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Automated CD-SEM Recipe Generation Utilizing Design Pattern Layout

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Outline

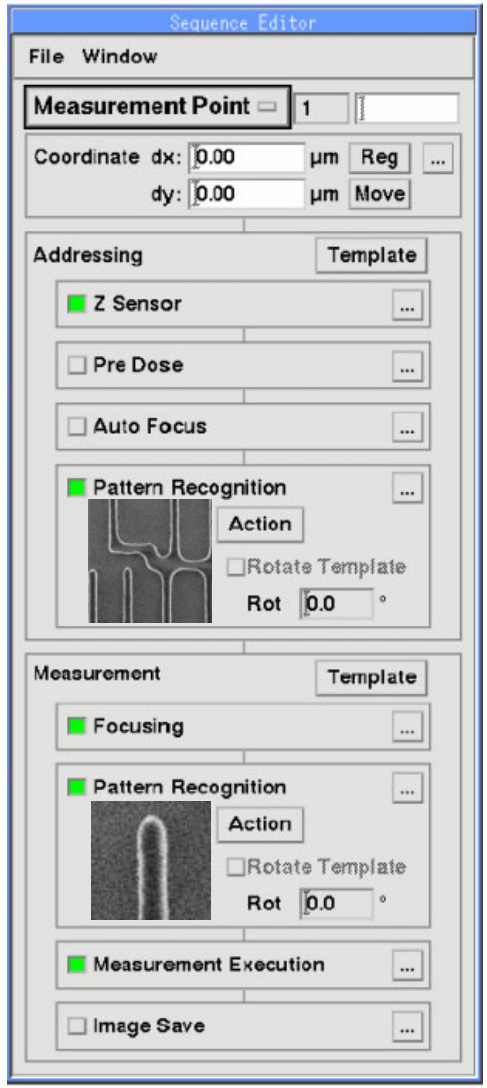
- Background.
- Conventional CD-SEM recipe creation.
- DesignGauge Introduction.
- DesignGauge Recipe Generation Flow.
- Template creation from design data:
  - Advantages.
  - Difficulties.
- Overcoming the difficulties:
  - Reduction of shape difference.
  - Advanced matching method.
- Examples.
- Conclusions.

Background

- Optical proximity correction (OPC) and Etch Bias evaluation play a vital role in the semiconductor process.
- The number of CD metrology measurement points for these applications has increased to several hundred per layer.
- Capability of automatic recipe generation becomes one of the key functions of CD-SEM:
  - Template creation for pattern matching in conventional recipe requires a CD-SEM tool, a wafer, and an operator.
  - Manually acquired CD data is unreliable due to uncontrolled image acquisition conditions (shrinkage, contamination, charging).
- Using templates from design data is key to realizing full automatic recipe generation.

Conventional CD-SEM Recipe Creation

- Conventional CD-SEM recipe creation requires manual (or semi-manual using Recipe Builder) registration of measurement points including coordinates, addressing image, measurement image, measurement parameters and focusing information.
- Recipe creation for OPC or Etch Bias evaluation is a time (and resource) consuming process.
- To expedite CD-SEM recipe creation, it is essential to allow end users to create CD-SEM recipe in fully automated mode using design layout information.

