EECS 490 DIGITAL IMAGE PROCESSING

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SESSION 4 Integrated Circuit Mask Inspection

Nattapon Chaimanonart Photomask Analysis

Photomask Analysis

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Abstract

In this paper, a photomask analysis method based on Geometric Transformation, Image Registration, and Hit-or-Miss Transformation is proposed. By comparing a good design photomask from a database, defects from a developed photomask are shown in a result image with their corresponding locations. The algorithm is implemented via MATLAB. The accurate results of detecting several unclear and distorted photomasks are shown.

Keywords

Photomask Analysis, MATLAB, Geometric Transformation, Image Registration, Hit-or-Miss Transformation

1. INTRODUCTION

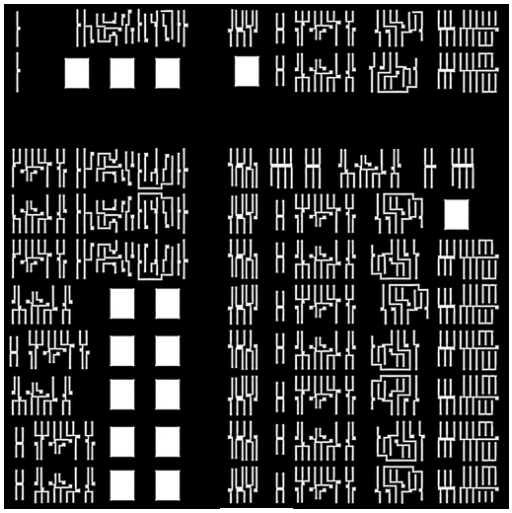
In the IC fabrication process, photomasks are used for patterning a silicon-chip based on a circuit layout. By shining a UV light through the various photomasks made of photographic quartz or glass plates, a multilayer integrated circuit can be formed [1]. It is obvious that a yield of the IC products depends on a quality of the photomasks. Therefore, the flawless photomasks without spots, extensions, bridging, pin holes, mouse bites, clear breaks, or other unclear areas, are highly desirable to achieve an expected functionality of the designed IC. In order to minimize these defects, an inspection of photomasks needs to be performed. In this project, the algorithm based on digital image processing for inspecting the defects on the photomasks is proposed. The process is developed by comparing between two masks, a good design from a database system and a distorted design. The result is the image containing the defects at their corresponding locations.

In this paper, the image processing techniques, such as Geometric transformation, Image registration, and Hit-or-Miss Transformation are utilized [2]. The proposed method is implemented by using MATLAB. The experimental results from various photomaks are presented and performance of this algorithm is discussed.

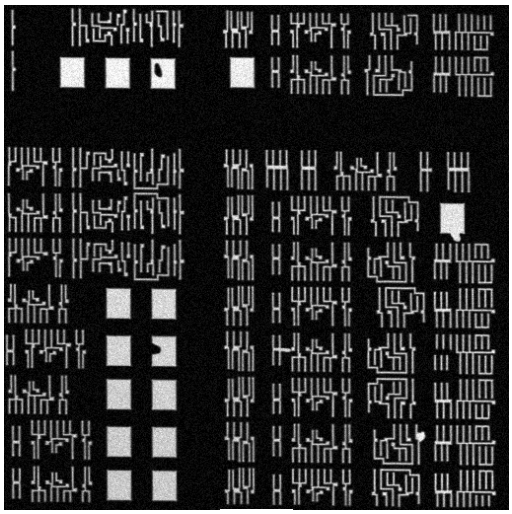
2. THE PROPOSED PROCEDURE

The goal of the project is to compare an image of the produced mask (containing unknown warping and noise) with the as-designed mask image and subtract the two images to identify the defects. The comparison procedure between two photomasks is described as follow.

1. Since the developed photomask is geometrically distorted from the database design photomask, the alignment process needs to be performed before the subtraction. The database design photomask and the original developed photomask are illustrated in Figure 1.a and Figure 1.b, respectively.



