Characterization of mask CD mean-to-target for hotspot patterns by using SEM image contours

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Outline

- Introduction
- Contour extraction, alignment & averaging
- Contour-to-CD matching
- Mask CD MTT characterization
  - Distribution histogram
  - Color map for specific patterns
  - Customized CD uniformity map
- Mask CD MTT Intra CDU correction
- Conclusion

Introduction – Mask CD MTT

- Mask CD mean-to-target (MTT) is one of the most important metrics for lithography process control.

- As more aggressive OPC is applied to push the resolution limit, conventional CDSEM measurement based MTT is not sufficient.

- We propose a flow to extract mask SEM image contours for the characterization of mask CD MTT for complicated 2D patterns.

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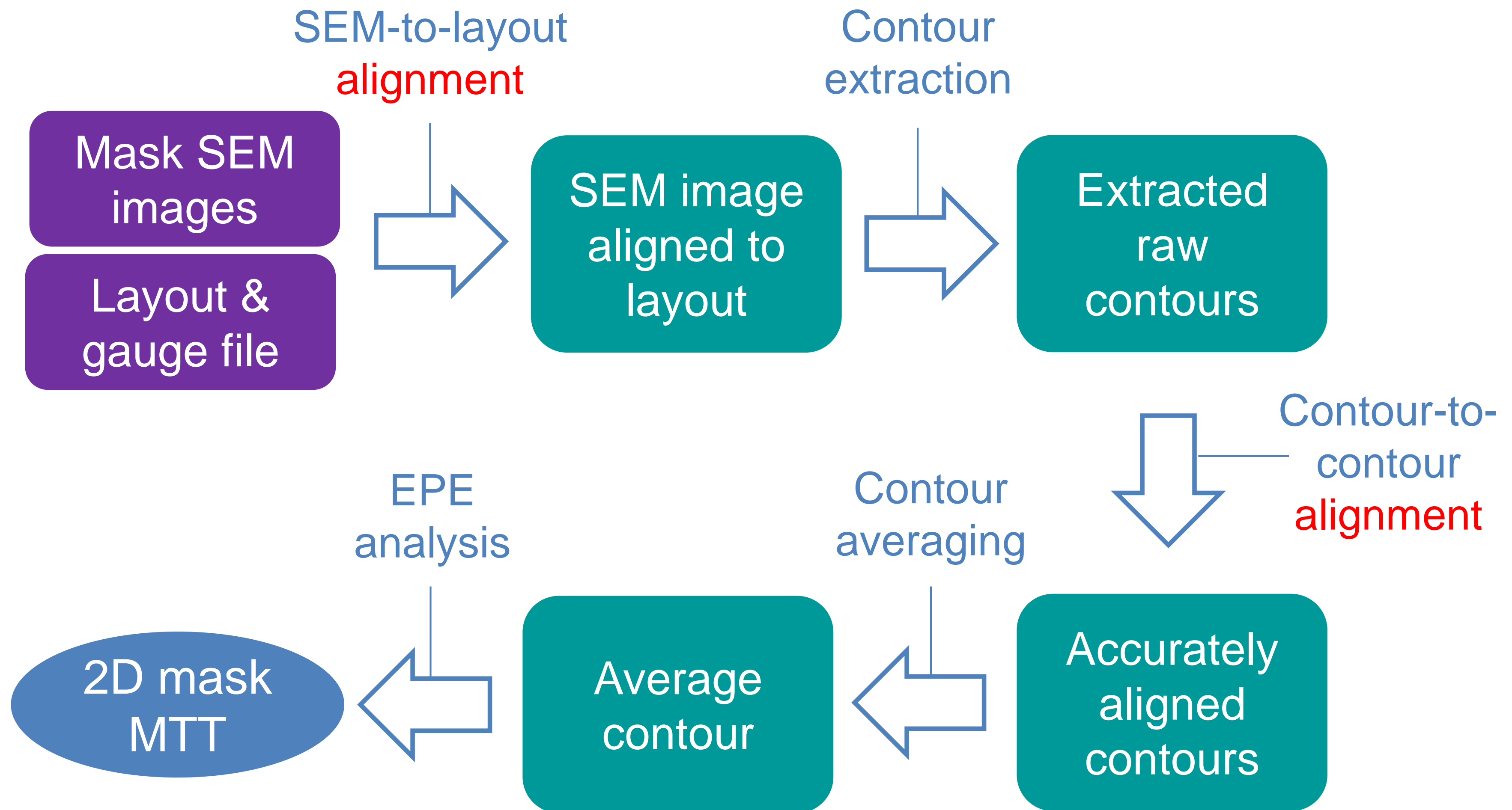
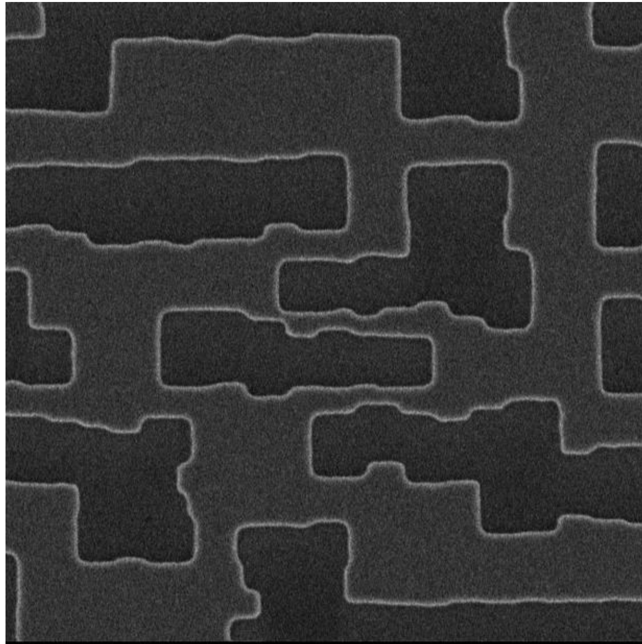
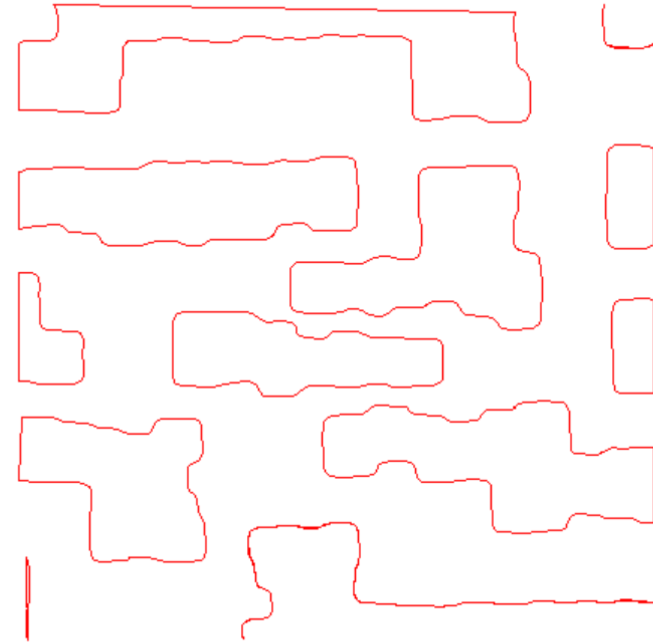
Contour Based Mask MTT Flow



