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SEM Image Processing for Defect Detection

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Abstract

*This project is aimed to perform Digital Image Processing on **SEM images** to align, measure and detect results for manufacture flow based on Python and Open CV libraries, and applied some adaptive clustering algorithm to achieve auto-selecting, the result shows that the bad defect image would be selected by this system well .*

A adaptive calibration for image of scanning electron microscope (SEM) system is proposed. The concept of auto generate reference point by contour moment is considered to create the system. It is aimed to perform digital image processing on SEM images to do alignment, measure and detect results for manufacture flow. And it would be helpful to replace manual inspection for more than thousands of SEM images. Here proposed a new threshold decision algorithm for foreground extraction in gray image. Then using a best contour selection method to solve non-reference point problem of big offset, and apply polygon moment method to find out small offset to get total alignment values of x-axis and y-axis. After alignment process, it could successfully execute gauge measurement for inner and outer range by peak to peak search (PPS) method of gauge on feature polygon and detect defect index of gauge on space polygon. Finally it constructs an automatic optical inspection system for nanometer process of mask synthesis.

Keyword: SEM, defect, optical inspection, mask synthesis.

1. Introduction

Scanning Electron Microscope (SEM) is a commonly used inexpensive metrology method to measure silicon result. SEM images are grayscale 2D arrays representing the reflecting density of electrons.

It would be helpful to replace manual inspection for more than thousands of images. Object offset is the major problem in this case which needs to be solved. The problem is there are so many SEM images produced from the semi-conductor factory every day, and it need human's judgement to pick up what is the defect. Because the producing SEM images is adding continuously, it needs a way to help people to reduce the involving of trivial routines for checking the SEM images are without defect or not.

2. Technical part:

The methodology for auto detection for SEM image would take 3 phase as phase 1 for Image Alignment, phase 2 for Width Measurement, and phase 3 for Defect Detection.

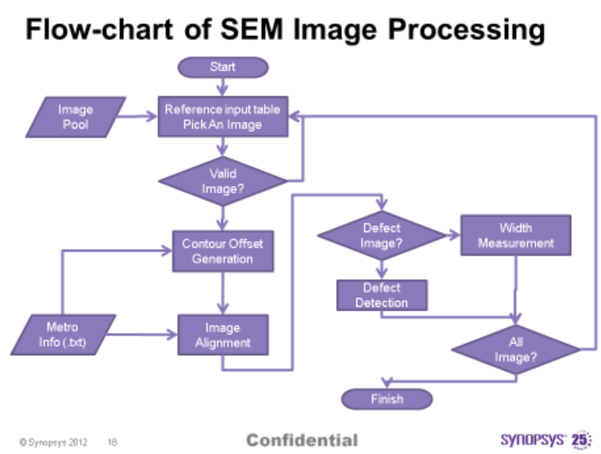


Figure 1: Flow-chart of SEM Image Processing

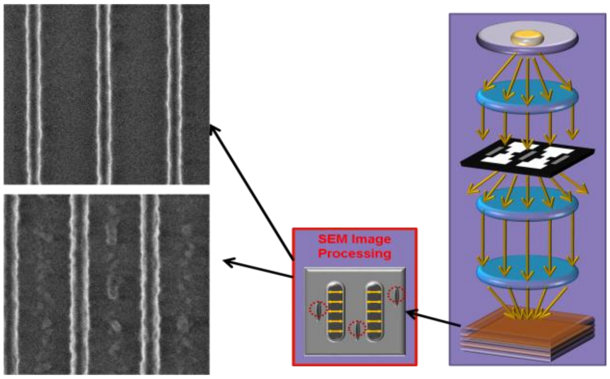
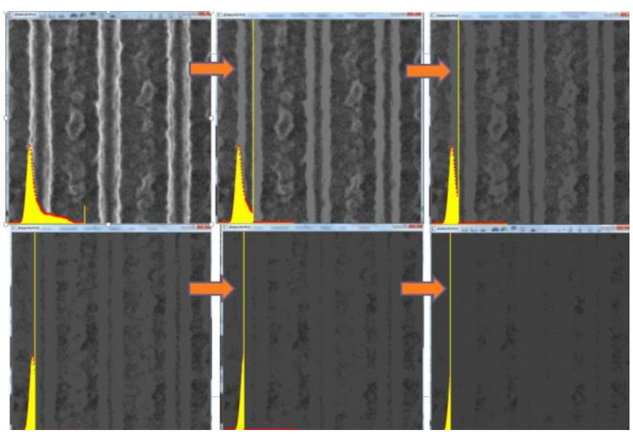