(a)



(b)

Figure 1. (a) Database Design Photomask
(b) Developed Photomask No.1

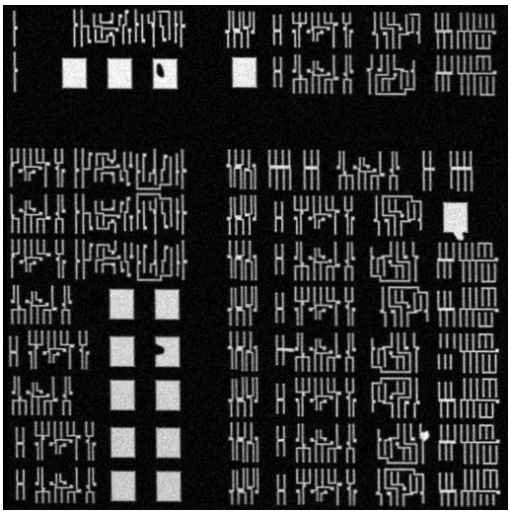


Figure 2. Corrected image using a Linear Conformal Transformation

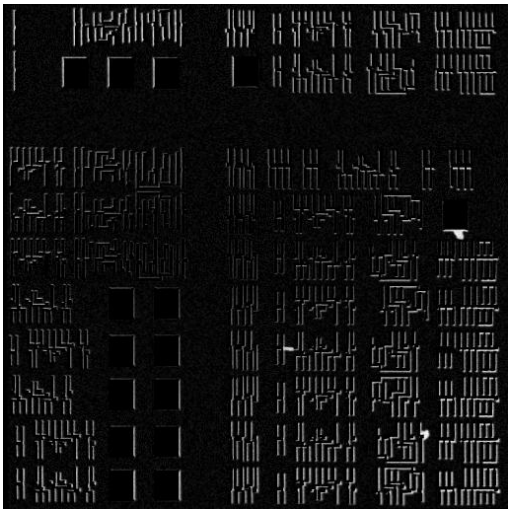


Figure 3. Result image by subtracting Figure 1.a from Figure 2

Image registration method, which seeks to align two images of the same scene, is used for correcting the distorted image. In MATLAB, the image processing toolbox has an interactive function called "imview", which can manually find the locations of control points, also known as tie points, from both image. Once the control points are known, the transformation structure can be created in a matrix form by using the function "cp2tform". In addition, the spatial transformation can be achieved by using the function "imtransform". The result of this transformation is shown in Figure 2. A Linear Conformal, which will scale, rotate and translate the image, is chosen as a transformation type [3].

2. Comparing these images by subtracting the database photomask from the geometrically corrected photomask. Some defects, such as extensions, and bridging will be shown as illustrated in Figure 3. Moreover, other defects, such as pin holes and cracks can be obtained by subtracting the geometrically corrected photomask from the database photomask. The result defects are shown in the Figure 4.

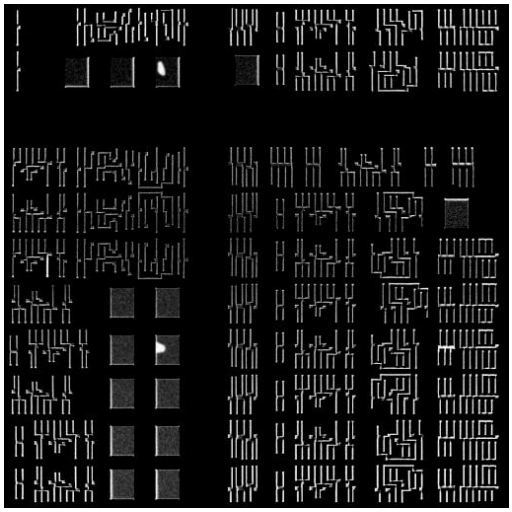


Figure 4. Result image by subtracting Figure 1.a from Figure 2

3. Determine the defects based on the subtracting images from step 2. The morphological Hit-or-Miss Transformation is utilized. Basically, this technique is a tool for shape detection. Therefore, in order to efficiently detect the defects, some structuring elements need to be specifically defined, which are based on types of defects. For a hole or extensions, the structuring element used is shown in Figure 5.a. In the case of missing horizontal and vertical lines, the structuring elements presented in Figure 5.b and Figure 5.c are used, respectively. A properly thresholding is required before performing the Hit-or-Miss algorithm. MATLAB implementation for the Hit-or-Miss algorithm and Thresholding is "bwhitmiss" and "im2bw".