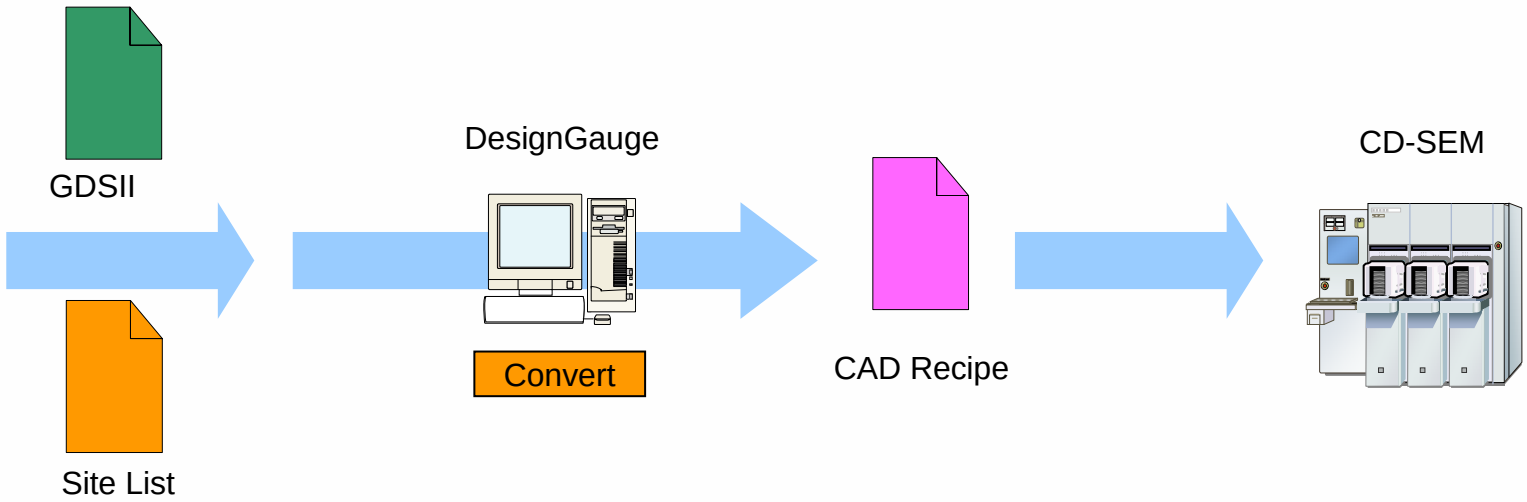


DesignGauge Introduction

- Implementation of Hitachi's DesignGauge system enables automated recipe generation using design layout information and provides solutions to complex metrology requests:
  - Recipes are generated based on the design information.
  - DesignGauge automatically generates a matching template from GDSII layout data.
  - Pattern matching between the template and the SEM image is done in real time.
  - The design pattern is used as a basis for the template instead of the actual SEM image.
- Significant reduction in time required to generate automated recipe:
  - Recipe creation can be achieved in a matter of seconds once the target site list is provided.
  - DesignGauge reduces the time to develop a technology node, from RET (Reticle Enhancement Technology), design rule selection, OPC model calibration and verification, to high volume manufacturing.

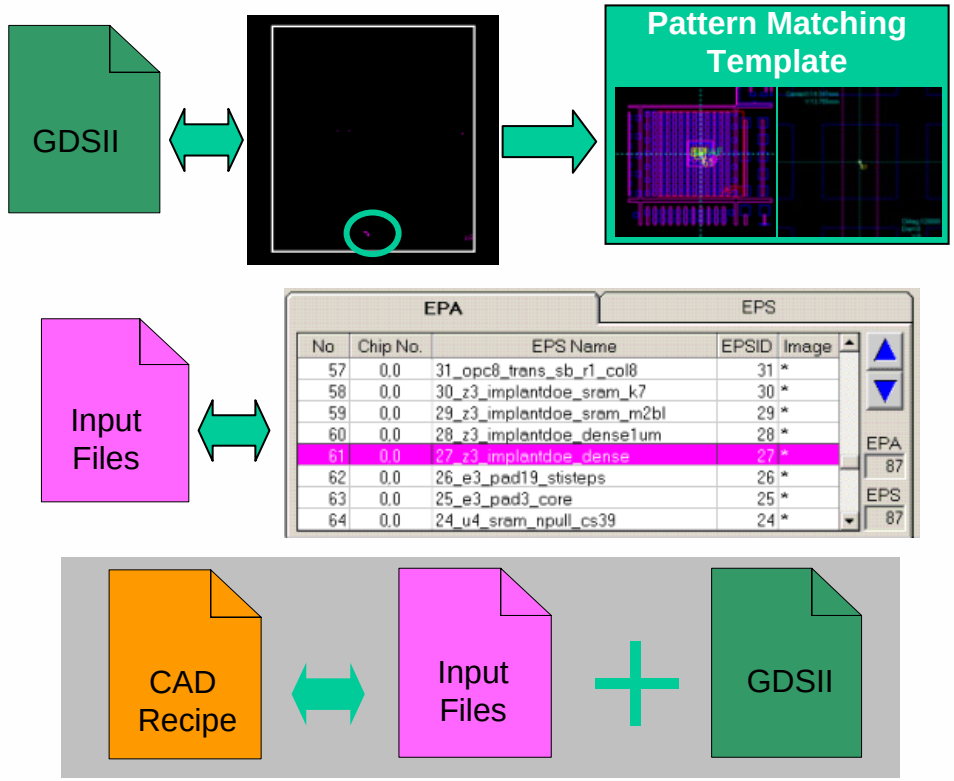
DesignGauge Recipe Generation Flow

- The sequence of steps for creating a recipe is as follows:
  - Define references, wafer map, and across wafer sampling.
  - Generate a target site list in the coordinate system of the CAD (typically GDS polygon representation).
  - Send the GDS and site list to the DesignGauge system.
  - Verify and run the recipe.



