CENTER FOR DEEP LEARNING IN ELECTRONICS MANUFACTURING

A SEM-based DL diagnosis system For identifying VSB mask writer defects

- Ajay Baranwal, et. al.

A PARTNERSHIP OF NuFLARE MYCRONIC D2S

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VSB writer system is a complex & reliable system

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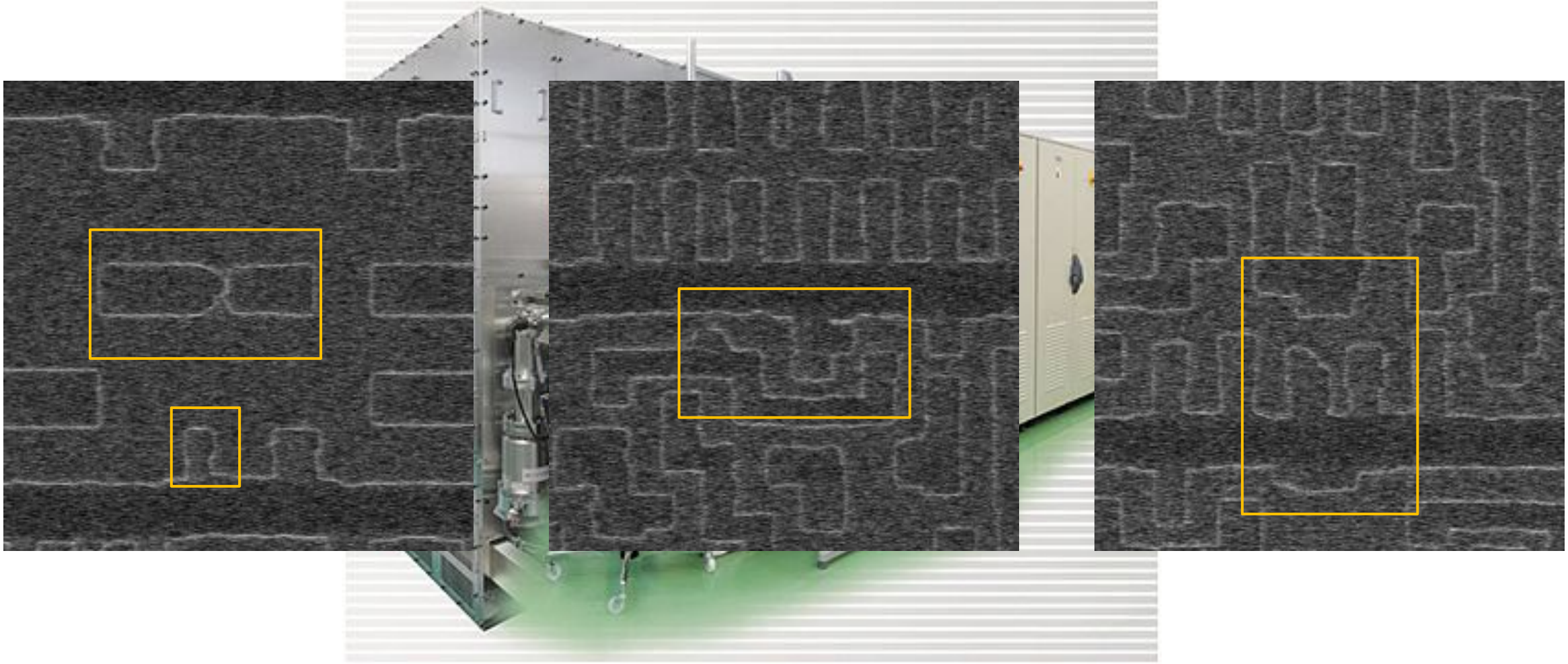
Rarely, something can go wrong

Need to diagnose and fix defects ASAP



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A quick overview of the VSB mask writer

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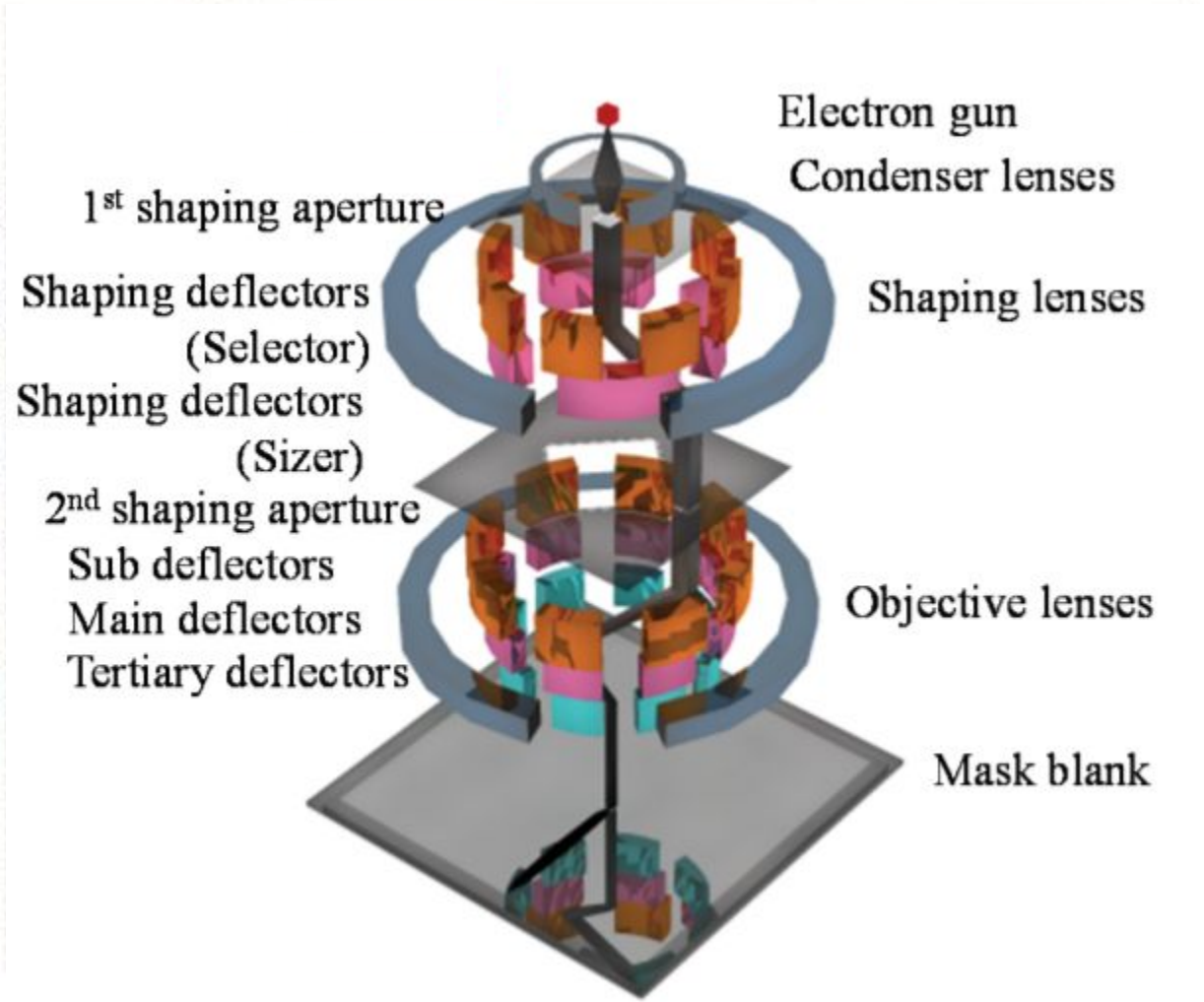
A quick overview of the VSB mask writer



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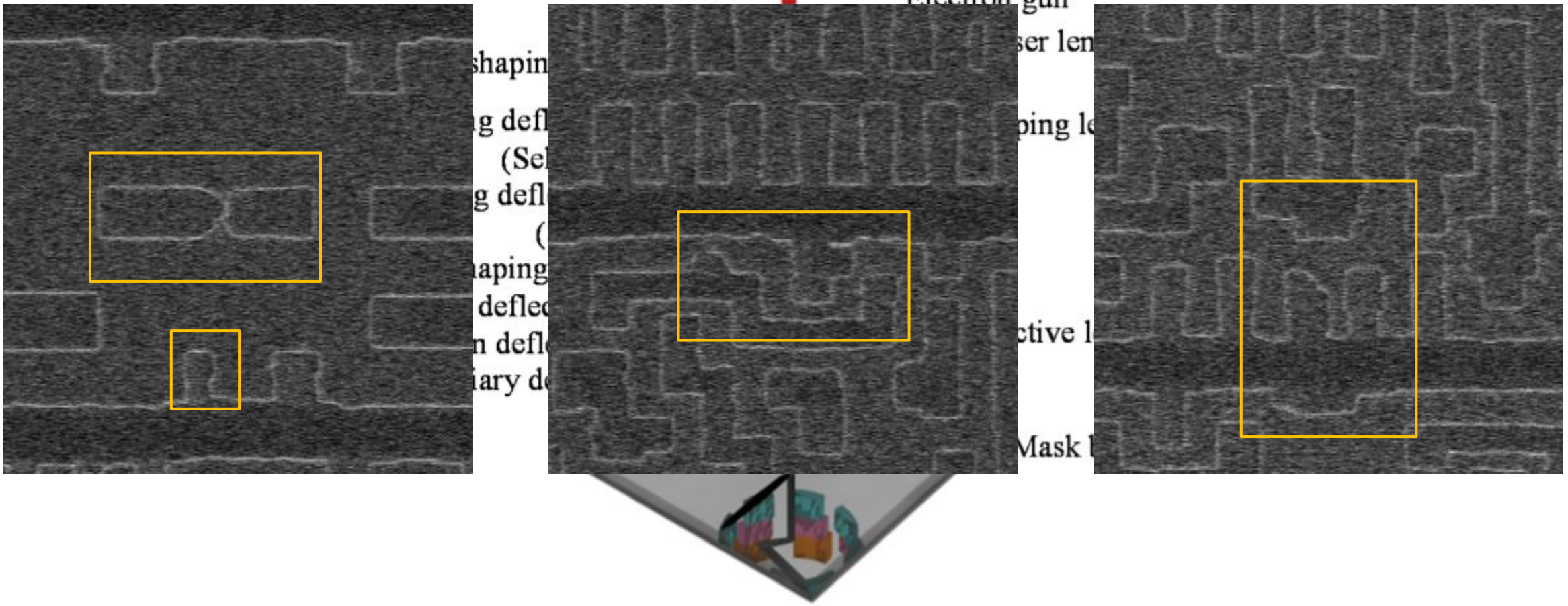
Mask vendors to diagnose and fix defects ASAP