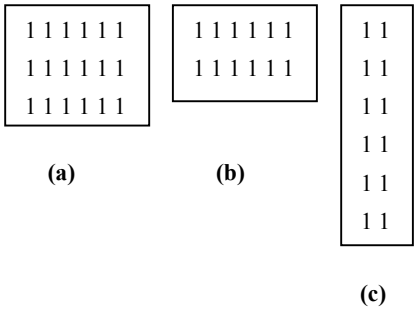


Figure 5. Structuring element to detect (a) holes, (b) horizontal lines, and (c) vertical lines

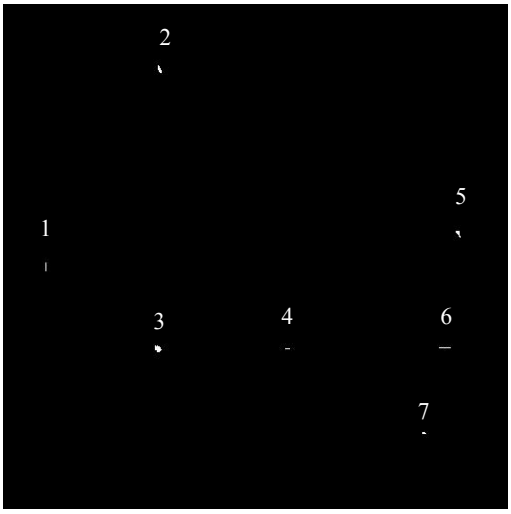


Figure 6. Result image by using Hit or Miss Transformation

4. Several defects are detected from different types of structuring element as described in step 3. By performing a logical "or" operation of these images, the final result image can be obtained as presented in Figure 6.

3. EXPERIMENTAL RESULTS

In this section, various types of photomasks are tested by using the proposed procedure. First, the same geometrically distorted photomasks in Figure 7 with much extensive random noise is performed. Since the noise is substantial, in this photomask, the image correction is required. The arithmetic mean filter is used to reduce the noise. Further, the edges of the filtered image are boosted with the High-Boost filtering. The corrected image is shown in Figure 8.