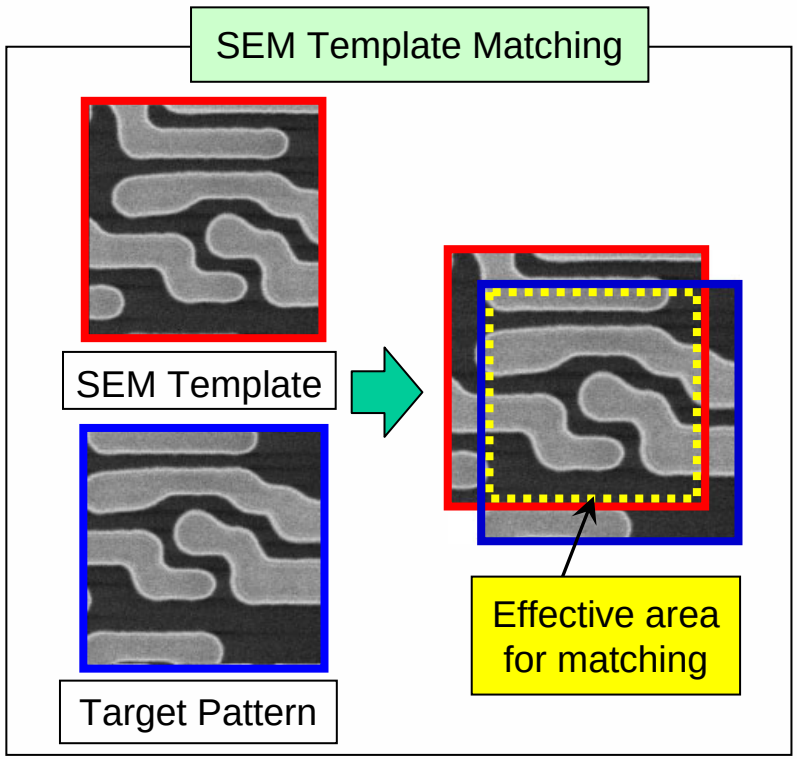
Files Required for Recipe Generation

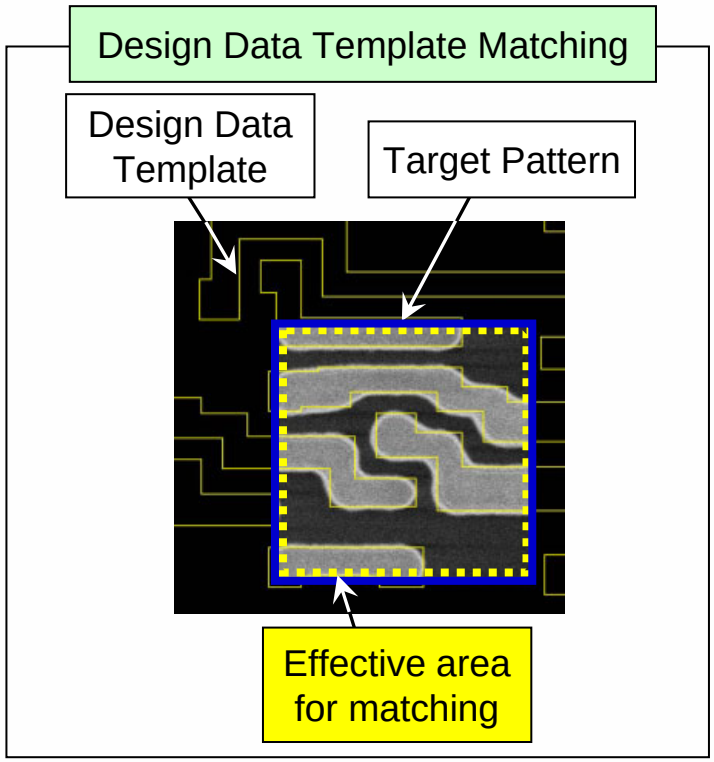
- DesignGauge requires two input files to generate the CD-SEM recipe:
  - Site list which includes:
    - Site name.
    - Site location.
    - Pattern Recognition FOVs.
  - GDSII file.
- The interface converts the input file into a recipe.



Template Creation from Design Data

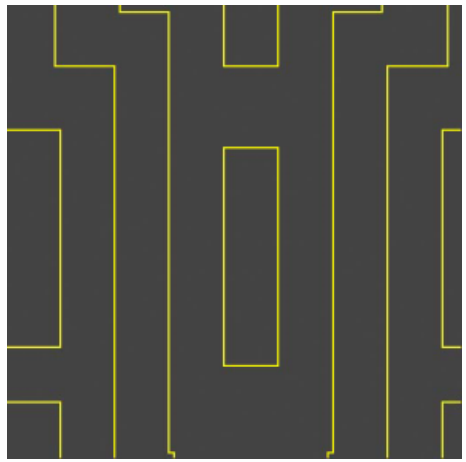
- Advantages:
  - Wafer-less and Tool-less recipe creation.
  - Compatibility of design data with Electronic Design Automation (EDA) tool.
  - Template larger than SEM image FOV.