To provide best customer service and support



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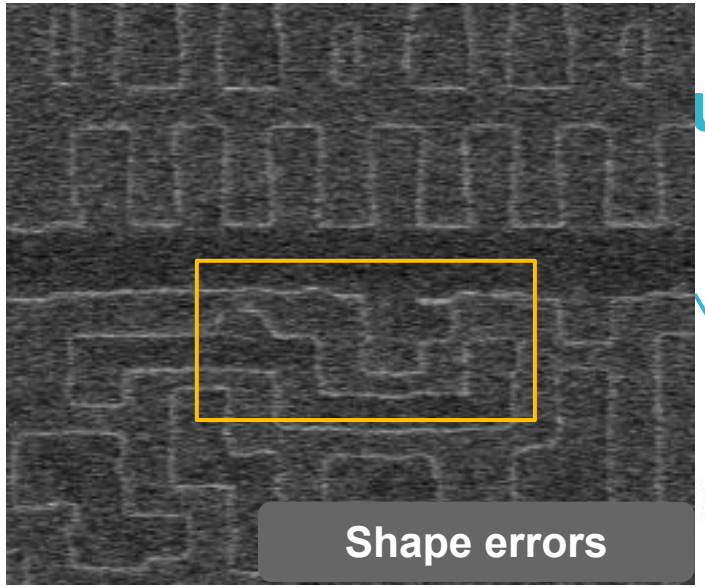
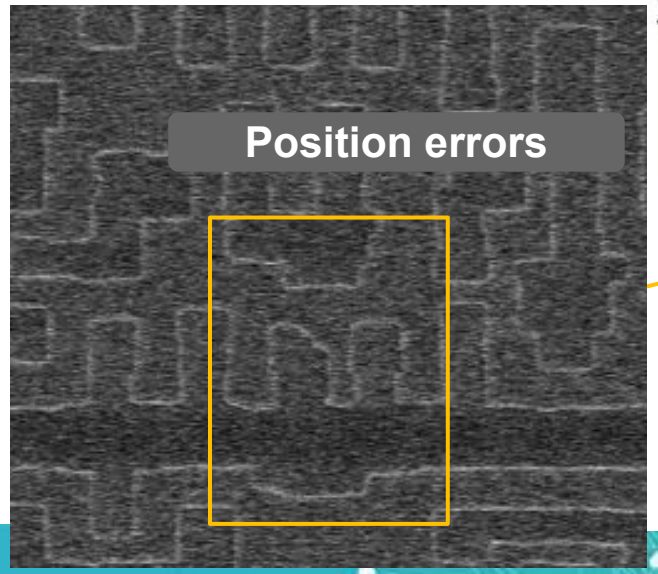
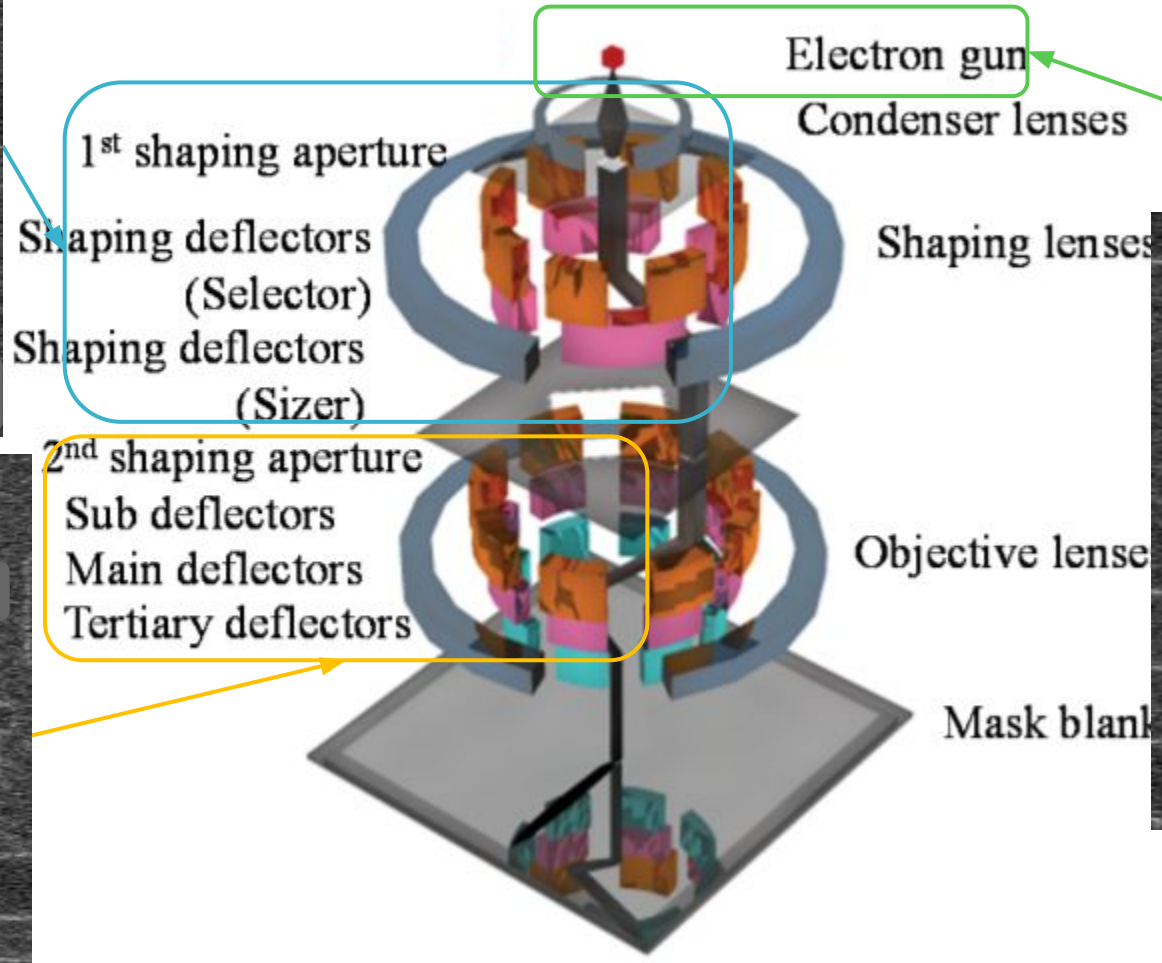
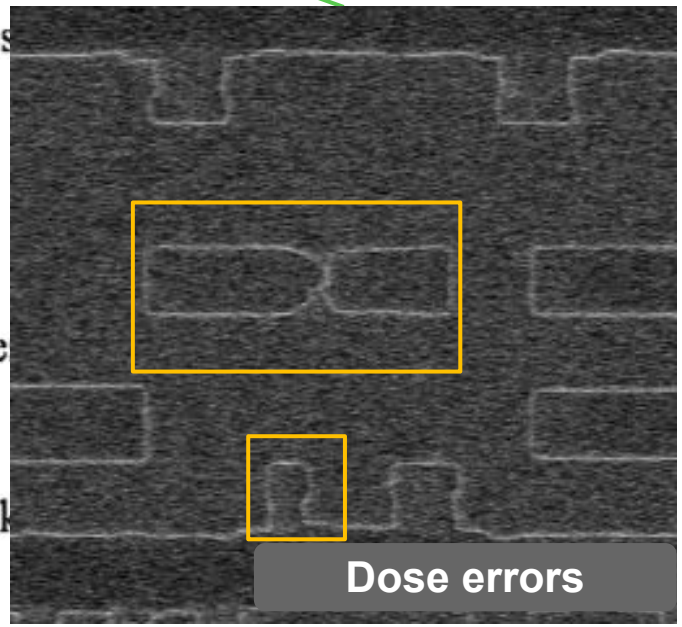
Writer defects need to be diagnosed and fixed ASAP

use the defect; repair and/or replace parts









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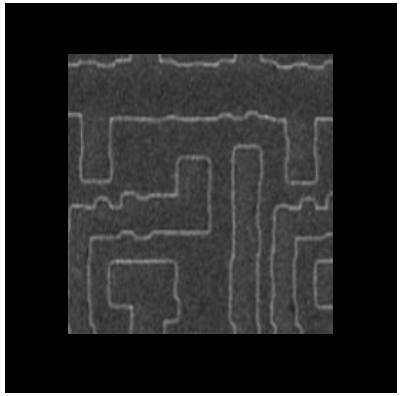
There are two SEM defect classification methods