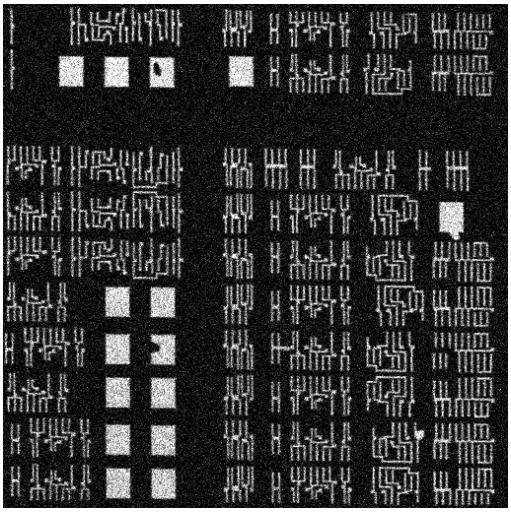


Figure 7. Developed Photomask No. 2

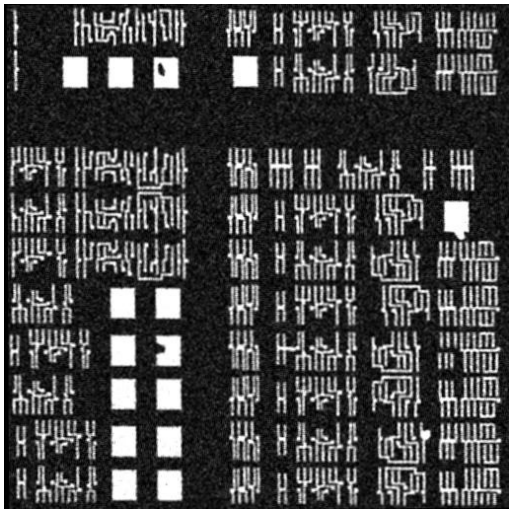


Figure 8. Corrected image using average mean and High-Boosting

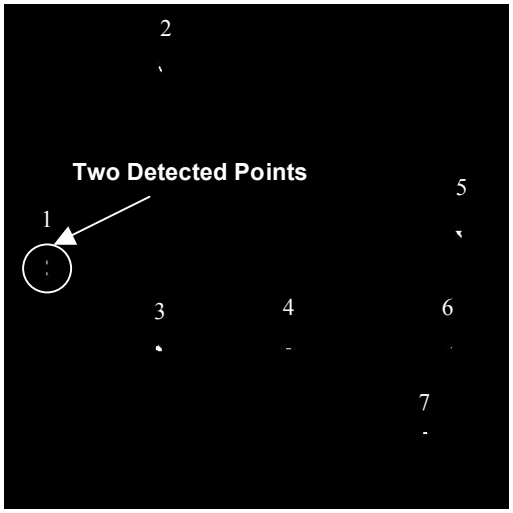
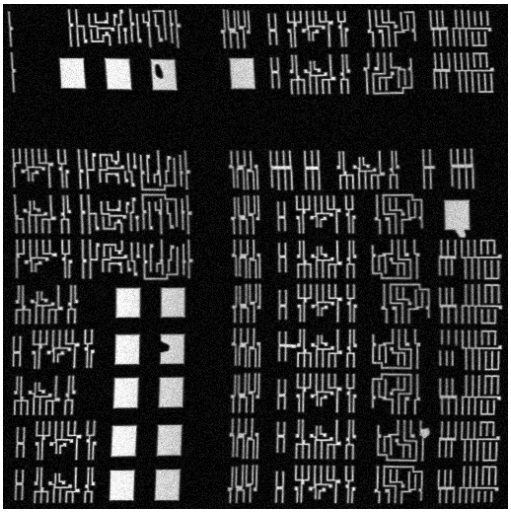


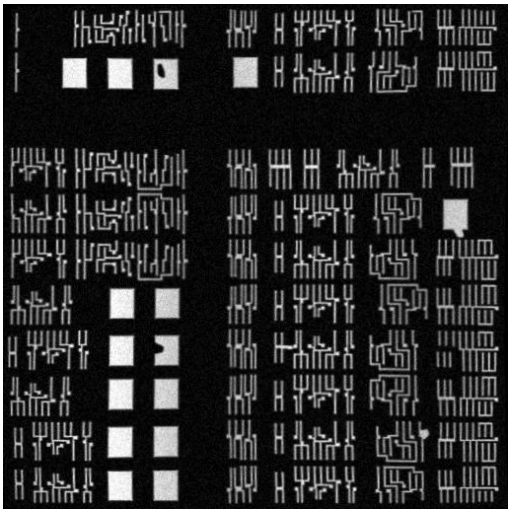
Figure 9. Result image by using Hit-or-Miss Transformation

Considering a result image by using the Hit-or-Miss Transformation in Figure 9, an unexpected defect is occurred. Two points are detected around the same area instead of one. Because the pepper noise is spread over the detected area, the vertical line is divided into half.