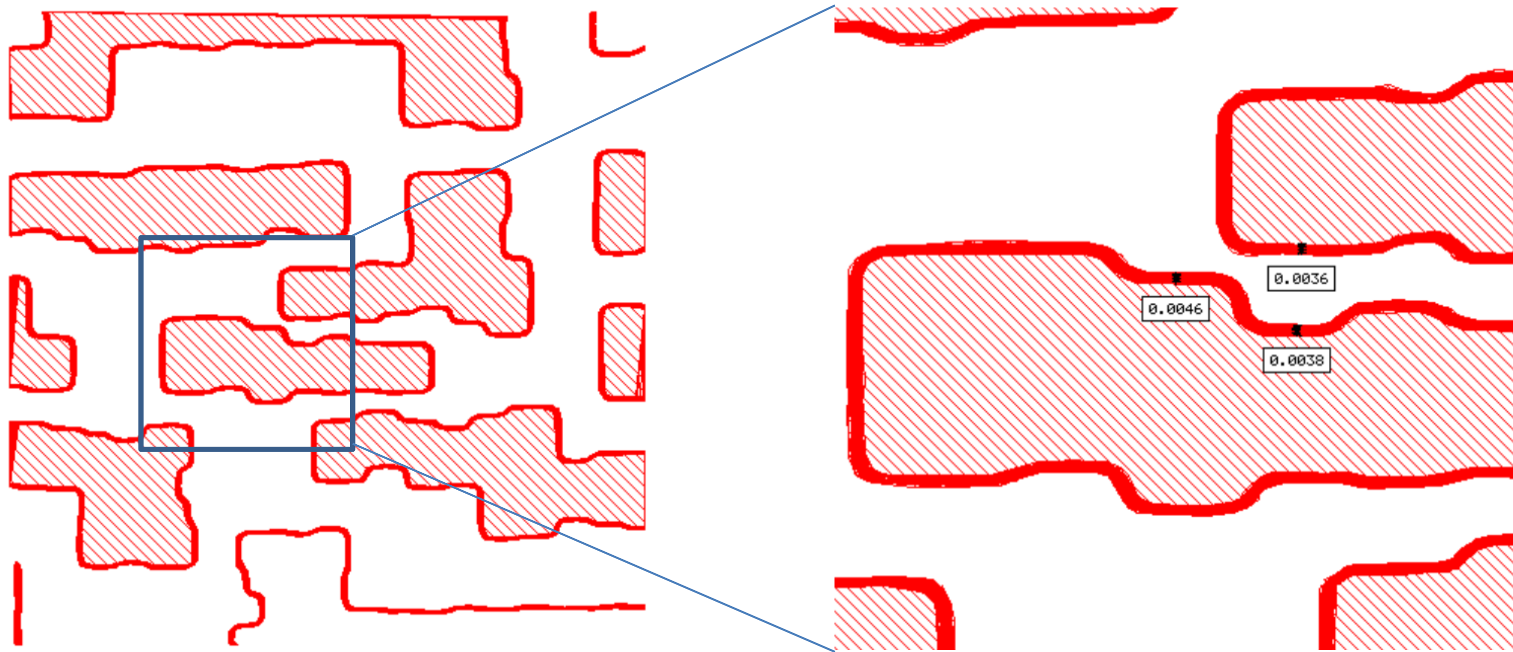
Mask SEM Image Contour Extraction





- In our contour extraction algorithm, the edges are defined as the local maximum of image intensity gadient.
- Fully-closed contours with good edge fidelity were obtained.

Contour-to-Contour Alignment



- **Totally 112 SEM image contours were extracted for one hotspot pattern, which were aligned to each other by using the contour-to-contour alignment algorithm.**

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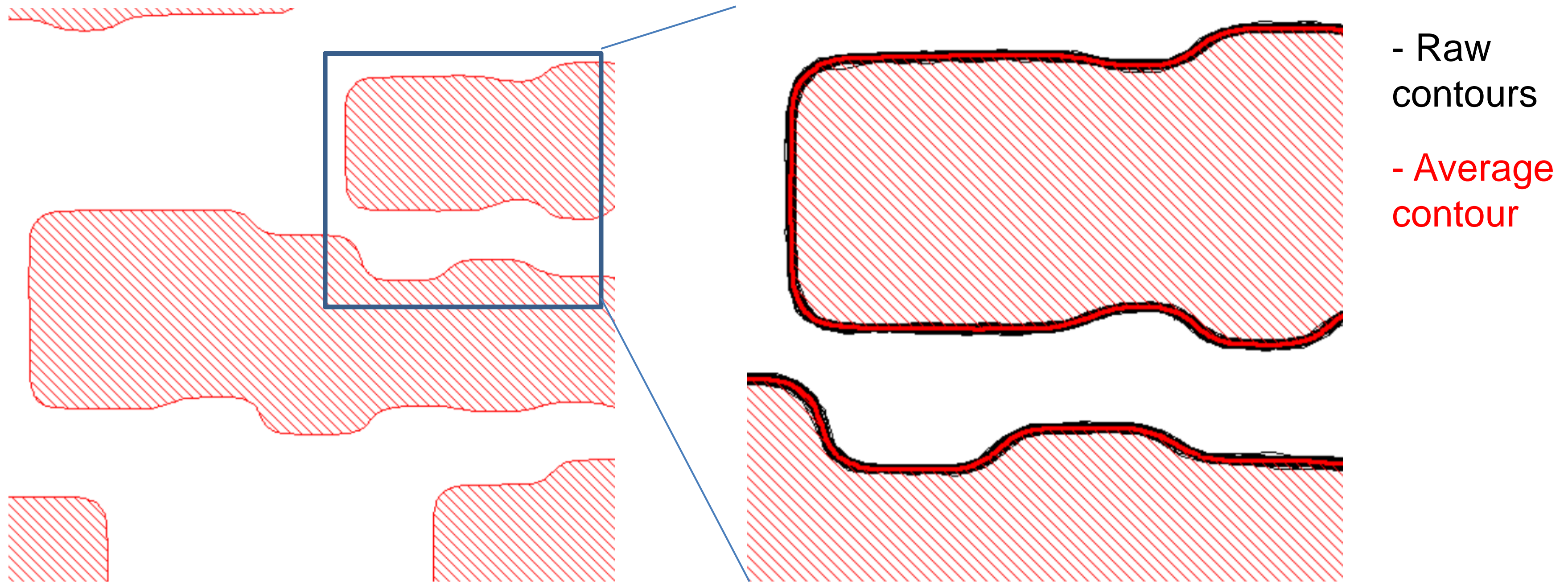
Contour Averaging