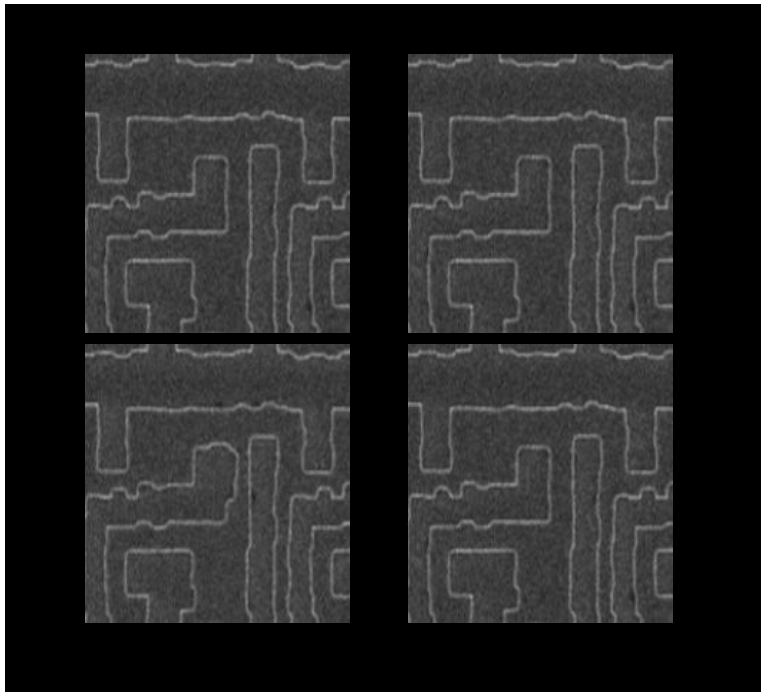
To identify the writer's defects

Note: Data not to scale
For illustrative purpose



Single Die reticle example

Die-to-database method
Compares with corresponding CAD data



2x2 Die-array example

Die-to-die method
Compares two Dies

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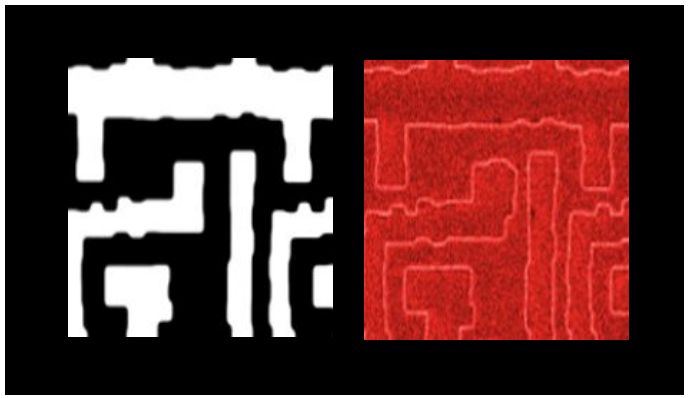
D2DB example
Reference CAD & defect SEM

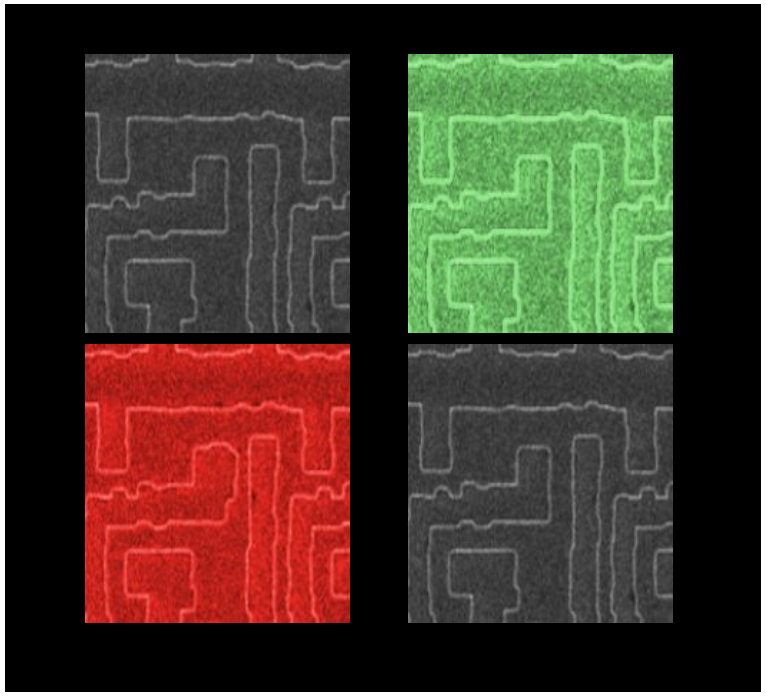
Note: Data not to scale
For illustrative purpose



CAD & SEM images

Die-to-database classifier
Compares with corresponding CAD data

D2D example
Reference SEM & defect SEM



SEM images

Die-to-die classifier
One Die acts as a reference

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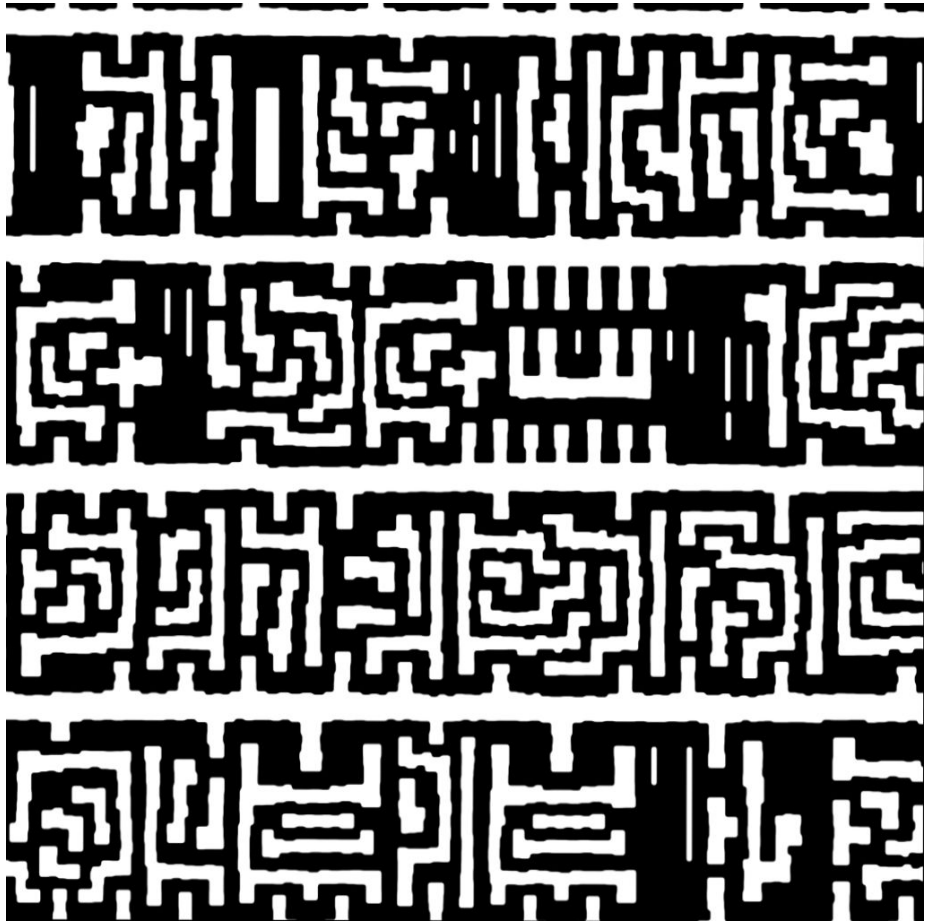
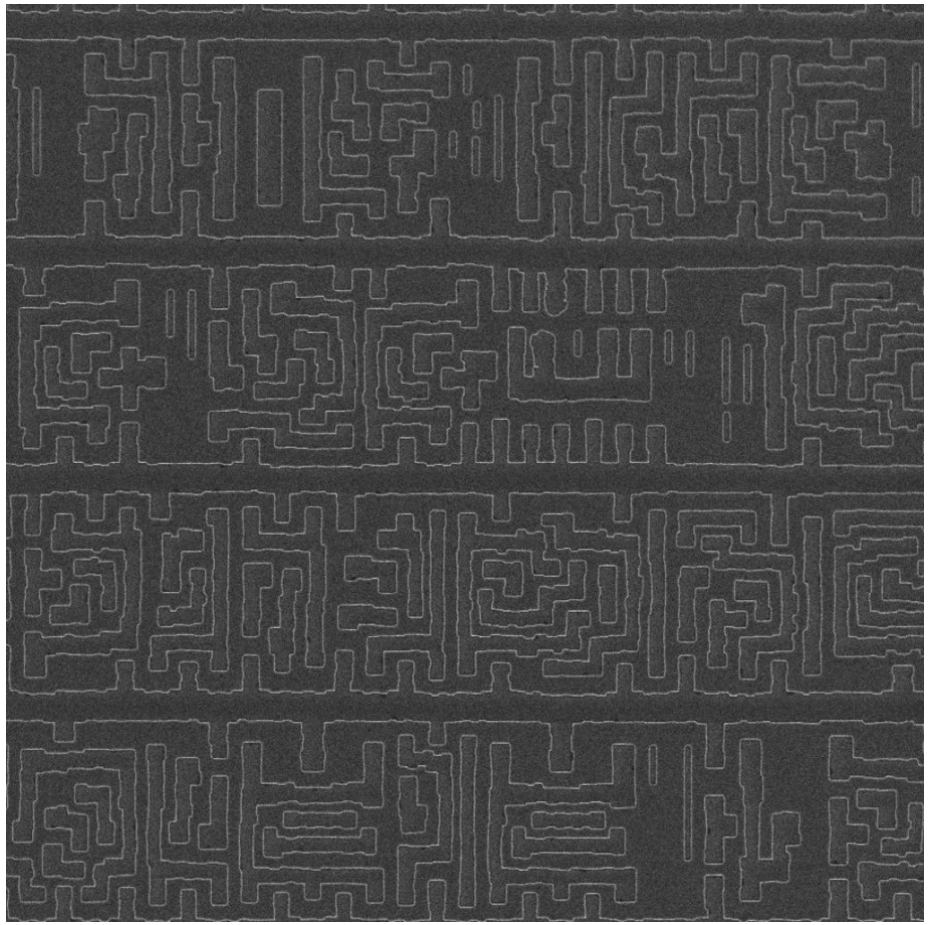
Hard for humans to classify the error

