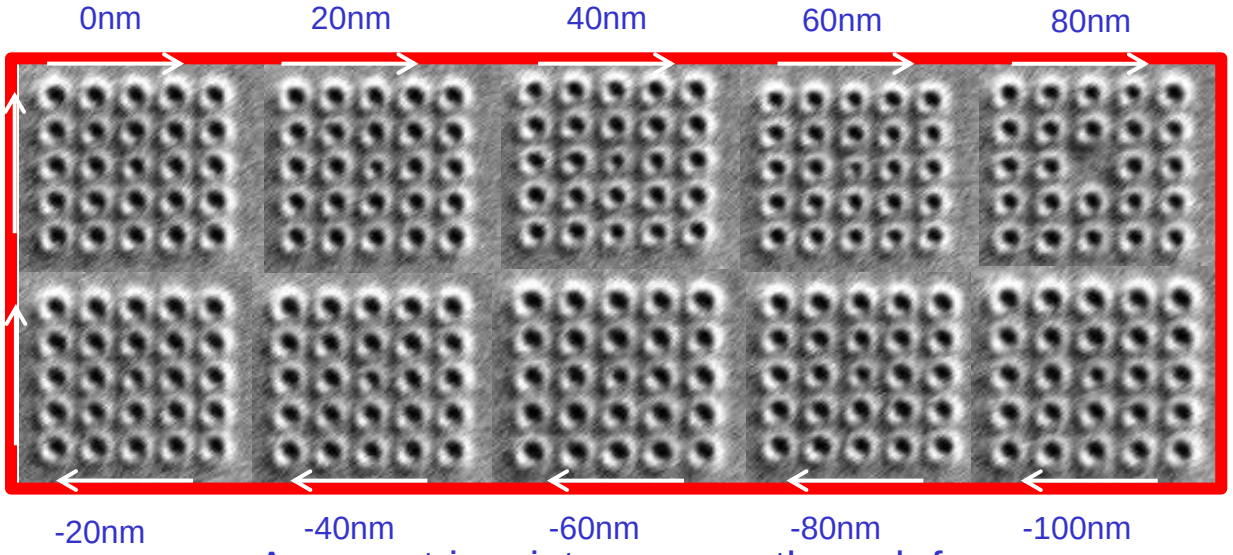
EUV Mask Qualification

- Mask House – Surface defects, design errors, some buried defects
- **Defect Inspection Infrastructure required for mask qualification and in fab monitor.**
- In Fab Mask Inspection – Surface defects buried defects and any printable defects
- Classification buried defects necessary to determine mask repair ability.
- Location of buried defects and print behavior can assist in appropriate repair strategy.