- **A sampling grid is placed, and the average position of the individual contour vertices is found for each grid to form the average contour.**
- **The average contour appears to be smooth and is not affected by the noise from individual contours.**

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Contour-to-CD Matching

	post-OPC GDS	CDSEM measured CD	Contour CD
Mask A	48.6 nm	48.5 nm	51.5 nm
Mask C	48.6 nm	48.5 nm	51.5 nm

- **The 1D anchor pattern (P90) was selected to identify the metrology offset between CDSEM measurement and contour CD.**
- **The metrology offset is ~3 nm. Hence, the average contour was biased down by 1.5 nm per edge for the subsequent MTT characterization.**

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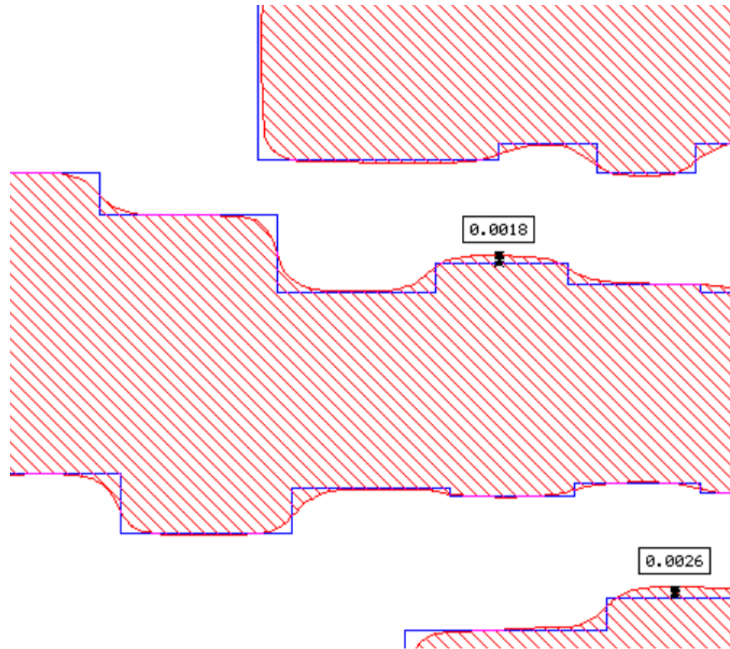
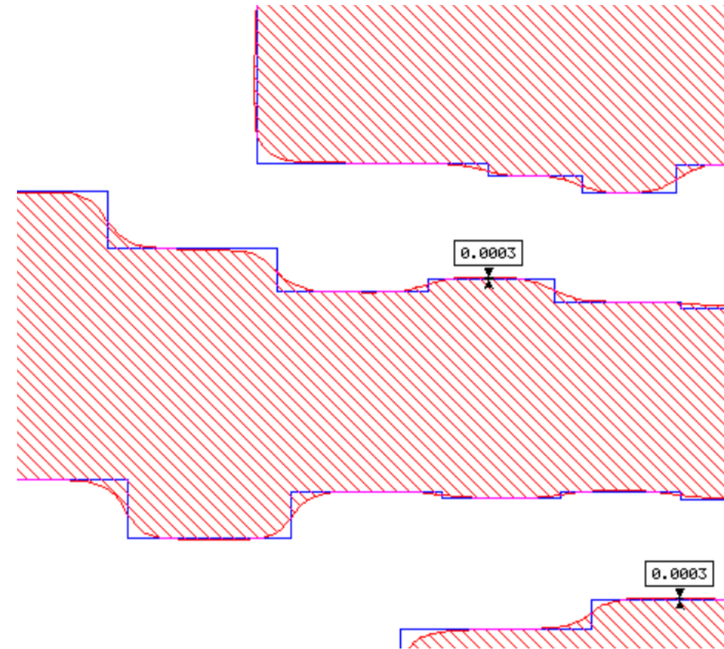
Mask CD MTT by EPE Check