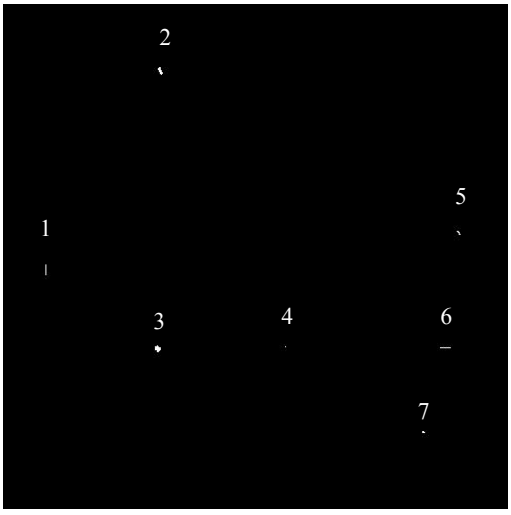
The photomask No.3 with more degree of geometrically distortion is presented in Figure 10.a. Due to the non-linear distortion, Polynomial, which input spatial coordinates are a polynomial function of output spatial coordinates, is chosen as a transformation type to build a transformation structure matrix. The corrected image is shown in Figure 10.b. The result output detection is also shown in Figure 10.c.



(a)

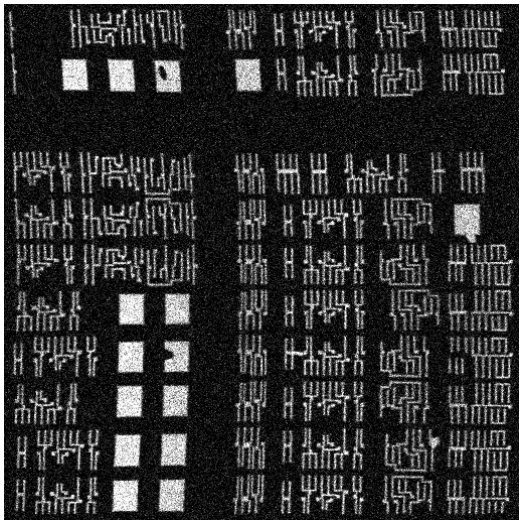


(b)

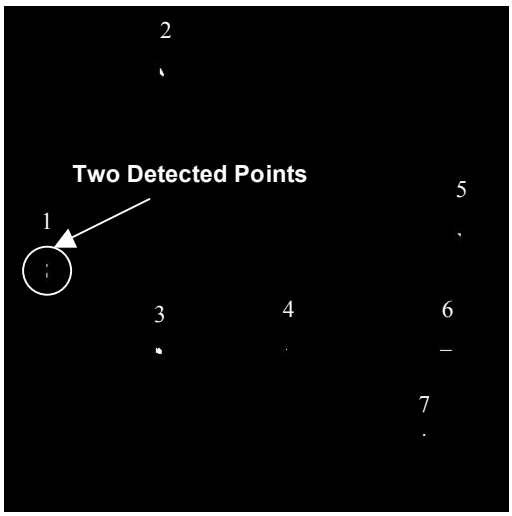


(c)

Figure 10. (a) Developed Photomask No. 3
(b) Corrected image using polynomial Transformation
(c) Result Image



(a)



(b)

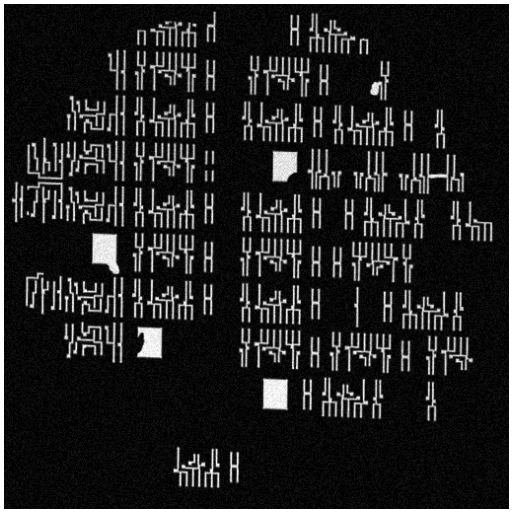
Figure 11. (a) Developed Photomask No. 4
(b) Result Image

Again, the photomask No. 4 with highly distributed noise illustrated in Figure 11.a produces the same error as mentioned in photomasks No.2. The evaluation photomask No. 5-8 with their results are shown in Figure 12-15