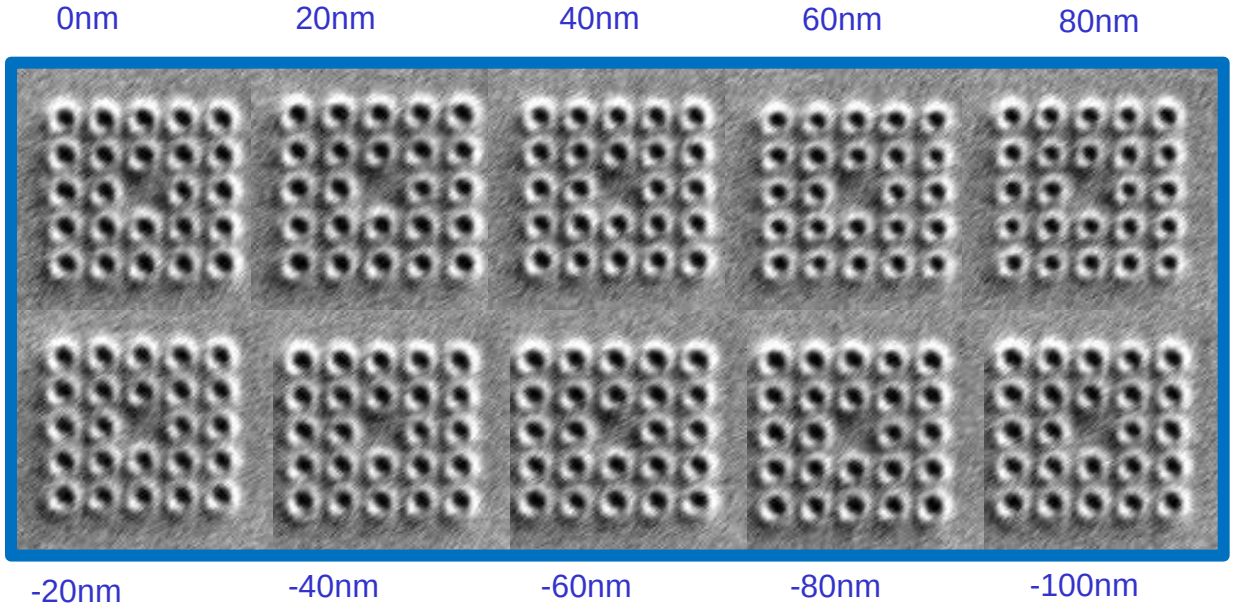


Buried Mask Defects – Print Response



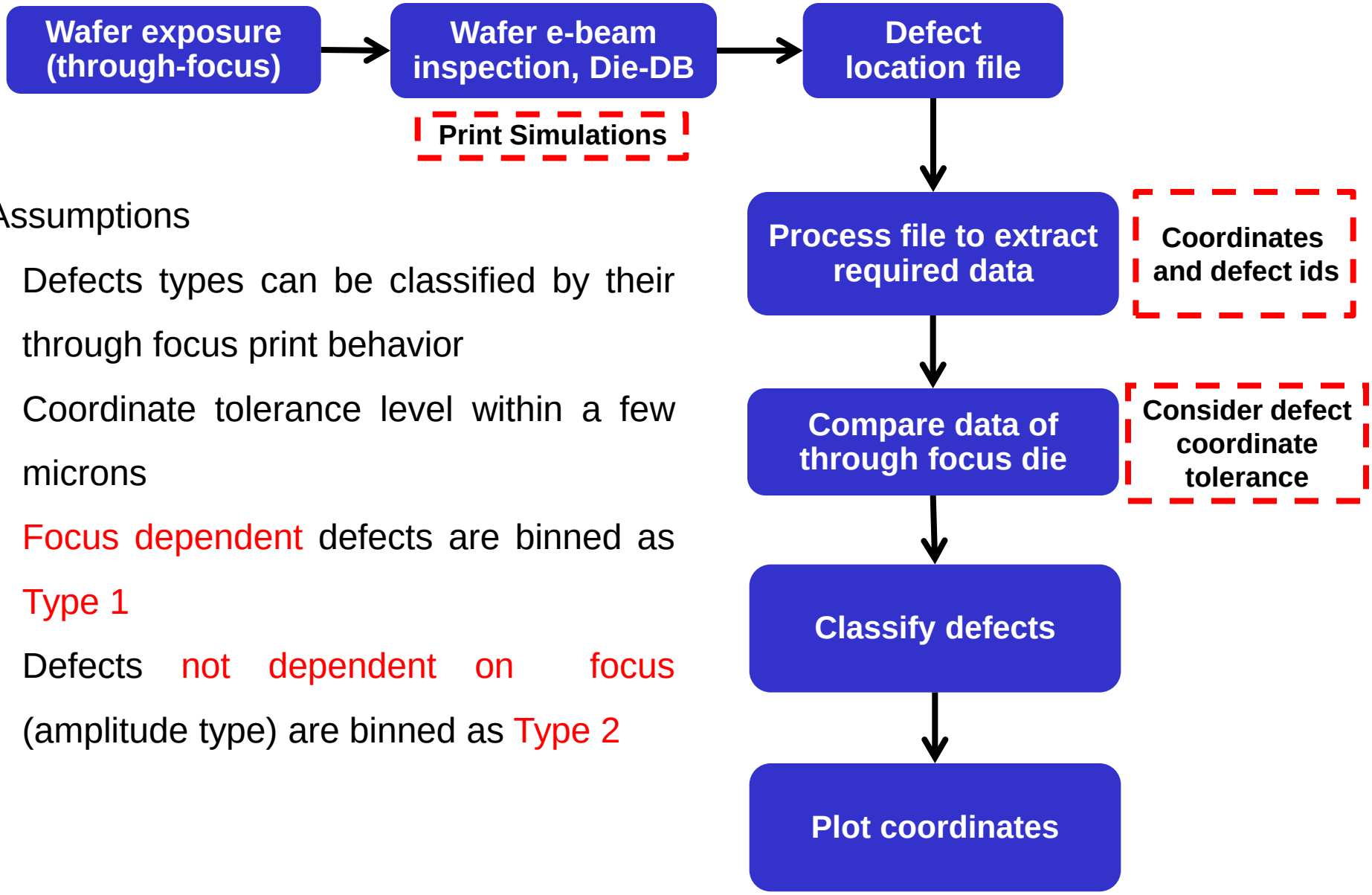


Asymmetric print response through focus



Strong amplitude type defect

Defect Characterization - Flow Chart

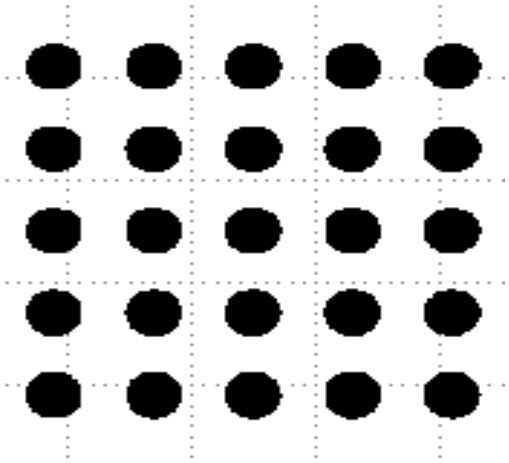


Assumptions

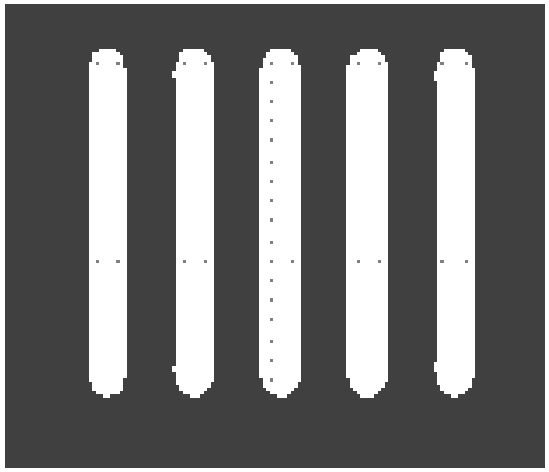
- Defects types can be classified by their through focus print behavior
- Coordinate tolerance level within a few microns
- Focus dependent defects are binned as Type 1
- Defects not dependent on focus (amplitude type) are binned as Type 2

Print Simulations

- Commercial FDTD software was used to perform print simulations
- Print Simulations used as design reference for defect inspection
- Line space (40nm HP) and Contact patterns (40nm HP) used for this work
- Printability of defects on wafer is also dependent on resist and process variations
- Focus dependent defects can be further classified based on their asymmetric behavior