Mask A

Mask C

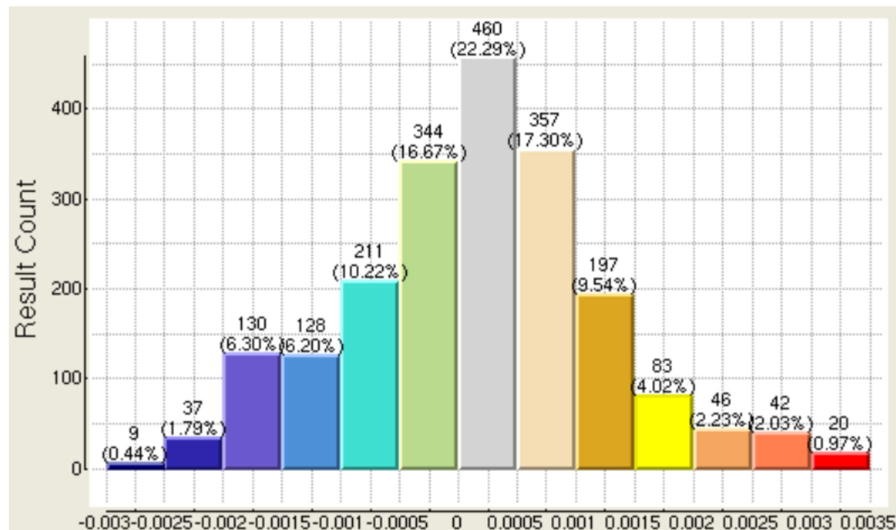




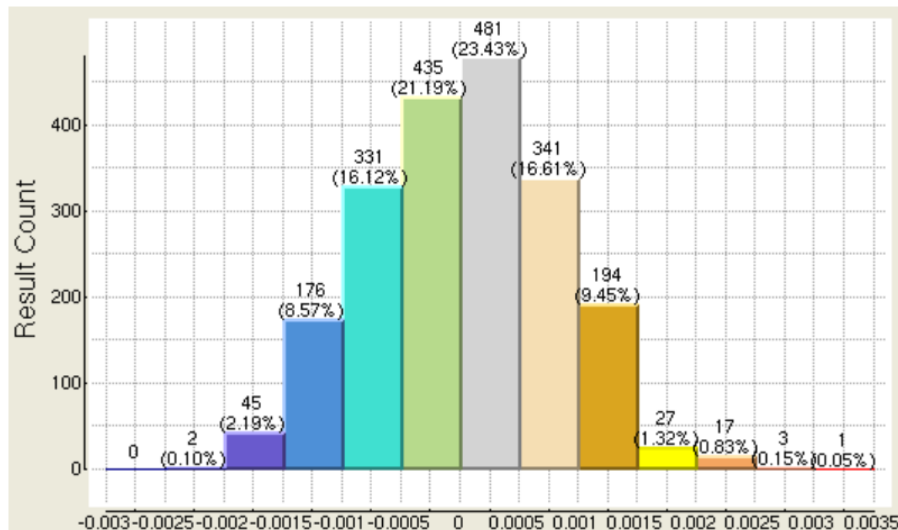
- **Mask A gives larger MTT than Mask C for two horizontal edges for this hotspot pattern.**
- **OPC verify engine is used for fast and systematic EPE analysis for all hotspot patterns.**

Mask CD MTT Distribution

Mask A



Mask C



- **The mask CD MTT distribution histograms were generated for the sampling sites from all hotspot patterns.**
- **Mask C gives a narrower MTT distribution than Mask A, indicating overall better mask CD control.**

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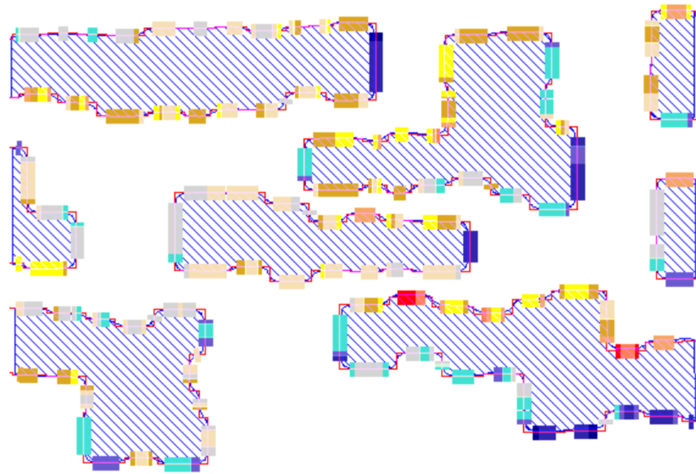
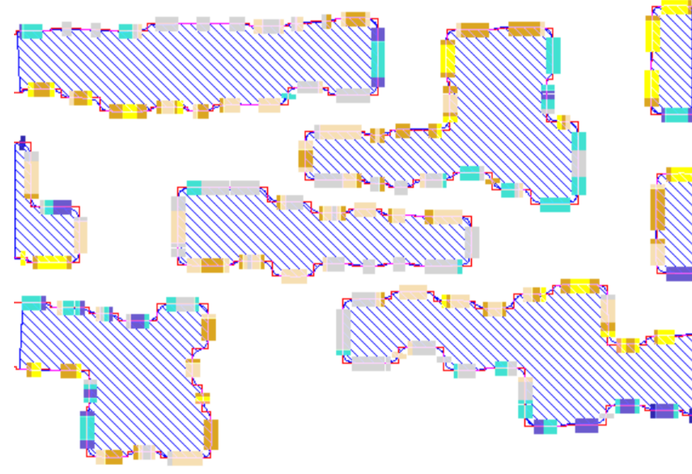
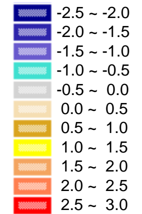
Mask CD MTT Color Map