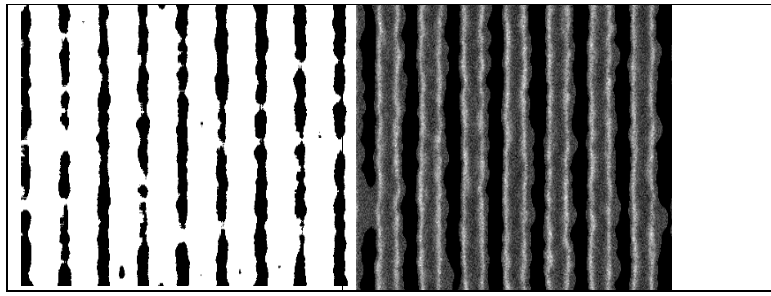
Figure 2: Flow-chart of SEM Image Processing, SEM Defect Test with Offsets.

2.1. Phase 1: Image Alignment

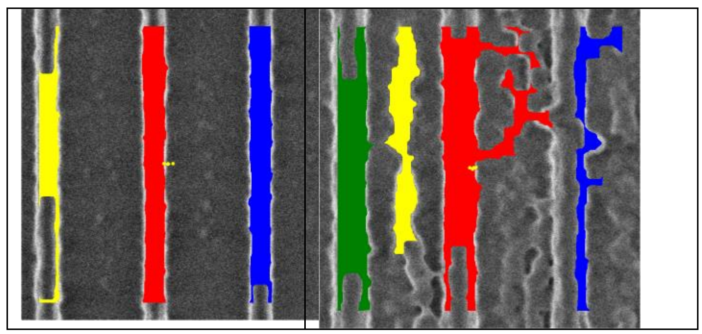
Including image enhancement, foreground, and background extraction Steps. Contouring algorithm. To correct the target offset for fitting the layout polygon position.

The enhancement is applied by 5x5 pixels of median filter and then take the initial foreground extraction by Otsu algorithm with Push histogram method we suggested, in the end it would offer an optimized threshold value for this original image. And the optimized threshold value make the background of the original image become purely dark with pixels value, 0, and we get the ideal foreground from the image.



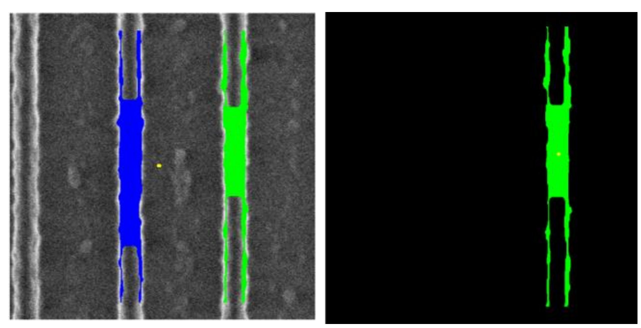


After the initial foreground extraction, it applied dilate and erode between 5x5 median filter again and again to get a smooth foreground contour.Then we take the foreground contouring byCHAIN_APPROX_TC89_KCOS algorithm. After all, it dynamically generates some contours of every polygon object from the whole SEM image.