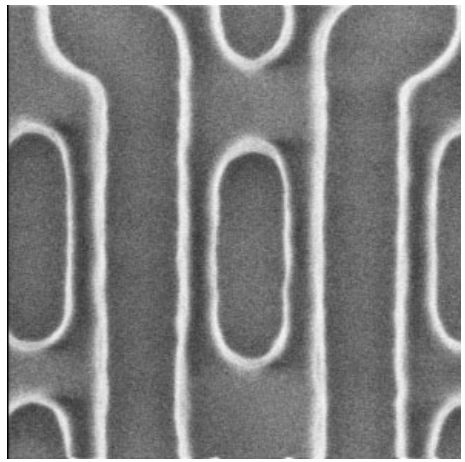


Template from Design Data - Difficulties

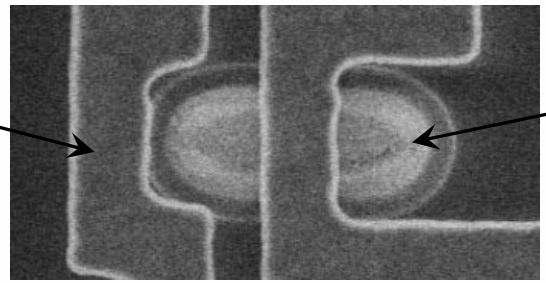
- Difference of shape:
  - Design data: Linear shape.
  - Real shape: Non-linear shape.
- Difference of size:
  - Design data < Real dimensions.
  - Design data > Real dimensions.
- Difference of edge width:
  - Design data: One-dimensional Line.
  - Real shape: White band.
- Difference of Design:
  - Missing edge in SEM image.
  - Lower layer, Double edge.



Design Data



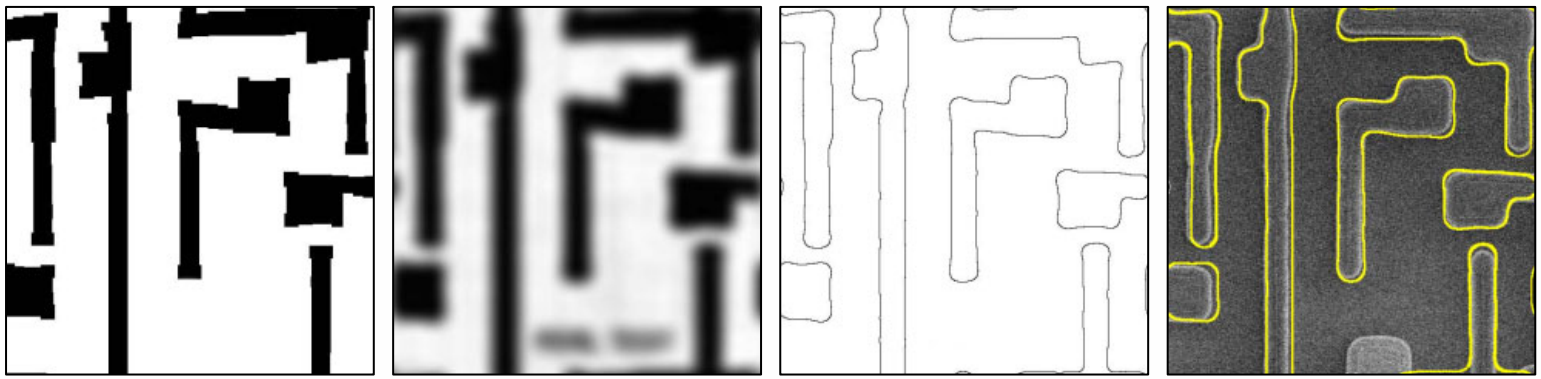
SEM Image



Reduction of Shape Difference

Process Simulation (e.g. Lithography process simulation) - conventional approach.

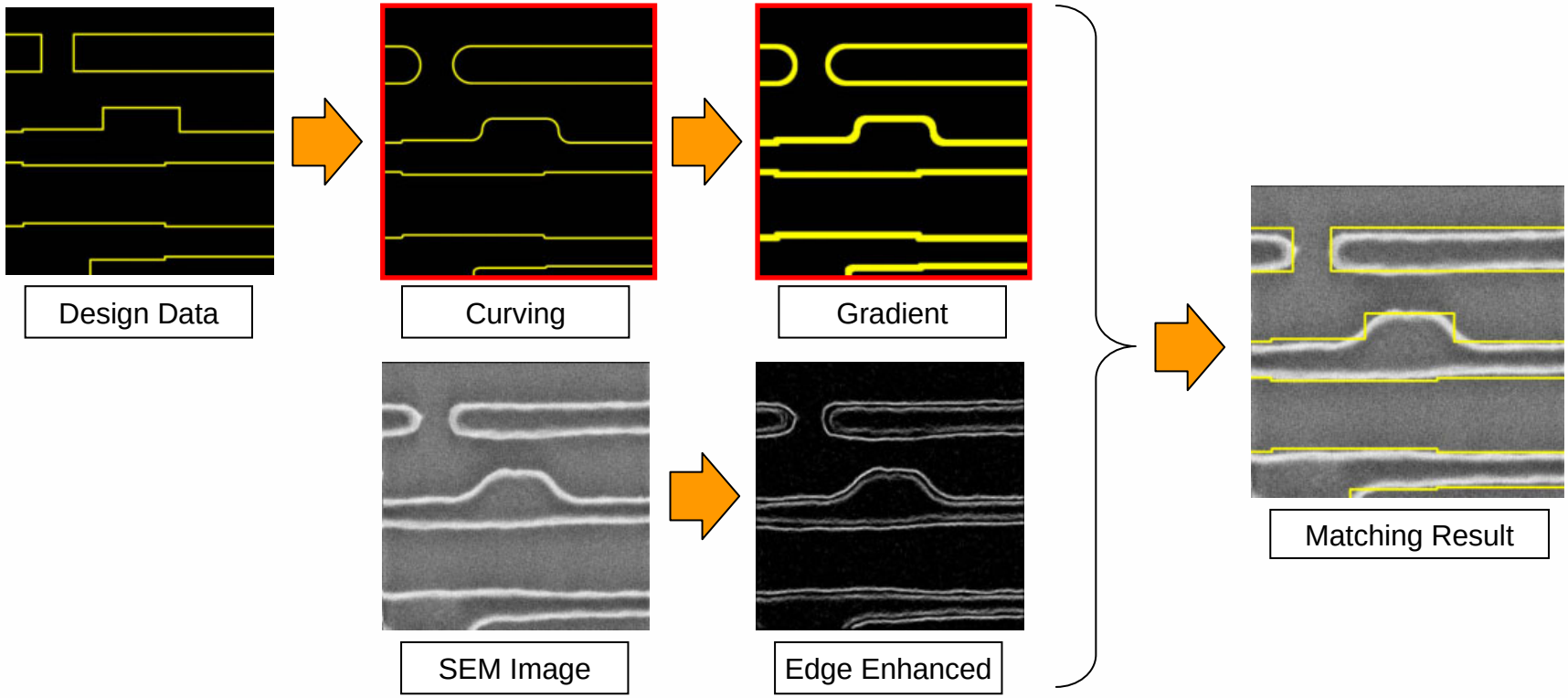
- Advantages:
  - Able to estimate real shape.
  - Able to simulate several conditions same as real process.
- Issues:
  - Requires information of process and materials.
  - Requires large amount of measurement data of test patterns.
  - Requires design data with OPC (large amount of data).
  - Long processing time.