A Die-to-database example



Reference CAD



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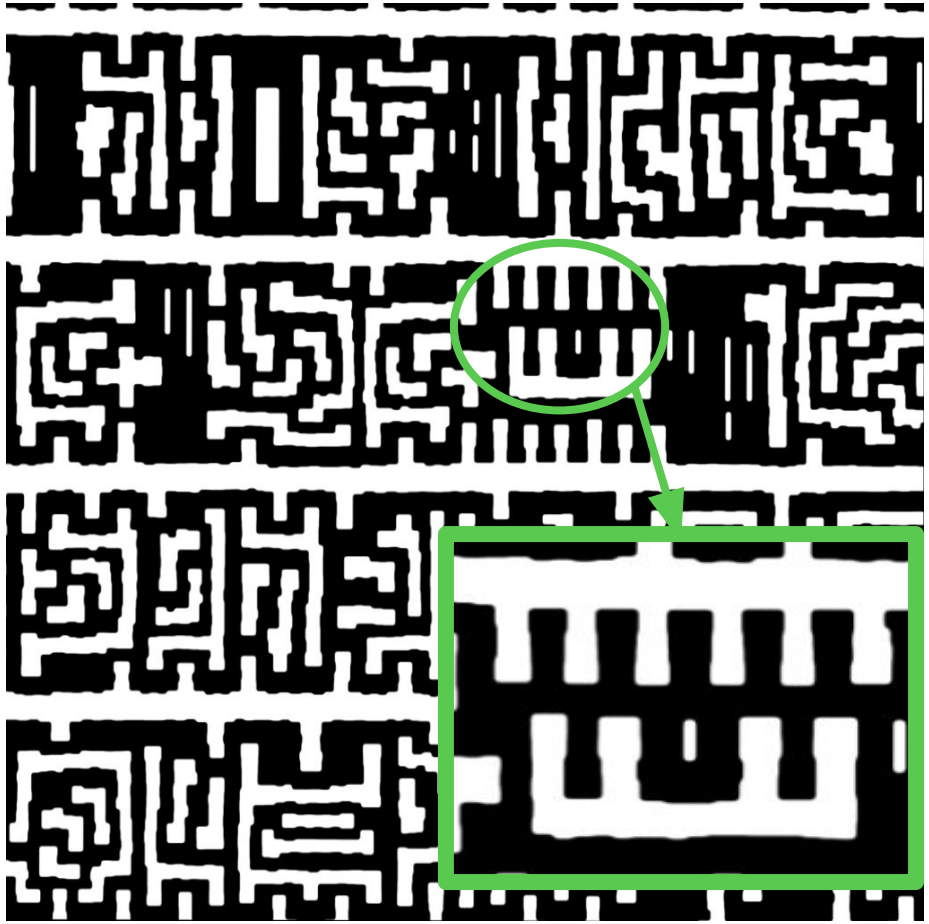
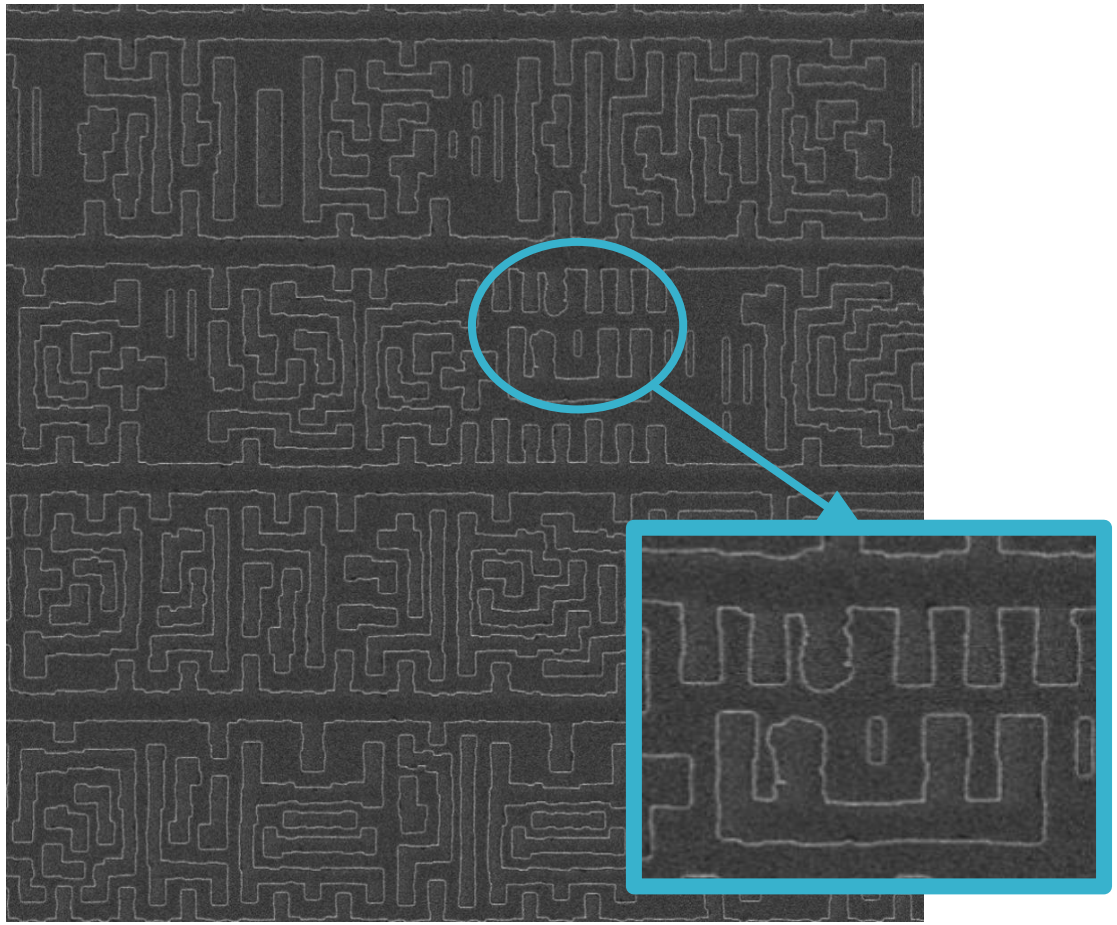
Hard for humans to classify the error

Needs overlaying, zooming-in/out; still hard due to noise, LER



Reference CAD



Defect SEM

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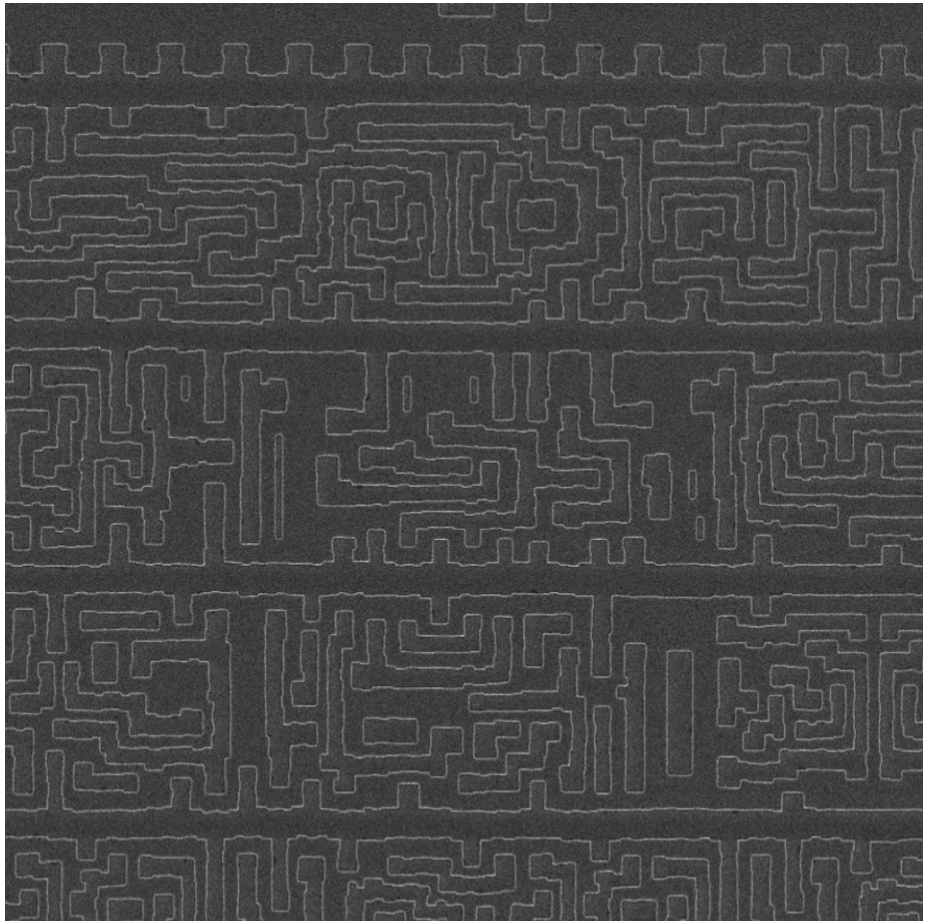
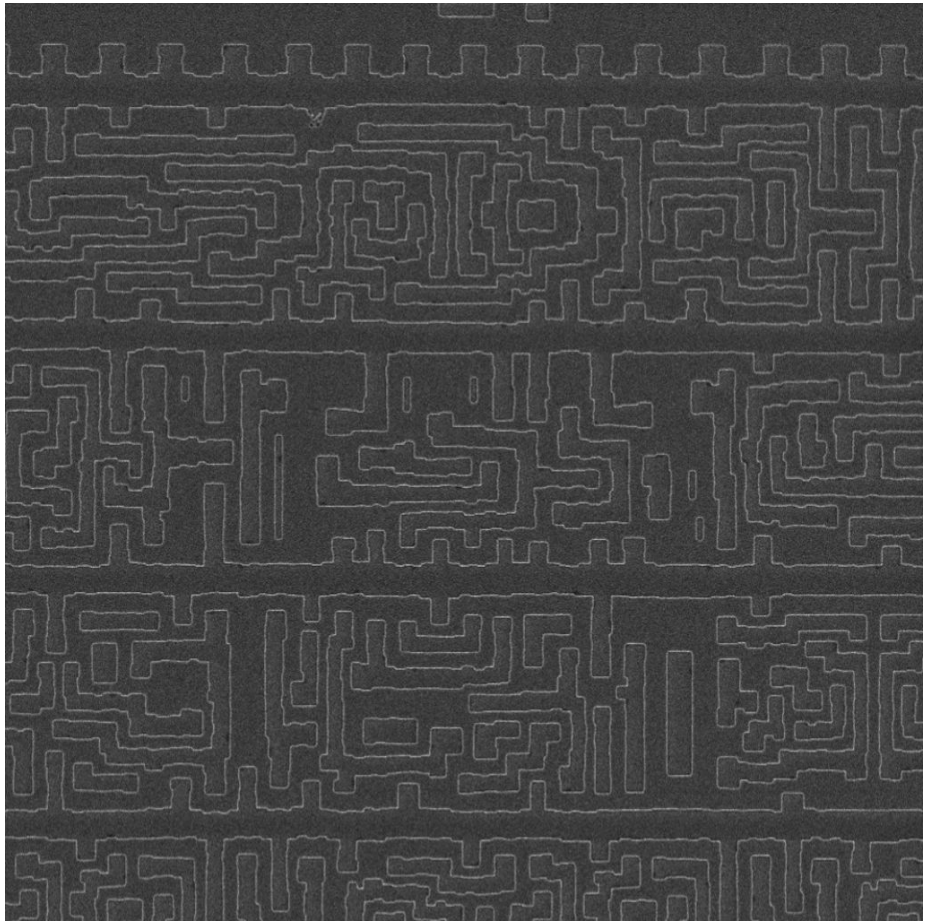
Yet another case: hard to classify

