A SEM-based DL diagnosis system
For identifying VSB mask writer defects
- Ajay Baranwal, et. al.
VSB writer system is a complex & reliable system
Rarely, something can go wrong
Need to diagnose and fix defects ASAP
A quick overview of the VSB mask writer
A quick overview of the VSB mask writer
Mask vendors to diagnose and fix defects ASAP
To provide best customer service and support
Writer defects need to be diagnosed and fixed ASAP. Taking into account the root cause of the defect; repair and/or replace parts.

- **Shape errors**
  - 1st shaping aperture
  - Shaping deflectors (Selector)
  - Shaping deflectors (Sizer)
- **Position errors**
  - 2nd shaping aperture
  - Sub deflectors
  - Main deflectors
  - Tertiary deflectors
- **Dose errors**
There are two SEM defect classification methods  
To identify the writer’s defects

Note: Data not to scale  
For illustrative purpose

**Die-to-database method**
Compares with corresponding CAD data

**Die-to-die method**
Compares two Dies
D2DB example
Reference CAD & defect SEM

Note: Data not to scale
For illustrative purpose

Die-to-database classifier
Compares with corresponding CAD data

D2D example
Reference SEM & defect SEM

Die-to-die classifier
One Die acts as a reference
Hard for humans to classify the error

A Die-to-database example

Reference CAD

Defect SEM
Hard for humans to classify the error
Needs overlaying, zooming-in/out; still hard due to noise, LER
Yet another case: hard to classify

A Die-to-die example

Reference SEM

Defect SEM
Yet another case: hard to detect and classify
Needs overlaying, zooming-in/out; still hard due to noise, LER

Reference SEM

Defect SEM
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

Position error
Dose error
Shape error
Normal
We built DL models for classification methods.

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

- Reference CAD images
- Defect SEM images

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

- Position error
- Dose error
- Shape error
- Normal

Type of error probability

CDLe
Though, design CAD and SEM need alignment
A new DL model; algorithmic methods limited for different domain images
D2DB DL model shows ~ 93% accuracy
For different CD-SEM machines; visualization shows confidence
D2D DL model also show ~ 91% accuracy
For different CD-SEM machines; visualization shows confidence
A SEM-based defect classifier system: D2DB & D2D
Possible with several DL models and Digital Twins to synthesize data
Mask vendors to diagnose and fix defects ASAP
To provide best customer service and support

- Dose error: 92.1% Accuracy
- Shape error: 85.9% Accuracy
- Position error: 90.2% Accuracy
Mask vendors to diagnose and fix defects ASAP
To provide best customer service and support

- Dose error: 92.1% Accuracy
- Shape error: 85.9% Accuracy
- Position error: 90.2% Accuracy
- No defect: 96.2% Accuracy
Mask vendors to diagnose and fix defects ASAP
To provide best customer service and support

- **Dose error**
- **Shape error**
- **Position error**

- **Accuracy**
  - No defect: 96.2%
  - 92.1%
  - 85.9%
  - 90.2%

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

CDLe
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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