Pattern Matching - Hitachi method

Advanced Normalized Correlation Matching Method - Approach 1:

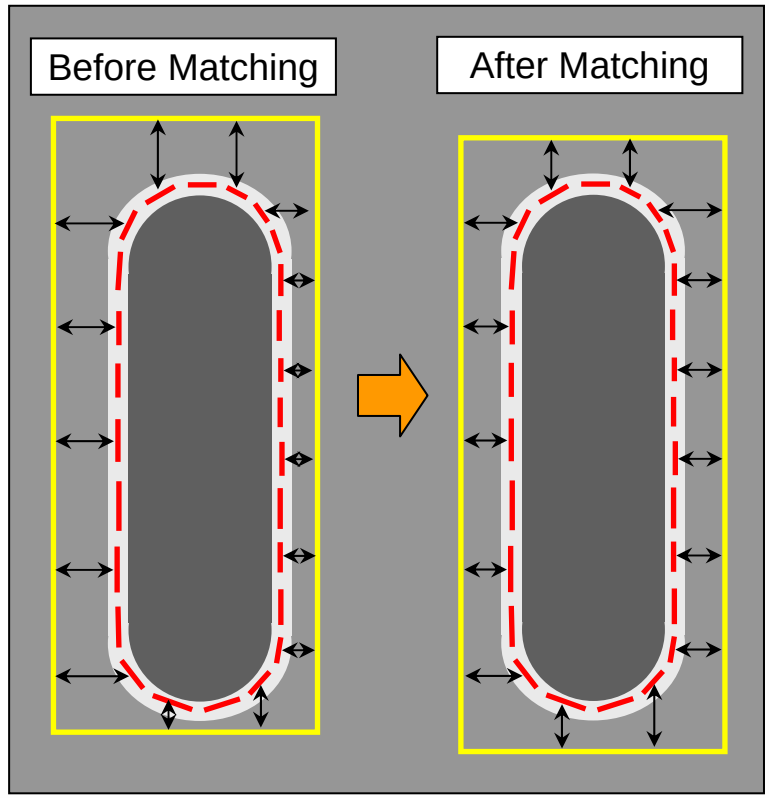
- Reduced difference of shape by curving and gradient technique.
- Edge of SEM extracted by filtering of edge enhancement.
- Matching using normalized correlation.



Pattern Matching - Hitachi method

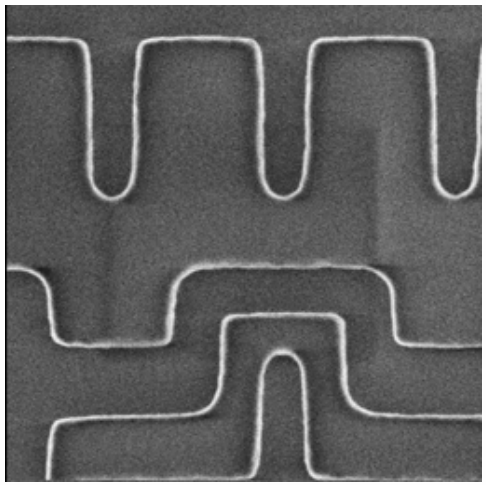
Advanced Vector Matching Method - Approach 2:

- Extract vectors from edge of SEM image:
  - Vector matching between design data and extracted vectors using Hough transformation algorithm.
  - Fine alignment by combined bitmap information and vector information.
- Advantages:
  - No need to overlap design and target of vector.
  - Amount of vector data is small.
  - Computation time for matching is much smaller than for normalized correlation method.