A Die-to-die example



Reference SEM



Defect SEM

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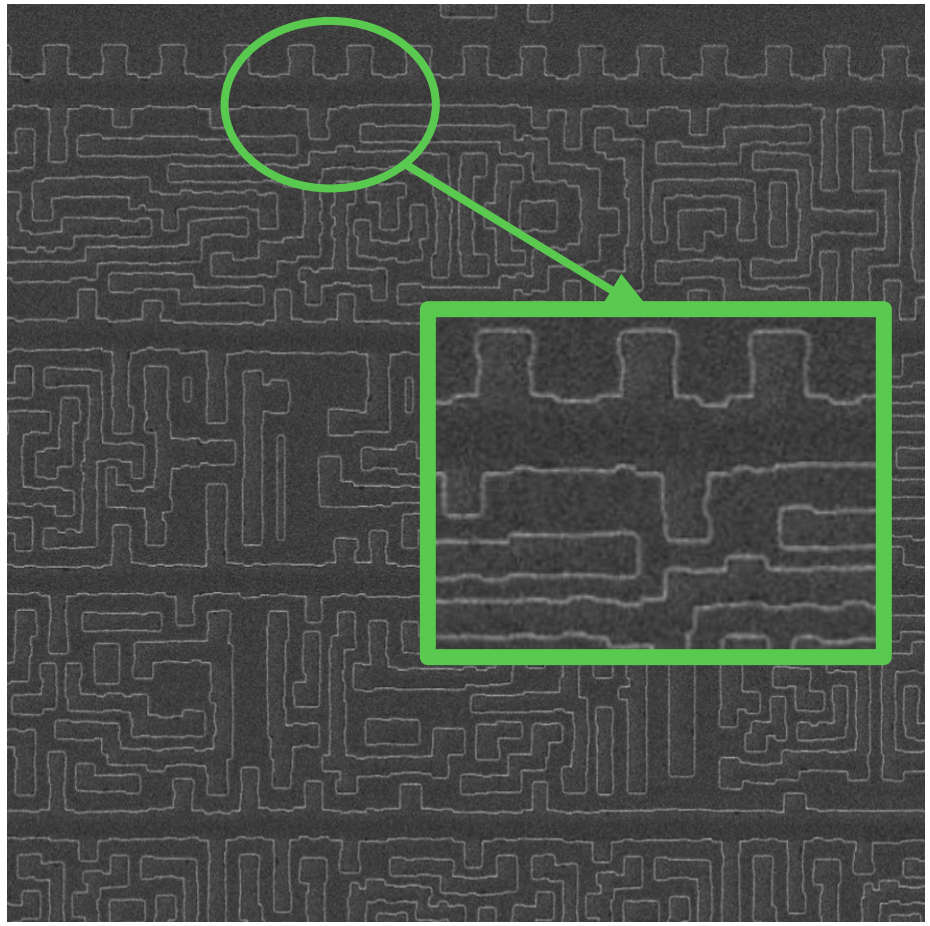
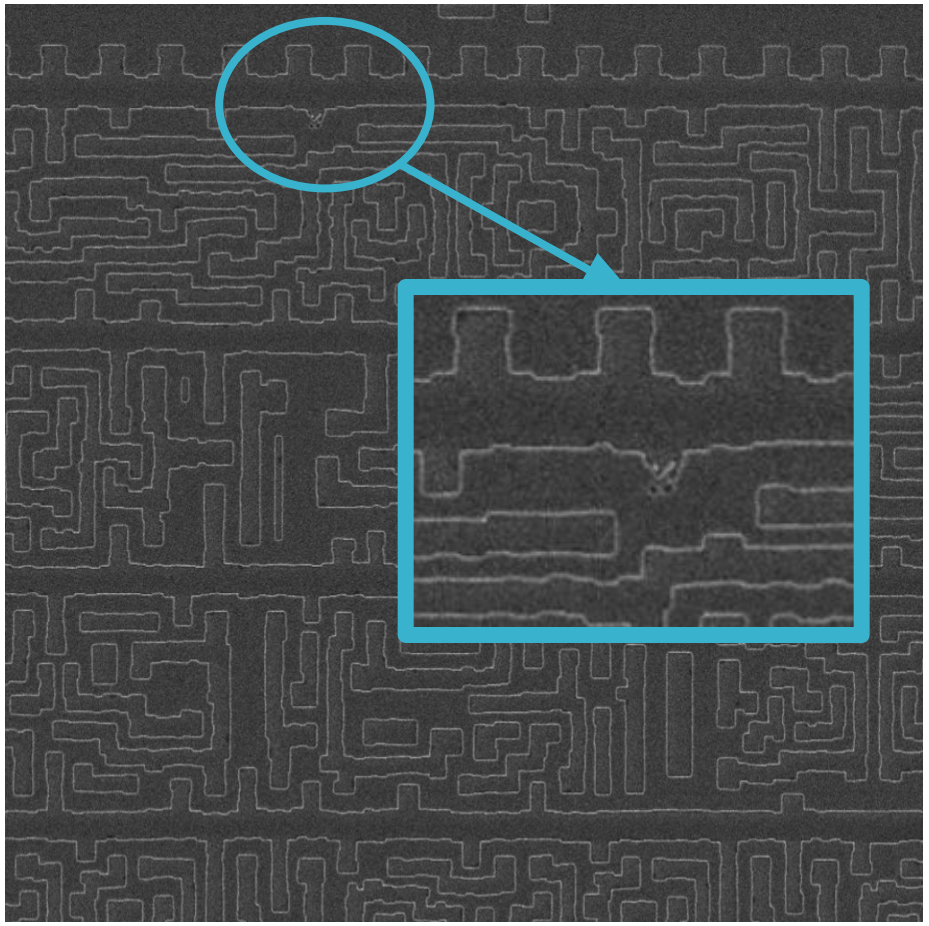
Yet another case: hard to detect and classify

Needs overlaying, zooming-in/out; still hard due to noise, LER



Reference SEM



Defect SEM

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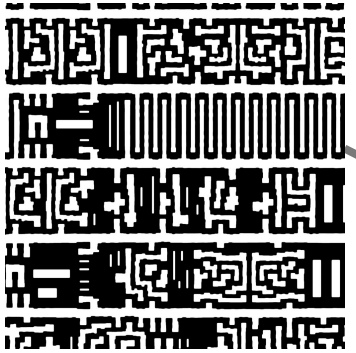
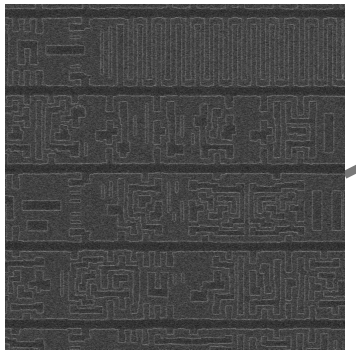
We built DL models for classification methods

DL works great on image patterns – match, differentiate, group, etc.