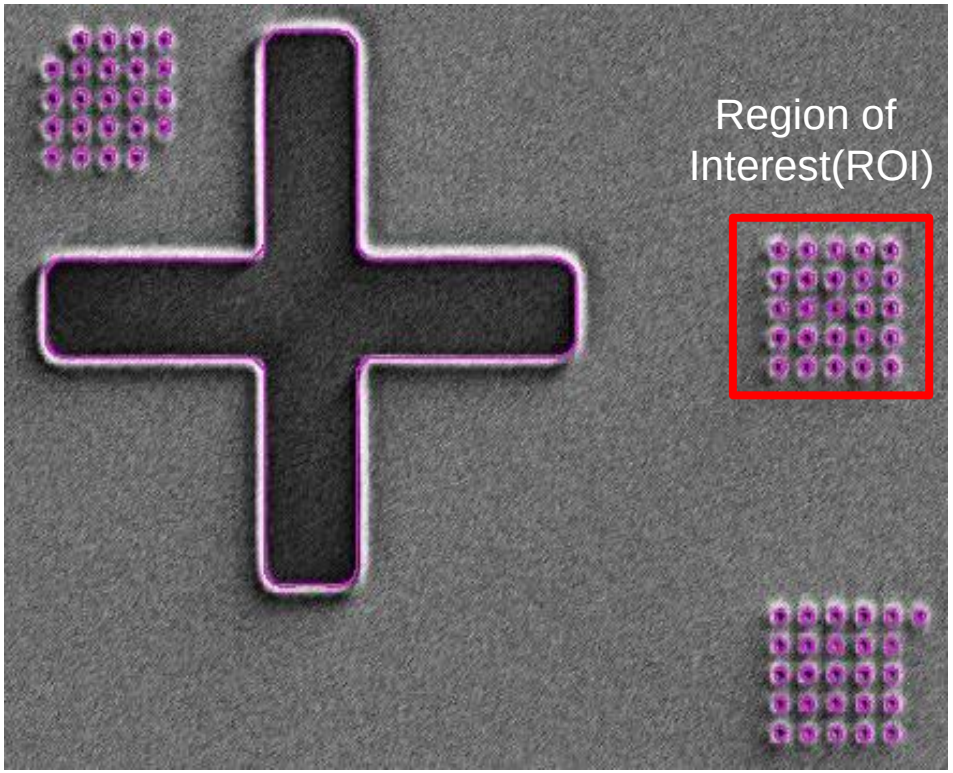


Contact Pattern (40nm) at best focus



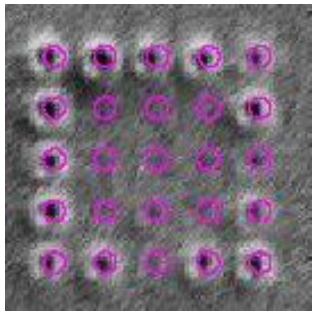
Line/Space Pattern (40nm) at best focus

Die to Database Inspection



Print simulation overlay on best focus pattern

ROI Best Focus



ROI Defocus (-200nm)

- Print simulations used for Die-Database inspection
- Defects with through focus behavior and process defects can be filtered from this methodology
- 11 defocus settings used with a focus step of 20nm, -100 to 100

Inspection output file

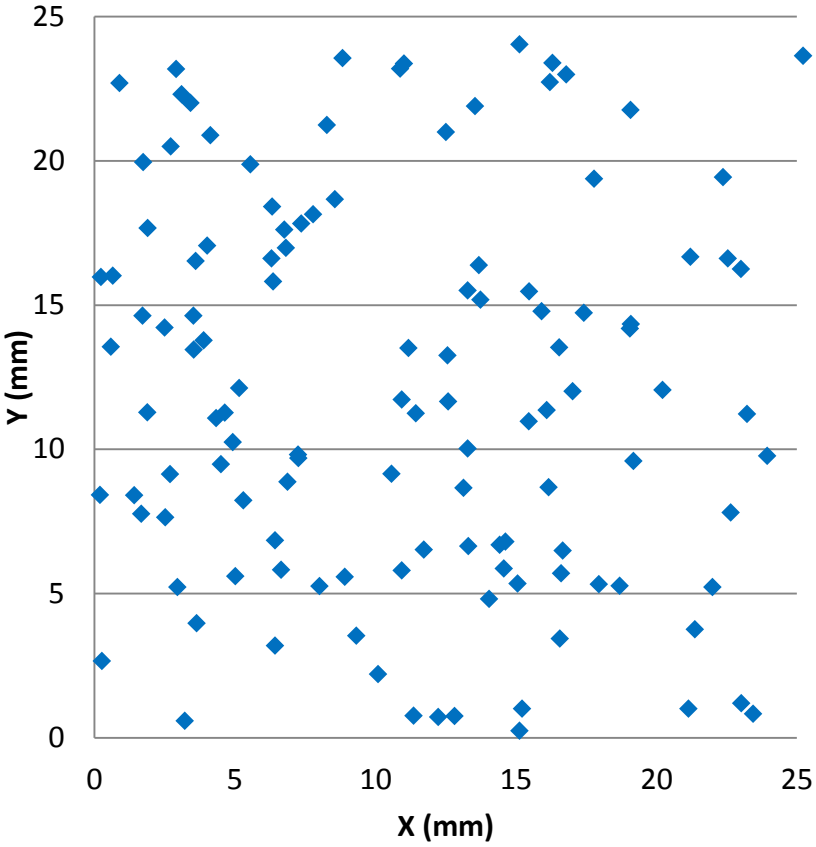
- Defect inspection output file contains defect locations along with defocus exposure index.
- Extract and compare defects from each defocus step to identify defect printability as a function of defocus.
- Defect size can also be extracted from inspection file for printability correlation
- Defect inspection threshold directly effects classification capability