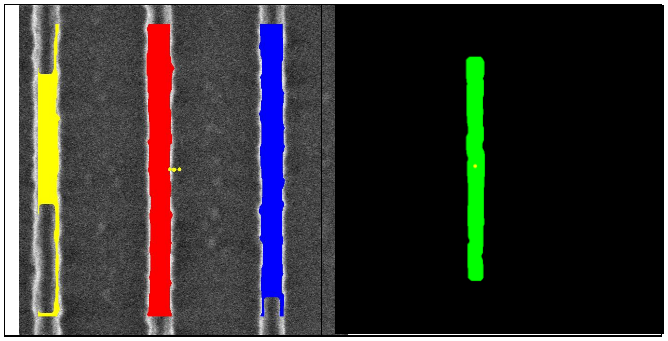


Although the foreground extraction generating the contours, the result may be not ideal because of the awful quality of original image. Next step we should get rid of the bad polygon contours, and select the best one, which means selecting one from N objects. To choose one from these contours as the real reference center.

How to select the best one polygon Contour? Here we suppose the Error Square Sum estimation (ESS) method, which is to find the best cluster center, get the minimum distance sum by every points for new basis for the offset selecting method idea



A good selection from 2 choose 1



2.2. Phase 2: Width Measurement

This phase would take the gauge lines in the best selecting foreground polygon. Here we apply a searching method called **Peak-Peak search, the steps is as above:**

Step1:

Search peak to peak (p-p search) process.

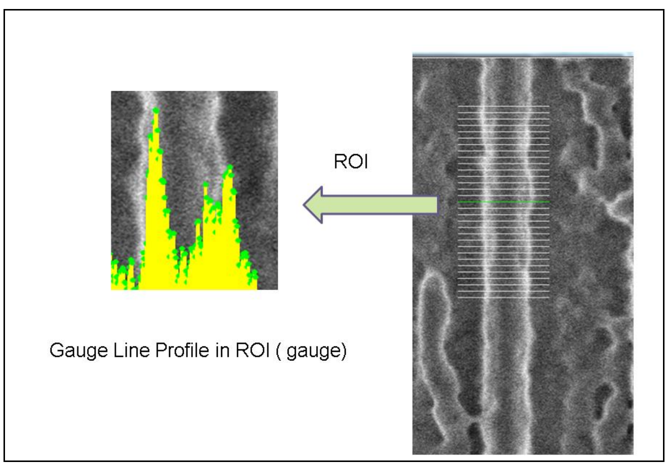
Reference the Inner and outer factor.

Parameter definition:

0.3 = INNER_CD_FACTOR

0.7= OUTER_CD_FACTOR

Reference Inner factor, 0.3, which stands for the strength of pixel value decrease from the peak of pixel value over 30 %.Reference Outer factor, 0.7, which means the strength of pixel value decrease from the peak of pixel value over 70 %.



Step2:

Inner search:

Between p-p, right search from left peak.

Between p-p, left search from right peak.

And to measure the distance between Left peak point and left inner point, and to measure the distance between right peak point and right inner point. Then it could find out the real inner distance between left inner point and right inner point for the polygon gauge line case.

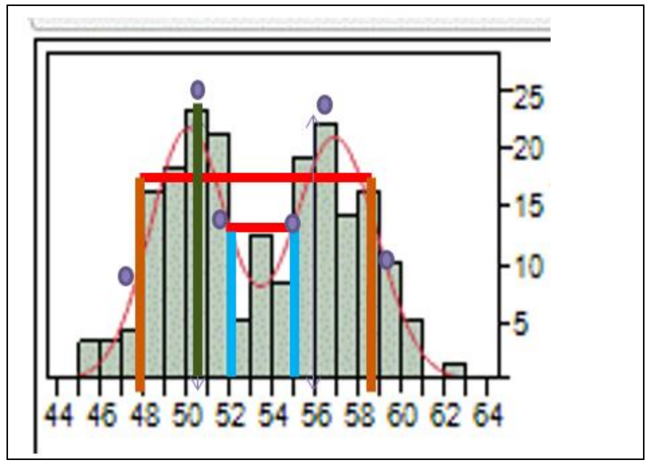
Step3:

Outer search:

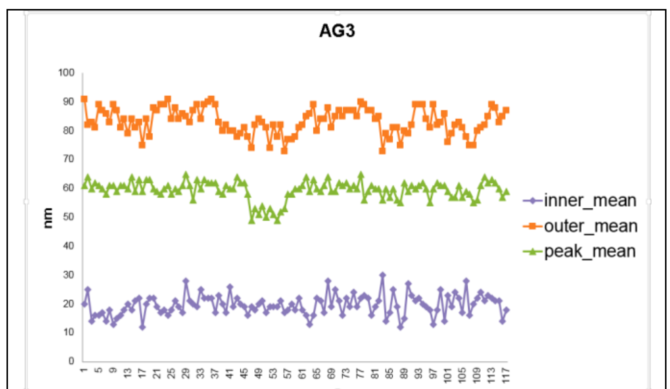
Left search from left peak.

Right search from right peak.

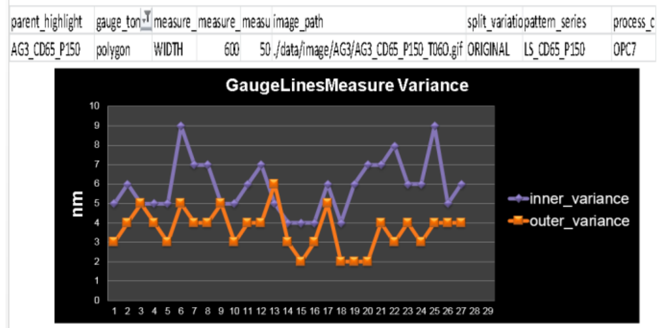
To measure the distance between Left peak point and left outer point, and to measure the distance between right peak point and right outer point. Then it could find out the real outer distance between left outer point and right outer point for the polygon gauge line case.



In p-p search, it'll conquered the unknown parameter for offsets of x-axis, too.



GaugeLinesMeasure(Polygon) , After Offset Fixing.

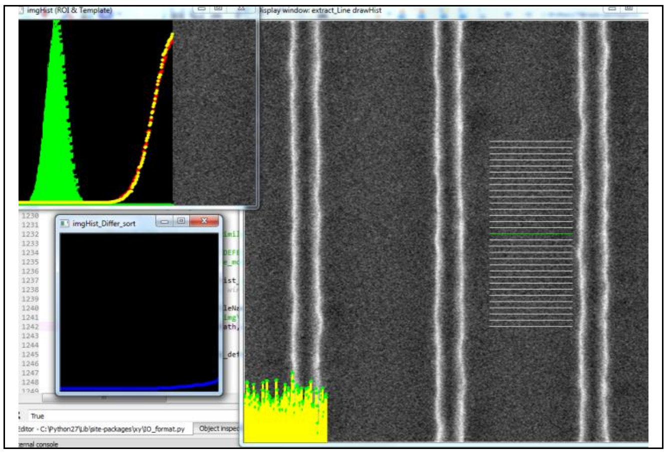


Inner variance is larger than outter variance, double

2.3. Phase 3 : Defect Detection

Steps1:

Extract Raw Image Pixel for ROI source from gauge of image, the space region, to be the clean template. Based on the clean sample, then we could make the comparison for defect levels.



Steps2:

Take ROI Histogram for Feature.