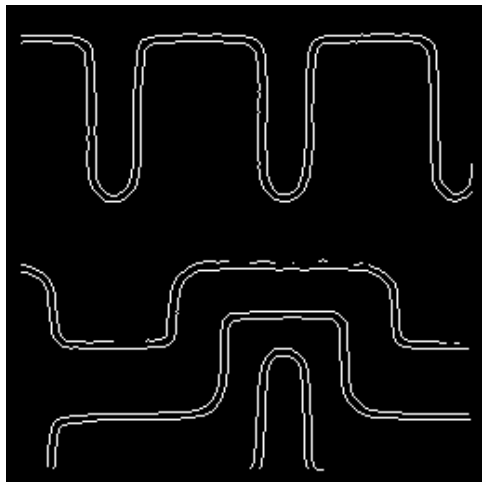


Vector Extraction from SEM Image

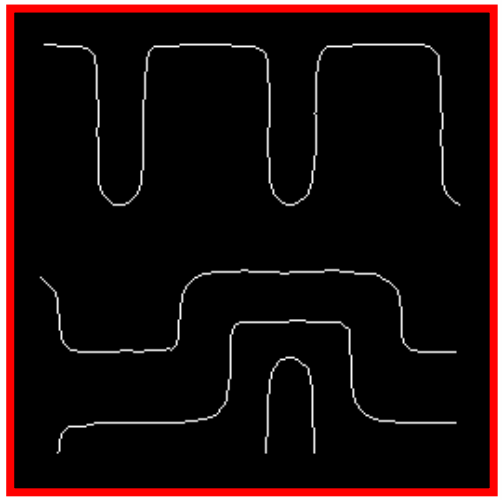
- High performance noise filter:
  - To reduce miss-detection of vector from un-patterned area.
- Double edge extraction method:
  - 1st differential method to detect edge.
  - Edges extracted from both sides of white band of SEM image.
- Single edge extraction method:
  - “Special” 2nd differential method to detect edge.
  - Single edge extracted from center of white band of SEM image.



SEM Image



Double edge extraction

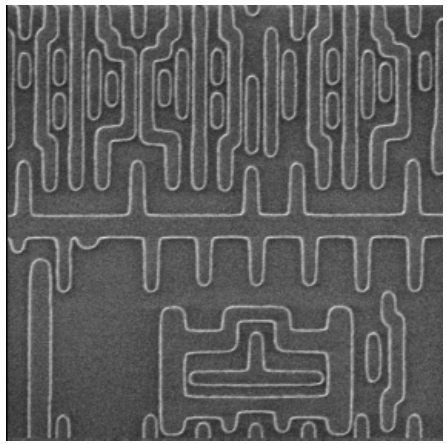
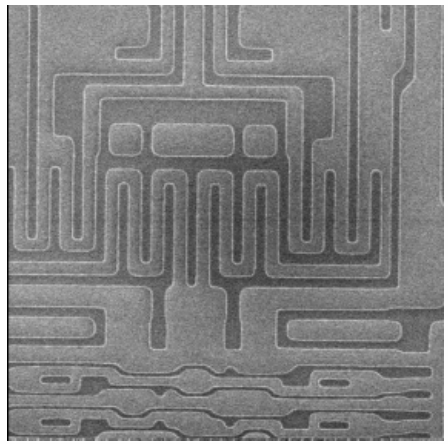
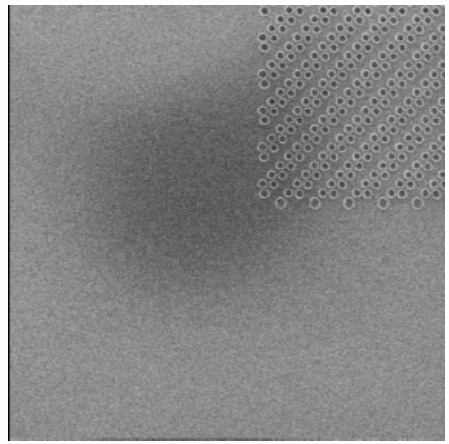


Single edge extraction

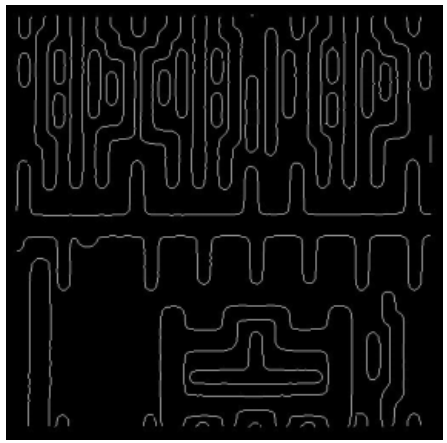
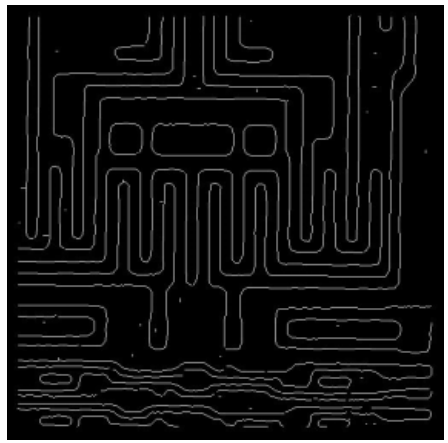
Vector Extraction - Example