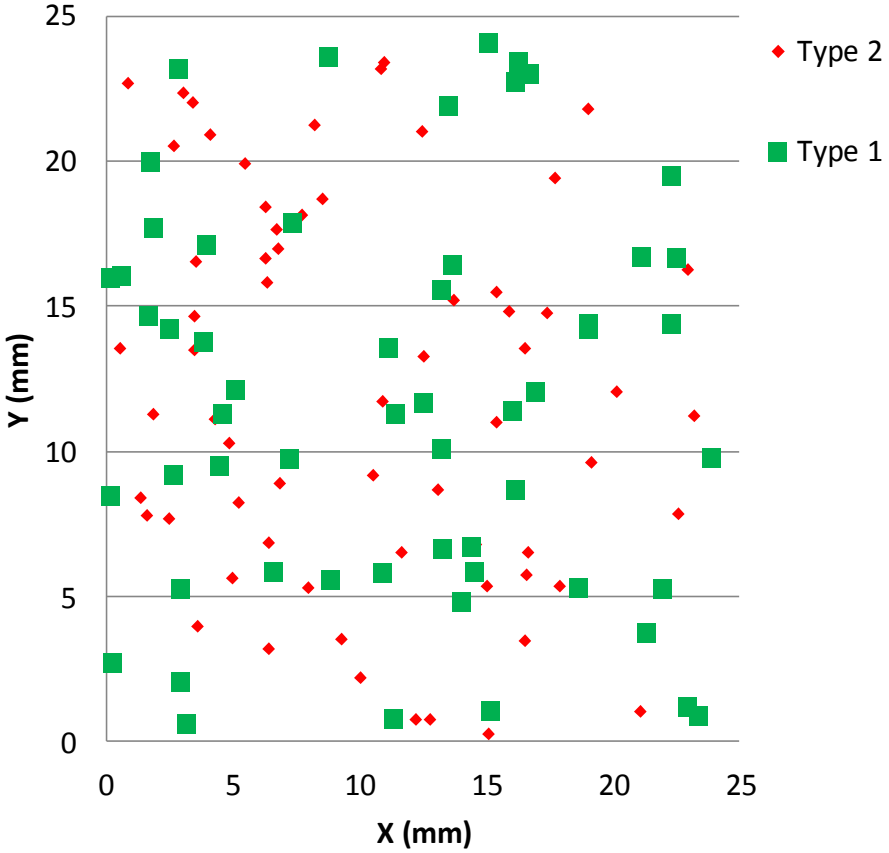
```
DefectRecordSpec 17 DEFECTID  XREL  YREL  XINDEX  YINDEX  XSIZE  YSIZE  DEFECTAREA  DSIZE  CLASSNUMBER
DefectList
    1 2.394333e+004 9.759956e+003 0 -2 0.009000 0.009000 0.000081 0.009000 807 3 807 807 807 0 0 0
    2 4.297618e+003 1.357319e+004 0 -2 0.009000 0.009000 0.000081 0.009000 807 3 807 807 807 0 0 0
    3 1.609506e+004 1.134494e+004 0 -2 0.009000 0.009000 0.000081 0.009000 807 3 807 807 807 0 0 0
    4 1.777997e+004 1.670669e+004 0 -2 0.010000 0.010000 0.000100 0.010000 807 3 807 807 807 0 0 0
    5 2.170445e+004 1.323006e+004 0 -2 0.009000 0.009000 0.000081 0.009000 807 3 807 807 807 0 0 0
    6 1.258523e+004 1.165410e+004 0 -2 0.009000 0.009000 0.000081 0.009000 807 3 807 807 807 0 0 0
    7 4.017139e+003 1.705395e+004 0 -2 0.012000 0.012000 0.000144 0.012000 807 3 807 807 807 0 0 0
    8 2.302950e+002 1.596113e+004 0 -2 0.009000 0.009000 0.000081 0.009000 807 3 807 807 807 0 0 0
    9 1.701742e+004 1.200941e+004 0 -2 0.010000 0.010000 0.000100 0.010000 807 3 807 807 807 0 0 0
   10 2.593933e+004 1.034297e+004 0 -2 0.009000 0.009000 0.(
   11 2.669050e+002 2.647123e+003 0 -2 0.009000 0.009000 0.(
   12 1.616883e+004 8.673730e+003 0 -2 0.010000 0.010000 0.(
```

Inspection output file

X (µm)	Y (µm)	Defocus step	Defect ID
2968	2017	5	51
23441	817	5	52
16296	23388	5	55
7367	17818	5	56
13289	10019	5	62
2968	2017	6	51
23441	817	6	52
16296	23388	6	55
7367	17818	6	56
25742	7627	6	57
2968	2016	7	51
23441	817	7	52
16297	23388	7	55
7367	17818	7	56
25742	7627	7	57