Mask A



Mask C





- **The mask CD MTT color maps were generated for one hotspot pattern.**
- **Mask C shows evidently better MTT than Mask A for this pattern, which is consistent with the trend of wafer defect counts given by the two masks.**

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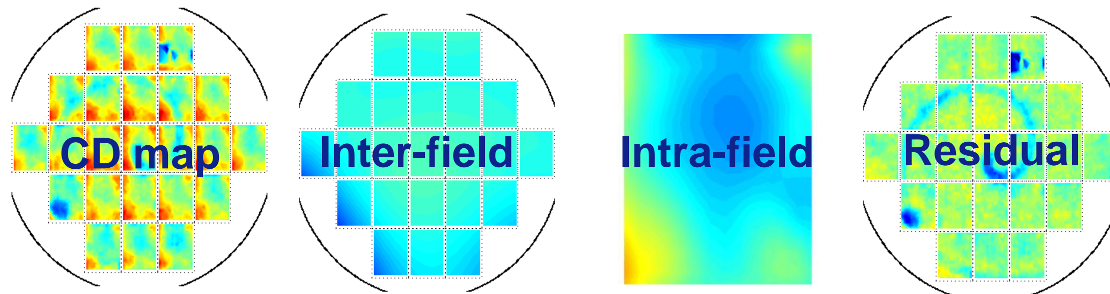
CDU budget

- **Wafer CDU including L2L, W2W, inter and intra CD uniformity (CDU). The intra field CDU budget for lithography process is typically explained by the following formula:**

$$\sigma 2_{total_intrafiedl} = \sigma 2_{mask_CDU} * \mathrm{MEEF} + \sigma 2_{Scanner} + \sigma 2_{Residue}$$



- **Contoured based CD MTT could void the correction error caused by measure instability, especially the hot spot patterns. However, hot spot patterns are the most likely yield killer, not the designed CD mark for traditional CDU control.**