- Vector Extraction:

SEM Image

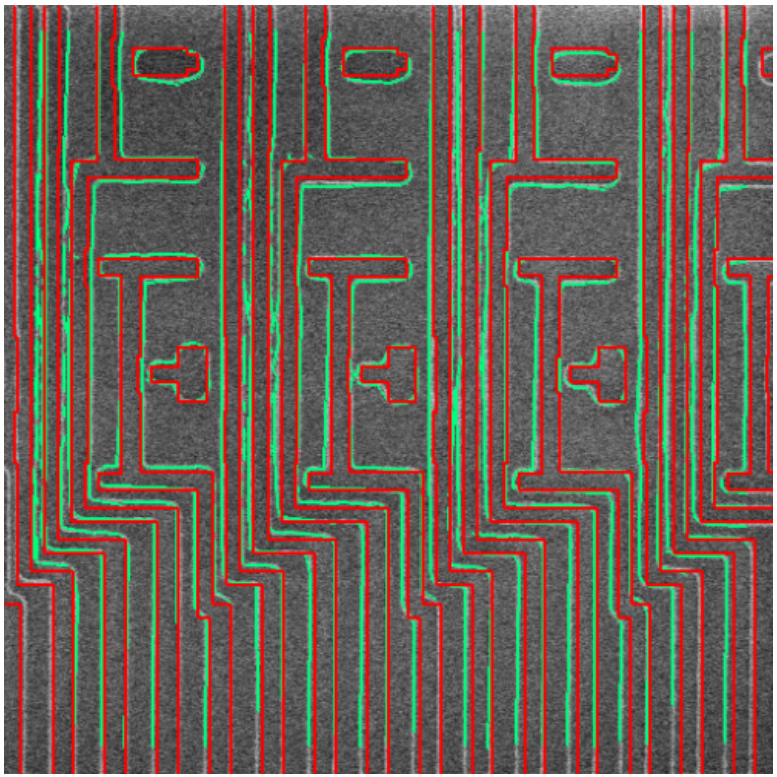




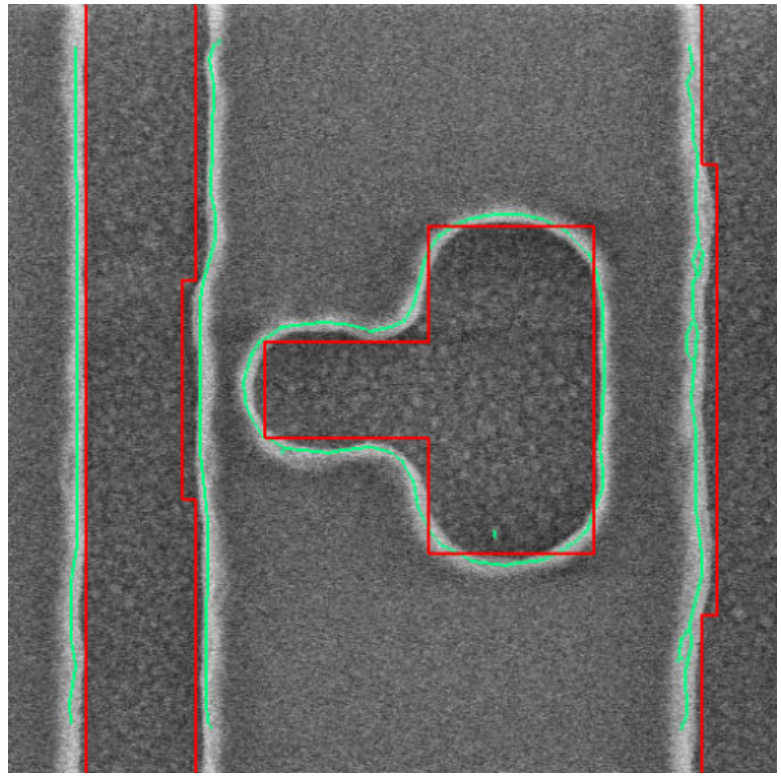
Extracted Edge (Single)