Reference CAD images

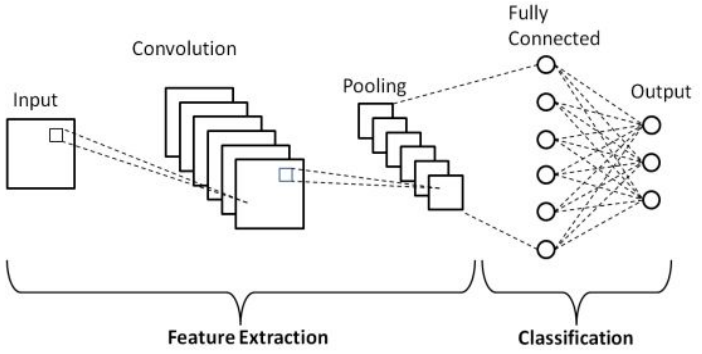


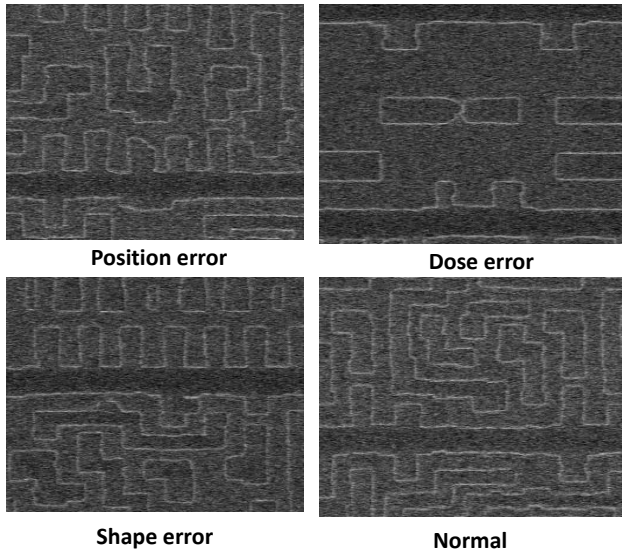


Defect SEM images

Deep NN

Trained on millions of
DT created synthetic SEM





Type of error probability

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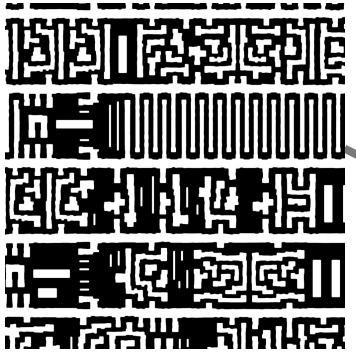
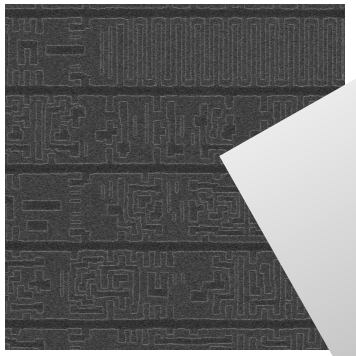
We built DL models for classification methods

DL works great on image patterns – match, diff…e, group, etc.

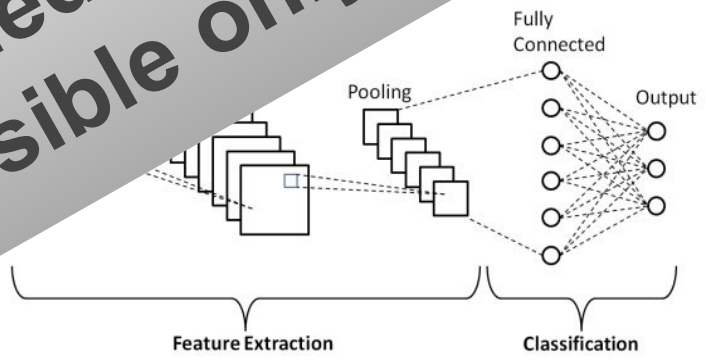
Reference CAD images

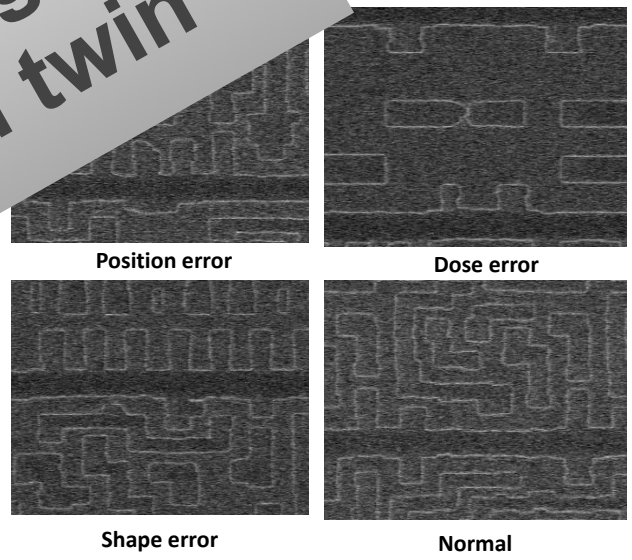




Defect SEM images

26 layers, 12 MN parameters
Trained with 850K SEM images
Possible only with a digital twin





Type of error probability

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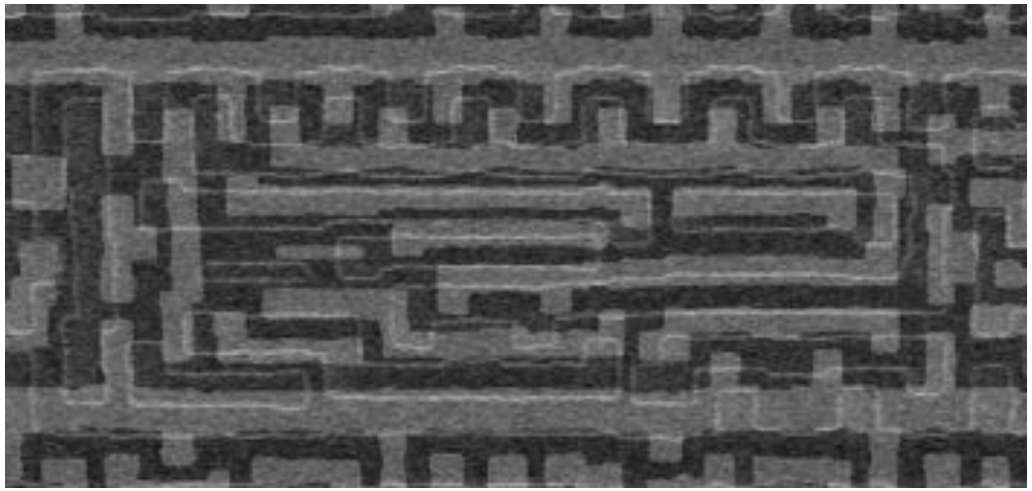
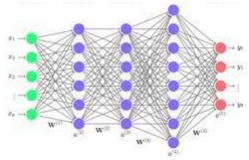
Though, design CAD and SEM need alignment

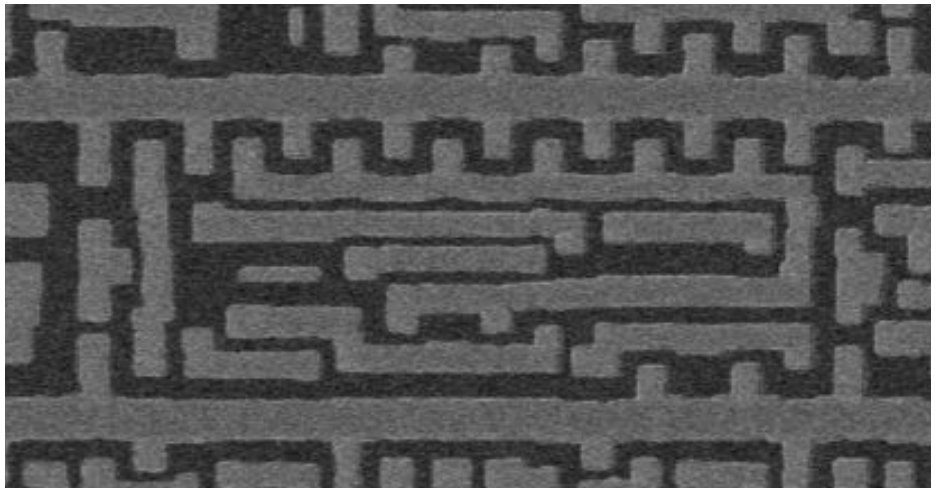
A new DL model; algorithmic methods limited for different domain images



Misaligned CAD & SEM

Image alignment





Aligned CAD & SEM

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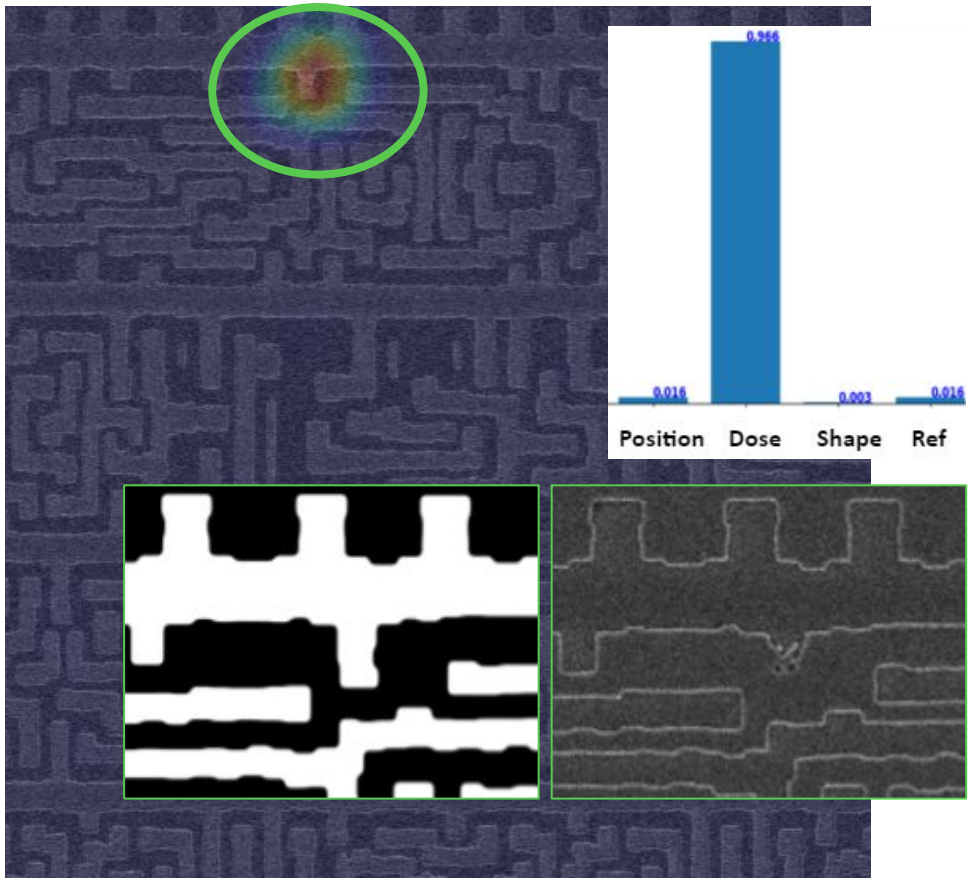
D2DB DL model shows ~ 93% accuracy