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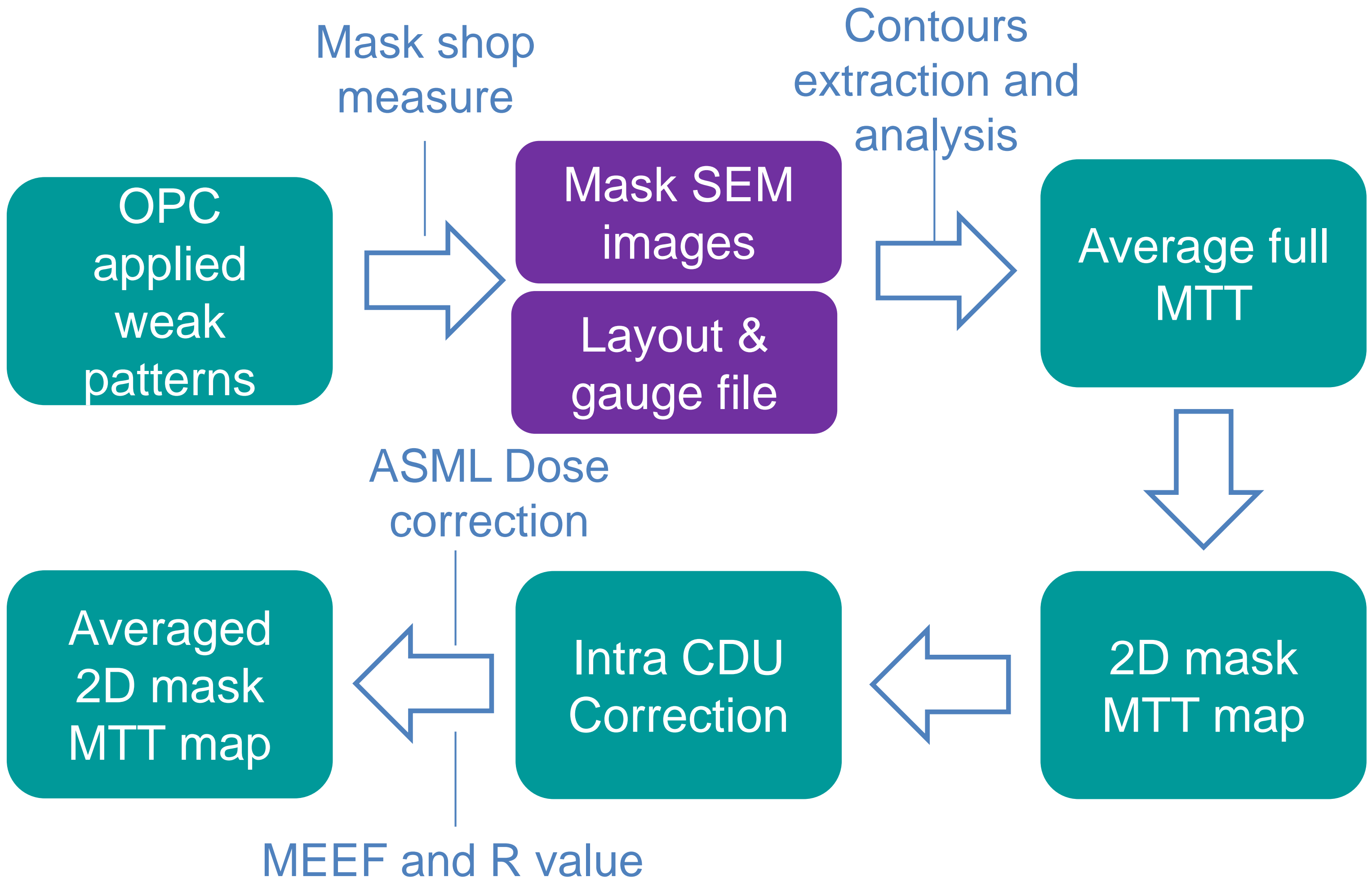
Contour Based Mask MTT Intra CDU correction Flow