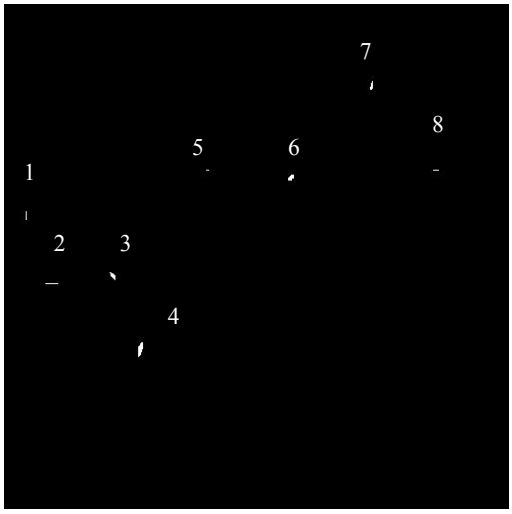
4. PERFORMANCE DISCUSSIONS

Although the proposed method employing Geometric transformation, Image registration, and Hit-or-Miss Transformation is very suitable for this application, it has some limitations. One of the limitations, which can be found from the experimental results, is that if the photomasks are highly corrupted by noise, some unexpected defects may occur, for example, the two-point detection. In addition, it is very critical that the image after the Geometric transformation is perfectly aligned with the database photomasks. Failure of this may cause a serious error, when the Hit-or-Miss Transformation is used.

(a)

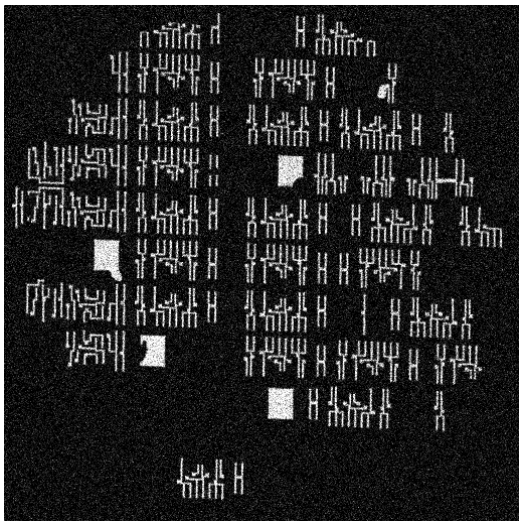


(b)

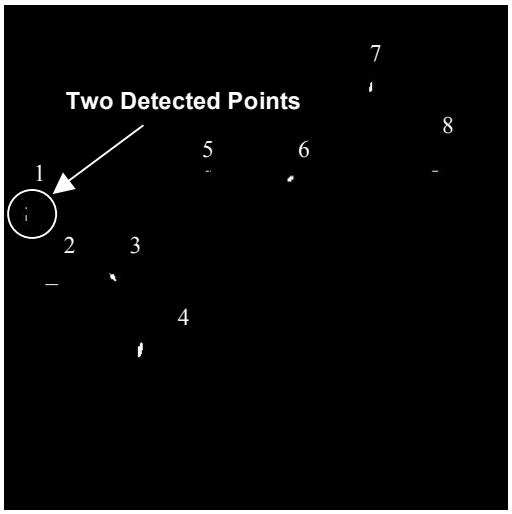


(c)

Figure 12. (a) Database Design Photomask
(b) Developed Photomask No. 5
(c) Result Image



(a)

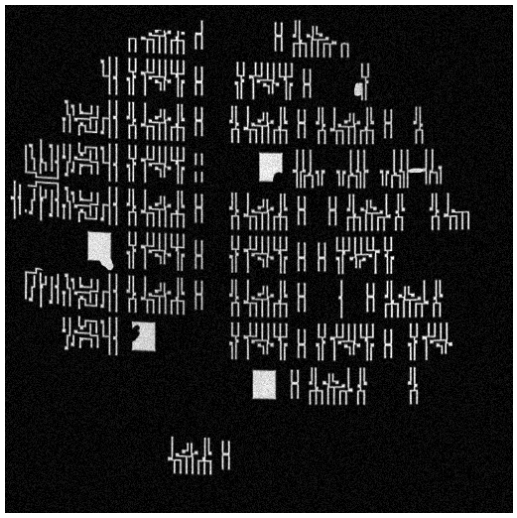


(b)