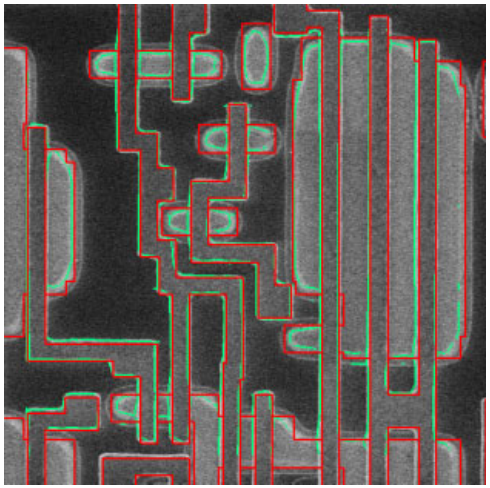
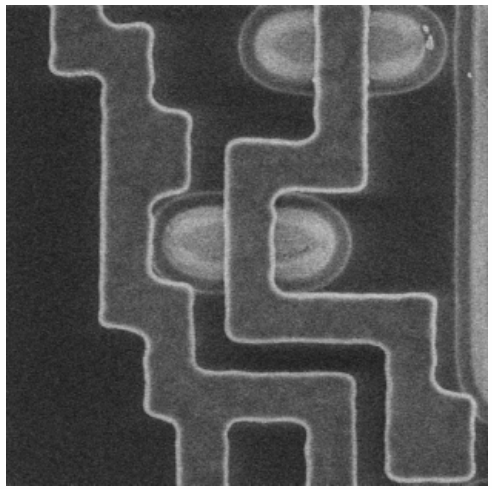
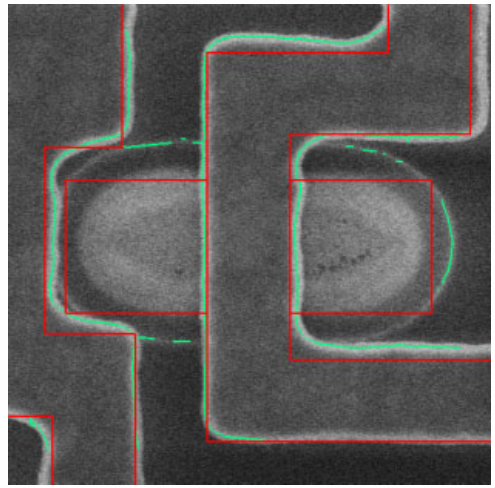
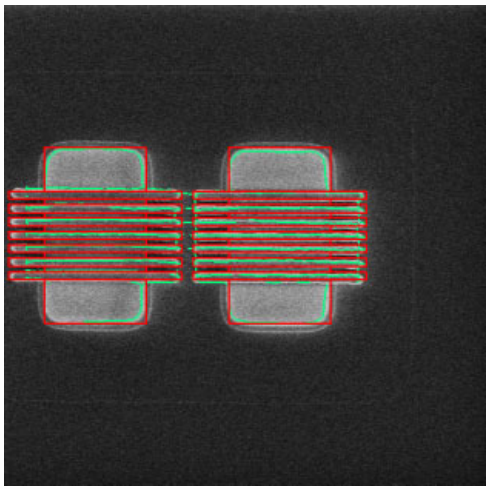
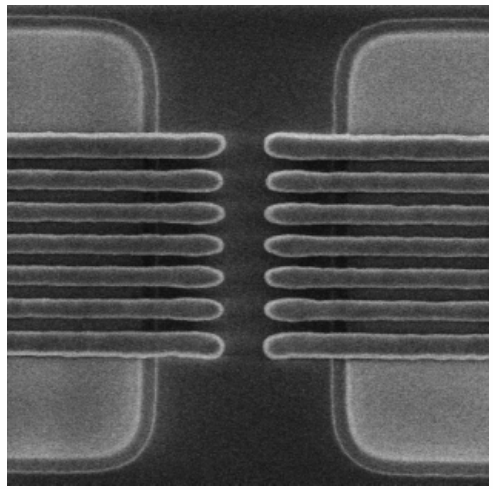
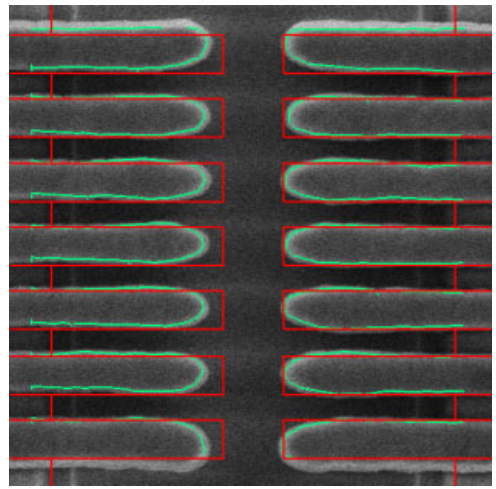

Metal DI Matching Example

- Successful matching of resist on dielectric for metal pattern CD analysis.





Multi-Layer Pattern Matching - Poly FI

Conclusion

- New methodology of automated CD-SEM recipe generation and management has been proposed.
- New matching methods using template from design data:
  - Advanced Vector Matching Method.
  - Advanced Normalized Correlation Matching Method.
- New method of design data shape curving to reduce shape difference between design data and real pattern.
- New edge extraction method:
  - High performance filter to reduce noise for edge extraction.
  - Single edge extraction representing real pattern edge faithfully.
- Multi-layer matching capability.
- High performance of matching results confirmed by experiments.

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