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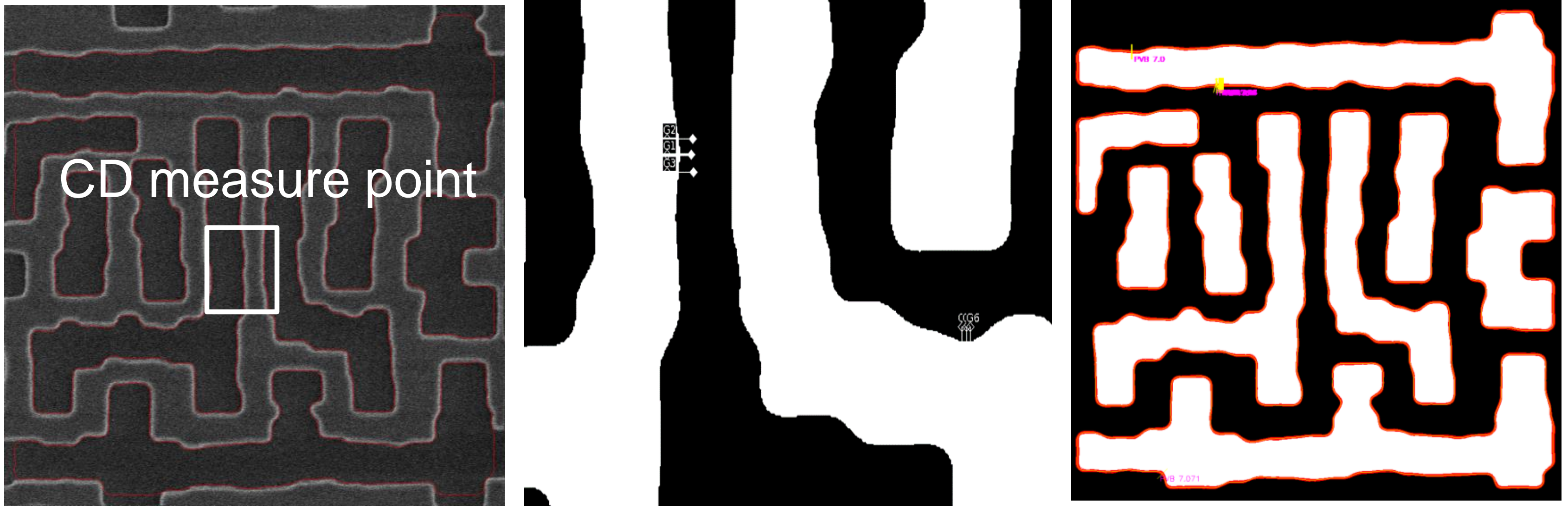
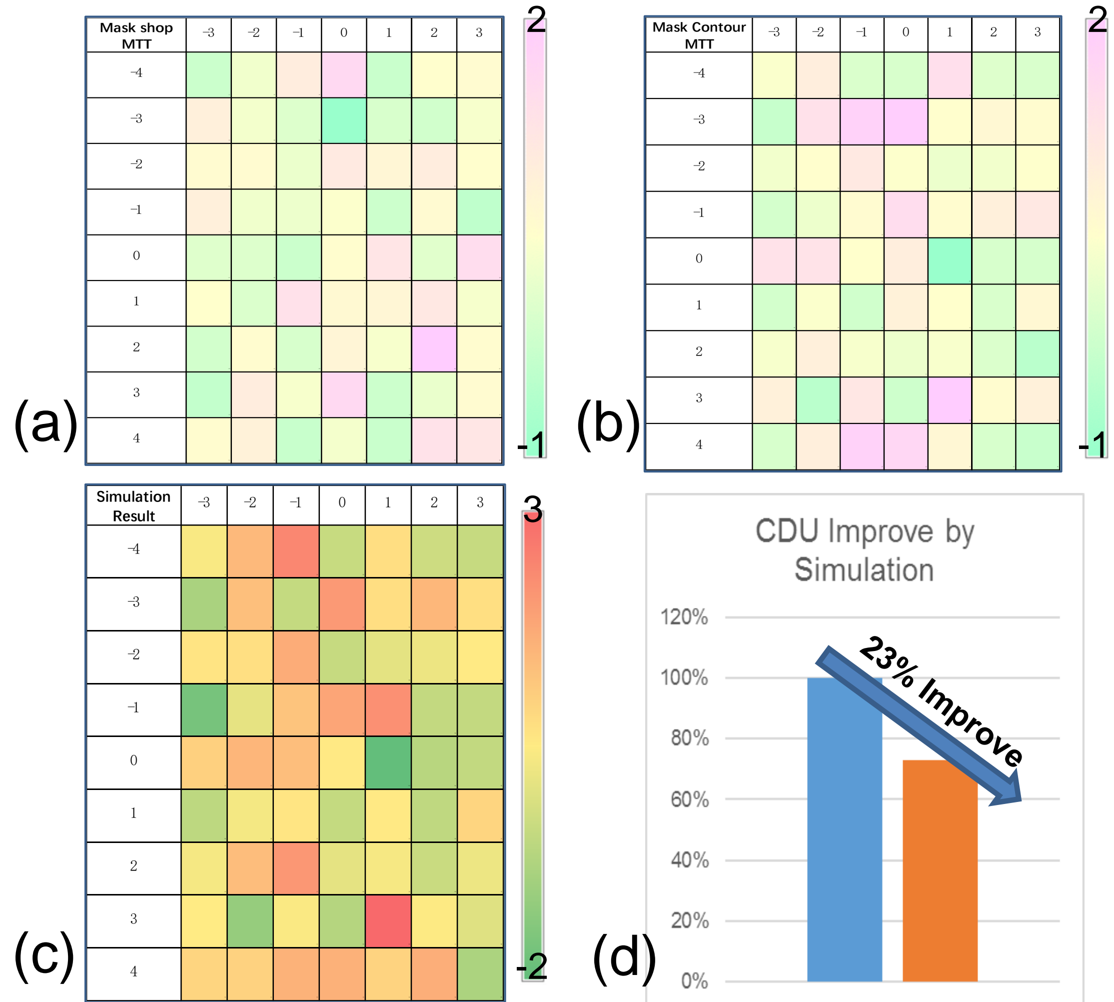


- The polygon at measured point is not straight vertical distribution, but has distortion in small distance. Hence, the contour based averaged MTT is much better choice for this complex pattern

Contour Based Mask MTT Intra CDU correction Result

- **Based on the simulation, 27% improvement was accomplished. More on wafer data and more accurate correction parameters will be finished in the future.**



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Conclusion

- The flow of mask CD MTT characterization by using extracted mask SEM image contours is demonstrated.
- Fast and systematic MTT analysis for all hotspot patterns was achieved by using OPC verify engine.
- The MTT results indicate Mask C has evidently better mask CD control than Mask A for the bridging hotspot patterns, which is consistent with the trend of wafer defect counts.
- Compare with the traditional method, more reliable result was arrived by our method. More works including wafer data collection are ongoing.