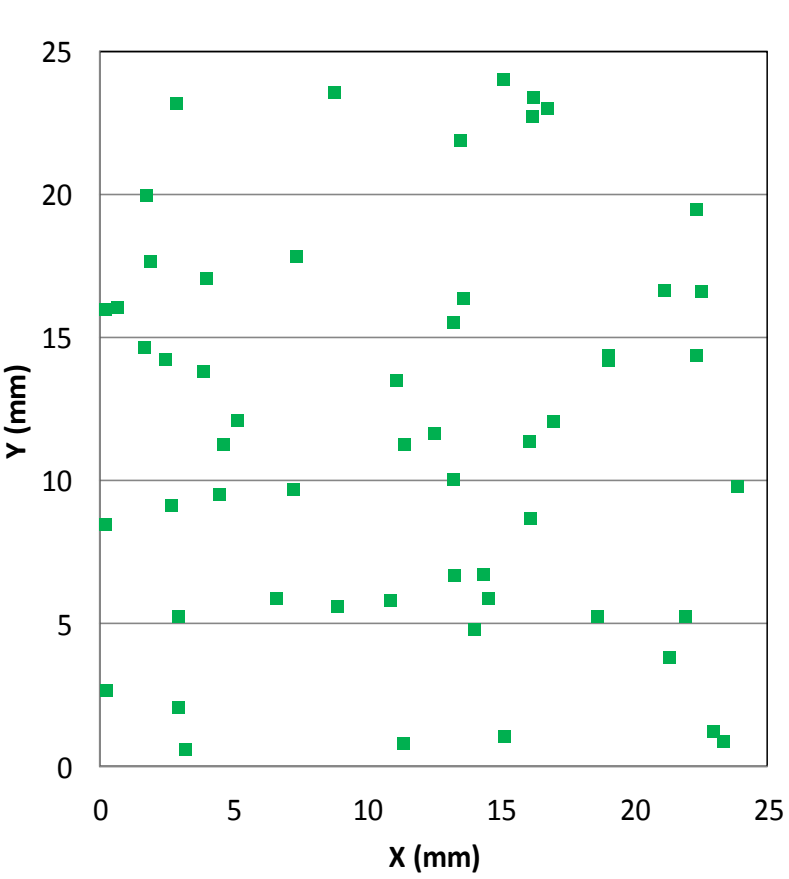
Results - Defects Characterization

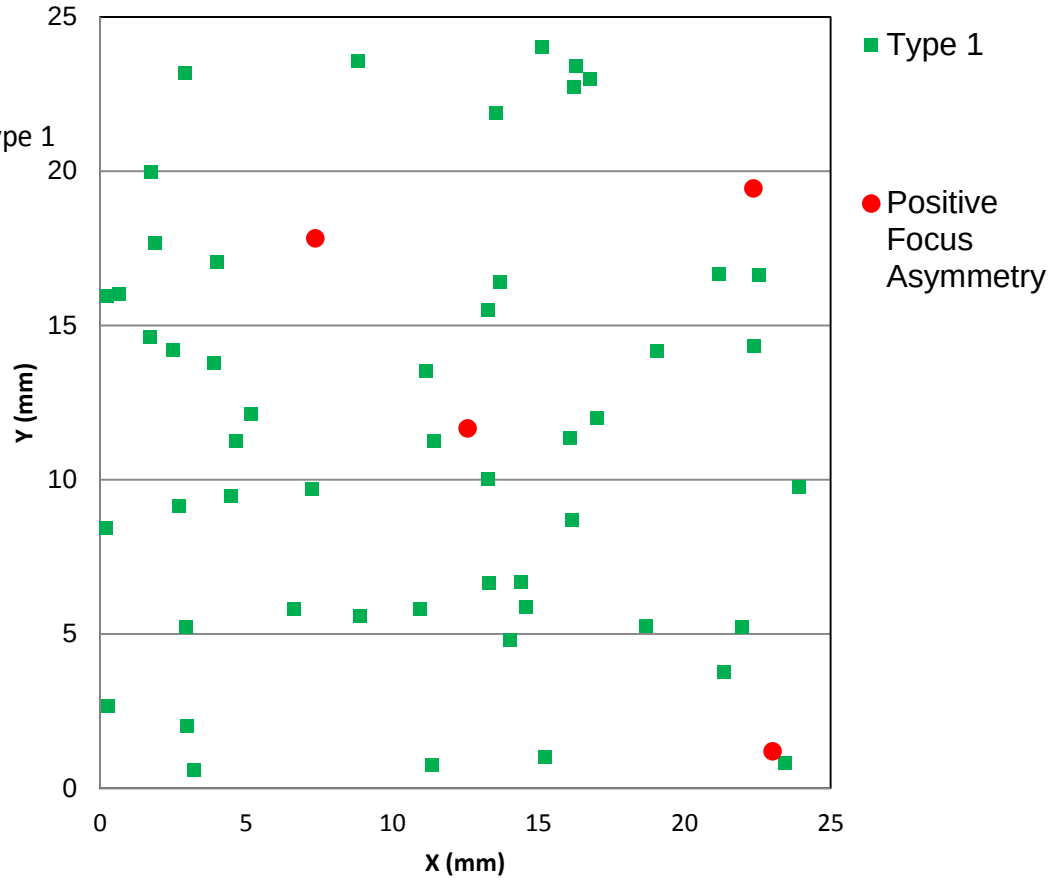




- Defect location file processed to identify focus dependent and focus independent defects, classified as Type 1 and Type 2 respectively
- Appropriate repair techniques can be applied based this distinction