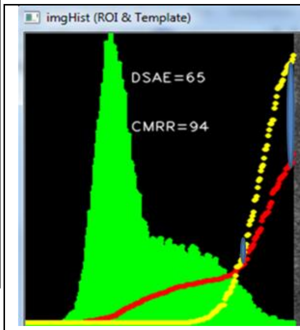
Similarity as the defect Index

1. DSAE (Differ Sum Area Error)
   - Absolute measurement
   - DSAE = Sum(Differ(Area))

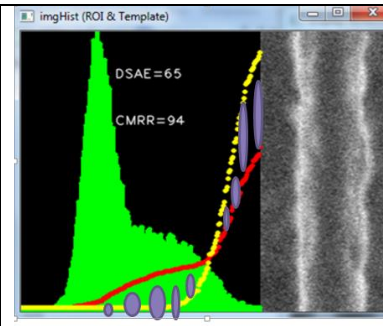
2. CMRR (Common-Mode Rejection Ratio).
   - Fuzzy measurement, the concept is like CMRR
   - Similarity(i) = Differ(Fa(i),Fb(i))
   - CMRR= (Smax-Smin) / (Smax+Smin)

Steps3:

Take ROI Histogram Rank for Differ (Feature) and then calculate the value of defect index by DSAE and CMRR.



DSAE:
Sum(Differ(Area))



CMRR:
(Smax-Smin)/(Smax+Smin)

3. Experiments

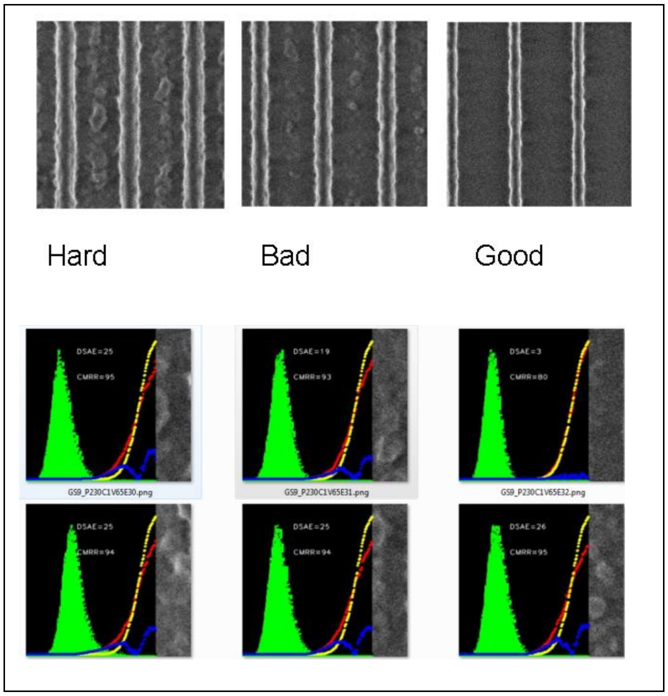
The experiment result for defect detection with CMRR Index:

CMRR<80: Clean.
100> CMRR >80: Defect.
For GS Defect detection with DSAE Index:
DSAE<7: Clean.
DSAE>7: Defect.

The Test source quality include Good (also assigned for template ROI), Bad (A litte defect), hard (obvious defect). And to apply the detection to these images to judge the result belong to defect or not. And give 26 Test image as the ground truth, the miss rate by the system is 5 %.

	DSAE>7	CMRR<80
DSAE>7	(Y,Y)=49	(Y,N)=0
CMRR<80	(N,Y)=8	(N,N)=3

(Y,Y) : 49, nice judge
(N,N): 3, miss
(N,Y): 8, CMRR Better
(Y,N): 0, CMRR Better
It displays the CMRR is more sensitive than DSAE.
Miss Rate= 3/52 = 5%



4. Conclusion:

After three phase processing, about Image Alignment, Width Measurement, and Defect Detection. Solving non-reference positioning challenge. The system is based on python implementation, running on operating environment with the need for opencv library. The proposed use python2.7, and opencv2.3.0. Per image (640x640) processing cost about 42 seconds. The miss rate by the system is 5 %.

1. **Image Alignment**
    1. Small offset , polygon moment method
    2. Big offset , contour moment method
    3. Solving non-reference positioning
2. **Width Measurement**
    1. ESS method
    2. P-P search method
    3. Auto measure Inner/ Outer length.
3. **Defect Detection**
    1. CMRR,DSAE
    2. Miss rate= 5%

5. References

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