For different CD-SEM machines; visualization shows confidence



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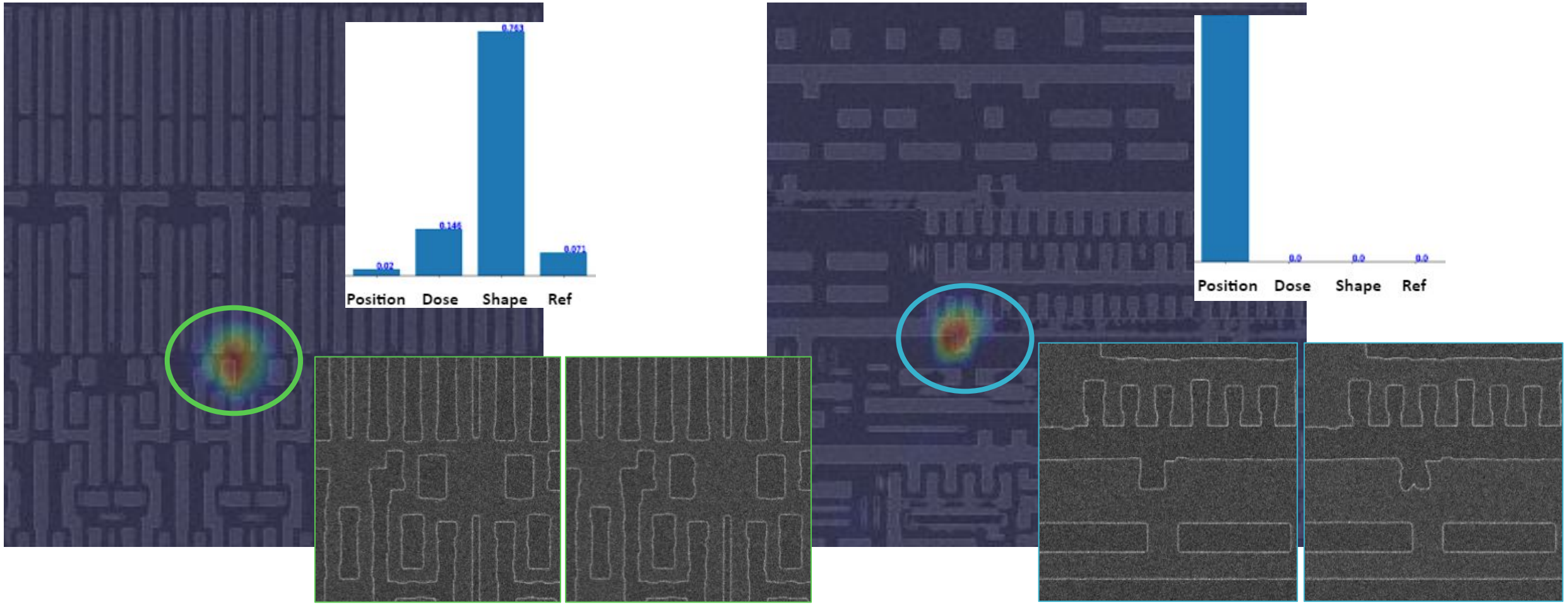
D2D DL model also show ~ 91% accuracy

For different CD-SEM machines; visualization shows confidence



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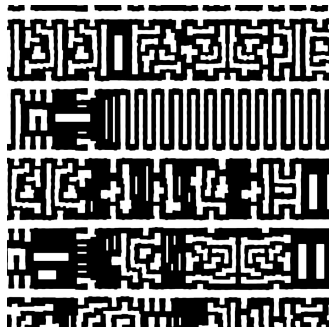
A SEM-based defect classifier system: D2DB & D2D

Possible with several DL models and Digital Twins to synthesize data

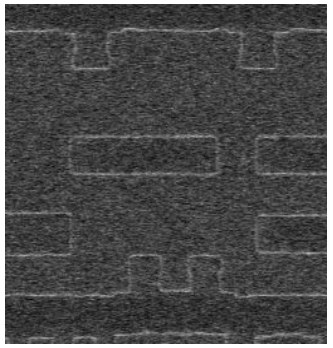
Reference CAD images



Defect SEM images

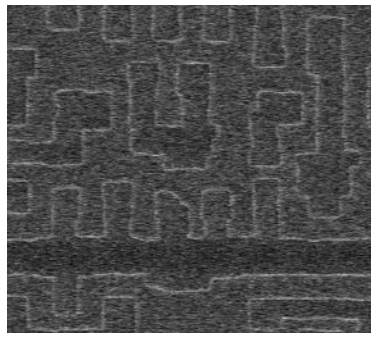
Die-to-database classification method

Reference SEM images

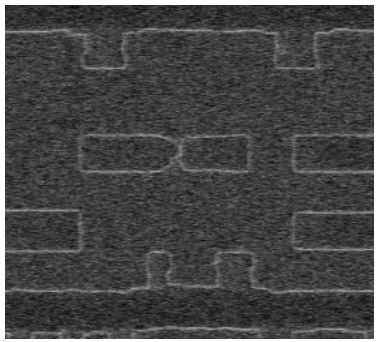


Defect SEM images

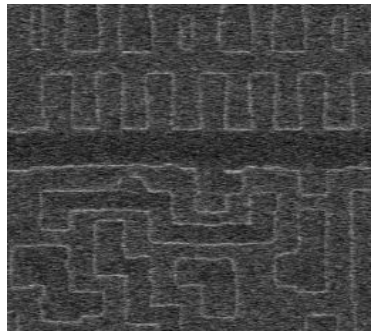
Die-to-die classification method



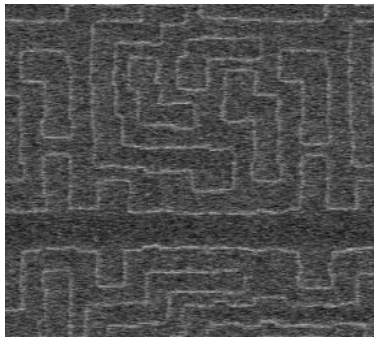
a. Position error



b. Dose error



c. Shape error



d. Normal

Error classification

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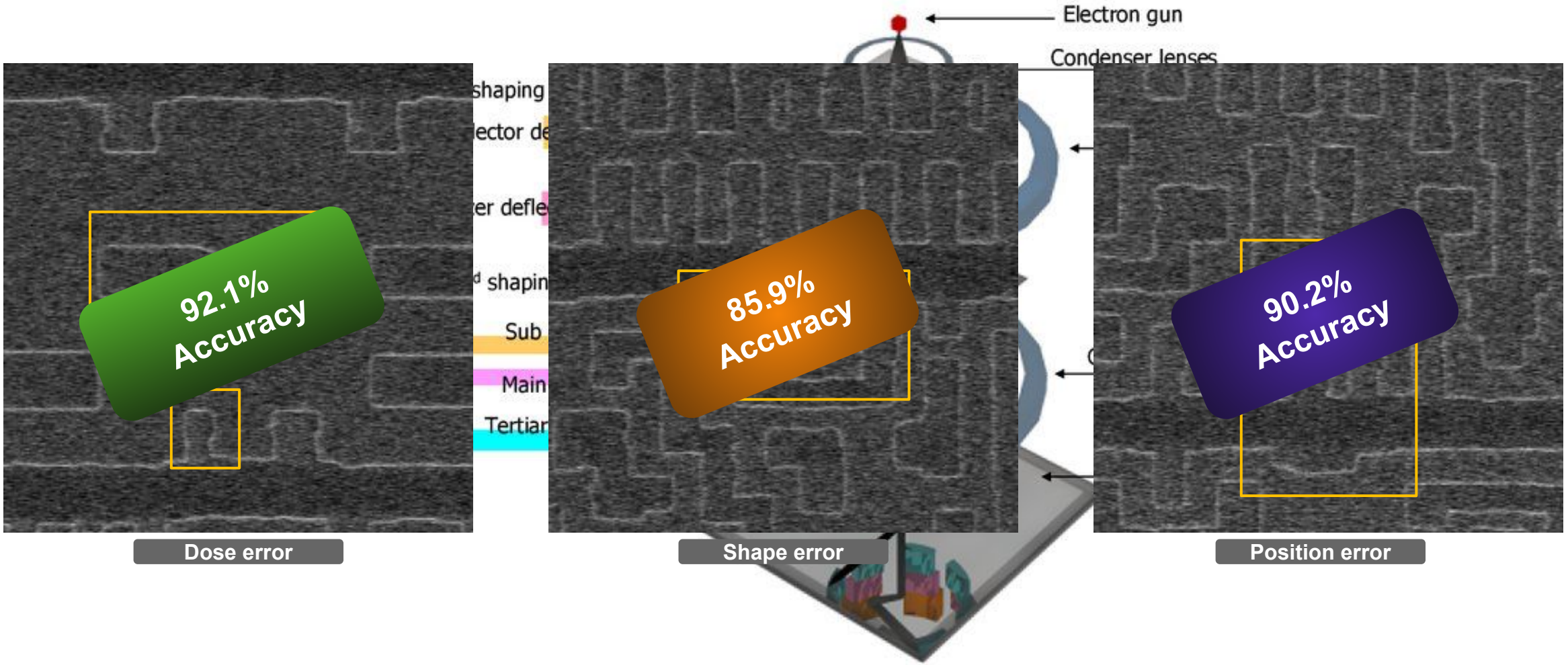
Mask vendors to diagnose and fix defects ASAP