Results - Defect Characterization

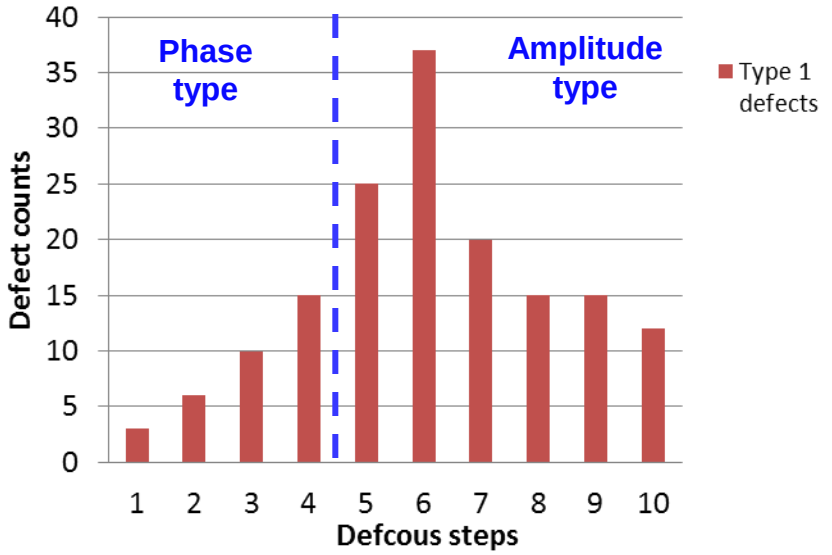


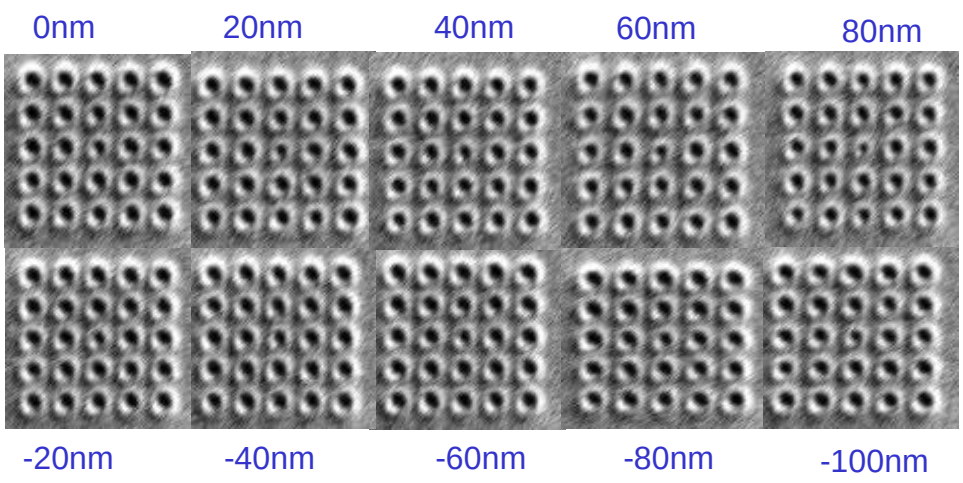


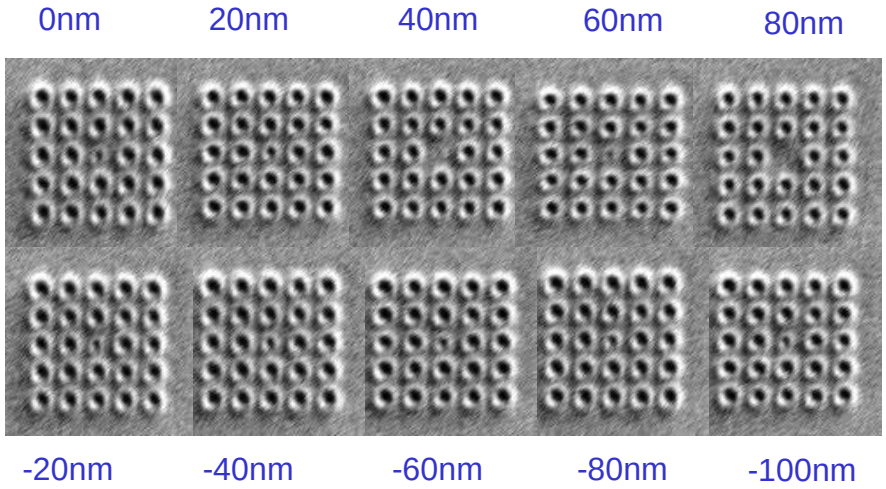
- Type 1 (focus dependent) defects can be further classified into defects with positive or negative focus asymmetry (bump/pit phase type defects), undersized contacts, small amplitude defect etc.

Results - Defect Characterization

- Defects visually inspected to determine focus dependence
- Defect counts analyzed based on their printability across defocus steps
- Classification of defects based on defocus threshold bin can estimate height of defects







Under-sized Contact due to buried defects

Summary

- E-Beam Inspection with Die to Database Methodology evaluated to identify defects with through focus behavior.