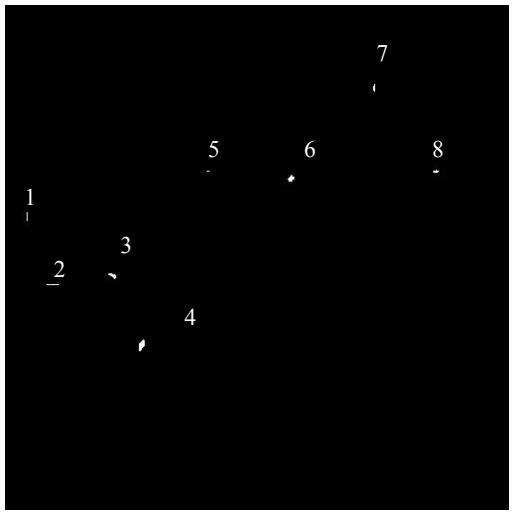
Figure 13. (a) Developed Photomask No. 6
(b) Result Image

6. CONCLUSION

In this paper, a photomask analysis method based on Geometric Transformation, Image Registration, and Hit-or-Miss Transformation is proposed. By comparing a good design photomask from a database, defects from a developed photomask are shown in a result image with their corresponding locations. The algorithm is implemented via MATLAB. The accurate results of detecting several unclear and distorted photomasks are shown.

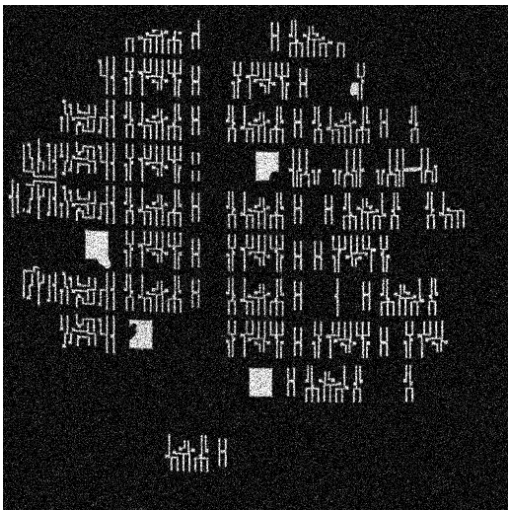


(a)

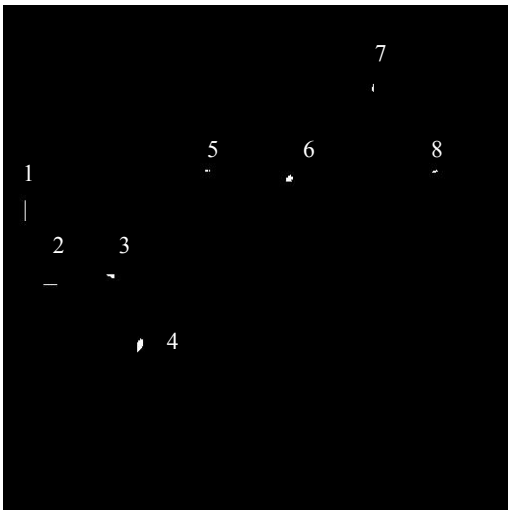


(b)

Figure 14. (a) Developed Photomask No. 7
(b) Result Image



(a)



(b)

Figure 15. (a) Developed Photomask No. 8
(b) Result Image

ACKNOWLEDGMENTS

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REFERENCES

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[3] R. C. Gonzalez, R. E. Woods, and S. L. Eddins, *Digital Image Processing using MATLAB*, 1st Edition, New Jersey, Prentice Hall, 2004.