To provide best customer service and support



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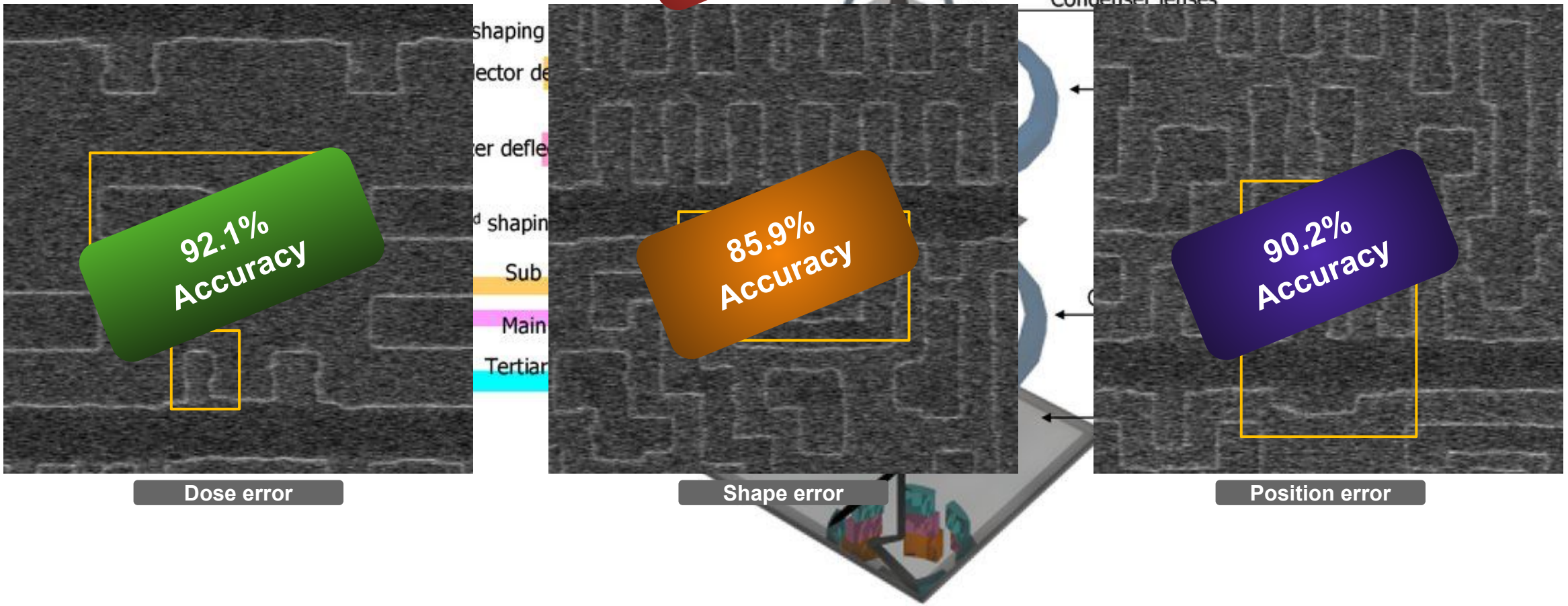
Mask vendors to diagnose and fix defects ASAP

To provide best c vice and support



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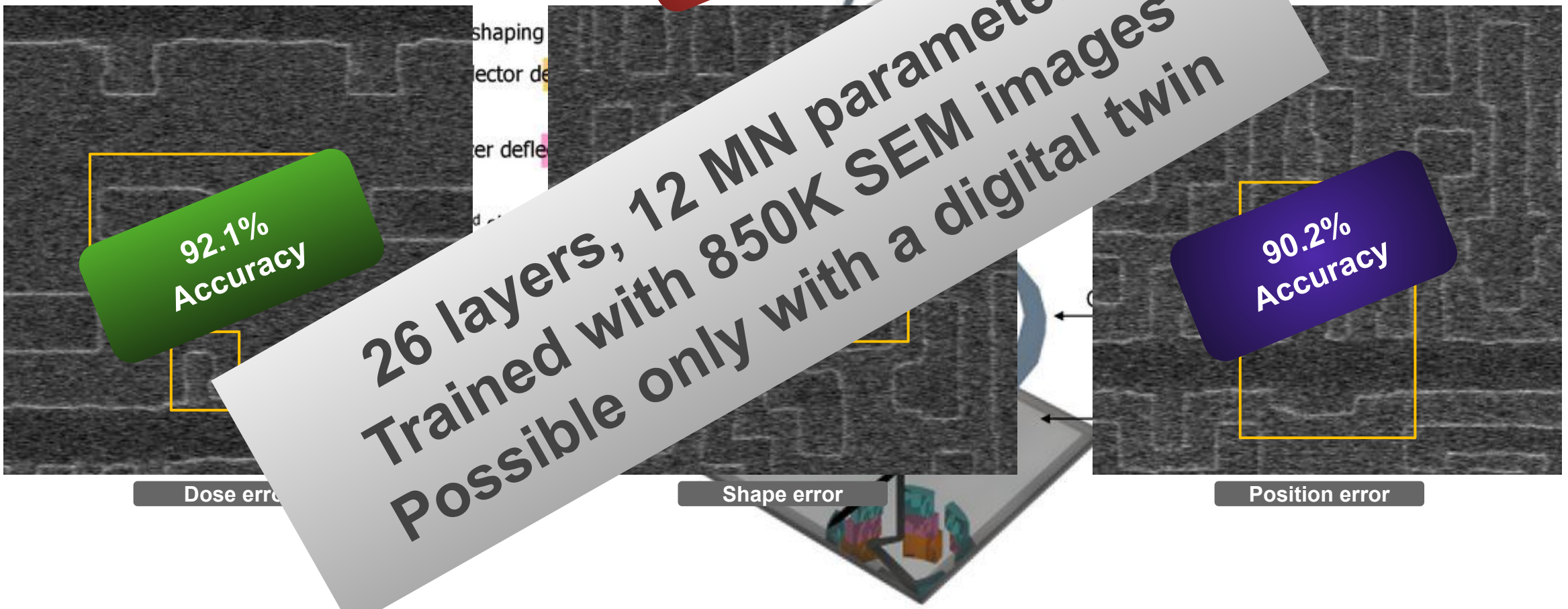
Mask vendors to diagnose and fix defects ASAP

To provide best c vice and rt



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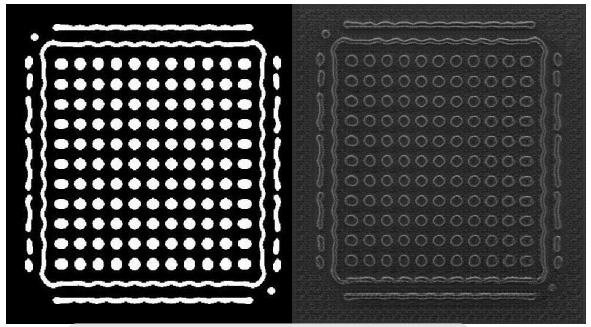
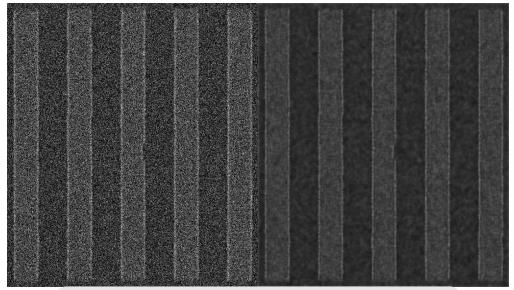
DL is great for SEM analysis!

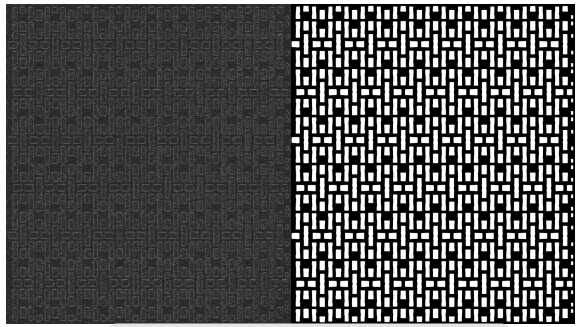
DL augments human taking faster and accurate decisions with large data



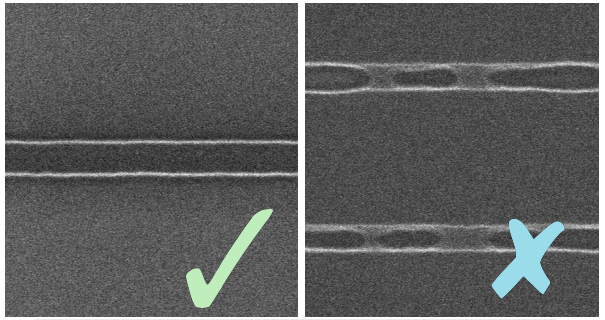
CAD2SEM digital twins



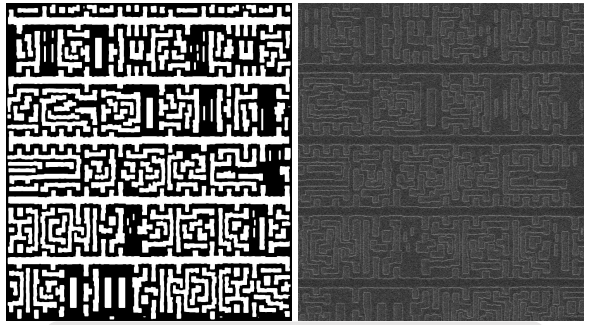
SEM denoising



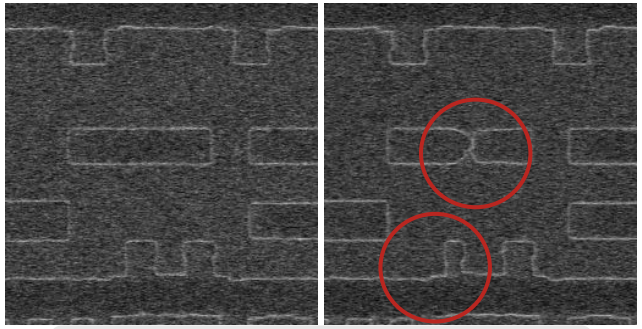
SEM2CAD digital twins



Filter good quality SEM



CAD to SEM Image alignment



VSB writer defect classification

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