- Print simulations utilized as design reference at different defocus levels for contact (40nm HP) and Line/Space patterns (40nm HP)
- Inspection output file processed to extract and classify defects based on wafer print behavior
- Classification of defects aids in application of appropriate defect repair strategy
- Information on defect height and its type can be estimated from analyzing defect printability through focus

Acknowledgements

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  - Mask Fabrication Team
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  - Greg McIntyre
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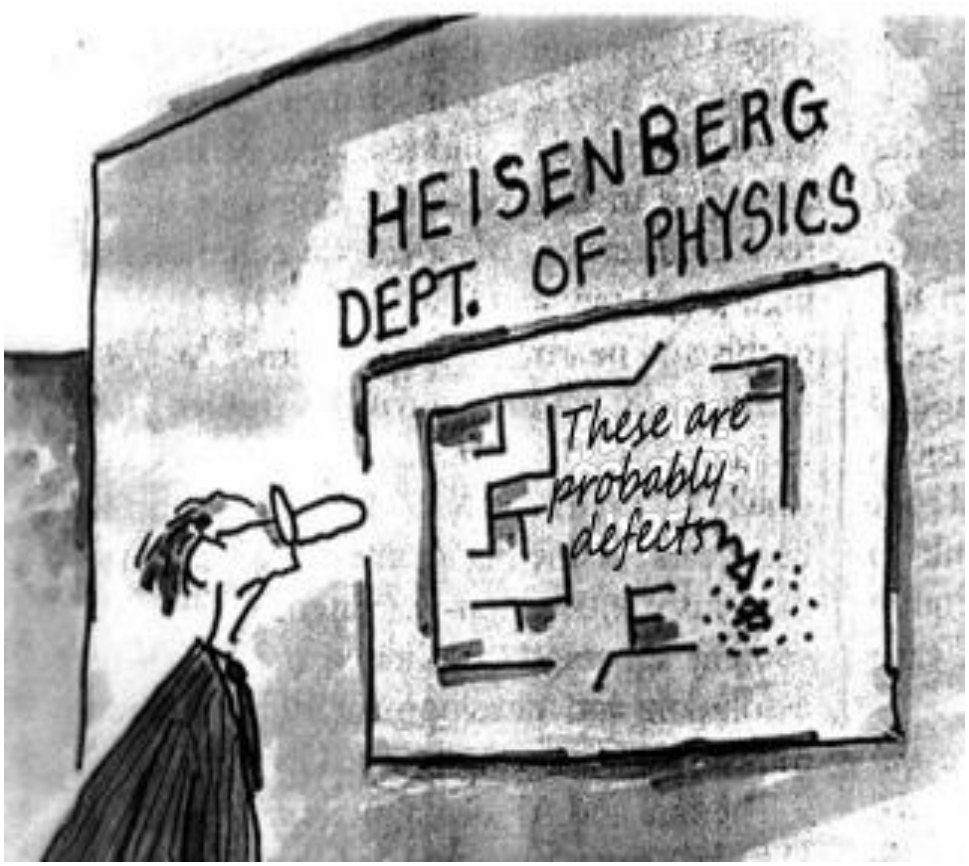
  - Daniel Corliss
- HMI
  - Daniel Tien
  - Fei Wang



Thank you for your attention