Study on defocus image-based template matching algorithm for extreme ultraviolet mask phase defect detection

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INTRODUCTION

Among EUV mask blank defects, phase defects have a great influence on the photolithography effect, and phase defects as high as 3.5nm can cause 10% change in critical dimensions on the wafer. Phase defects account for a large proportion of defects and are mostly located inside the mask, making it difficult to repair.

Table. 1 Types of Mask Blank Defects

Type of defect	Defect location	Defect impact
Amplitude defect	Multilayers top or upper layer	Reflected field amplitude
Phase defect	On the substrate or on the bottom of the multilayer	Reflected field phase

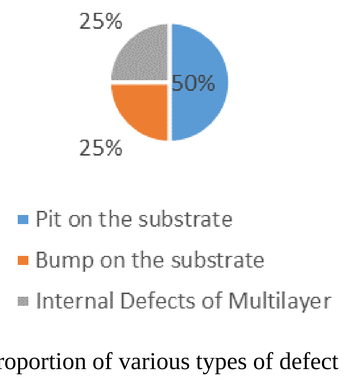

Fig. 1 Proportion of various types of defect in mask blank

Phase defects often become Gaussian bump or Gaussian pit due to the deposition in the multilayer manufacturing process, The main parameters include peak height and full width at half maxima.

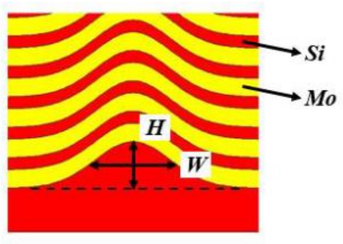

Fig. 2 Gaussian defect model

OBJECTIVES

The goals we need to achieve include

- **Types of phase defects detected.**
- **The size of the phase defect detected**
- **The location of the phase defect detected**

METHODS

In this paper, we first establish a model of mask blank with different types and sizes of phase defect, and then use the FDTD method to simulate the near-field reflected light field distribution map of the mask blank.

The defect characteristics are obtained after simulation as shown in Fig.3:

- Bump defect: the defect light field intensity is weak at the center and strong at the edge
- Pit defect: The intensity of the defect light field is strong in the center and weak at the edge.

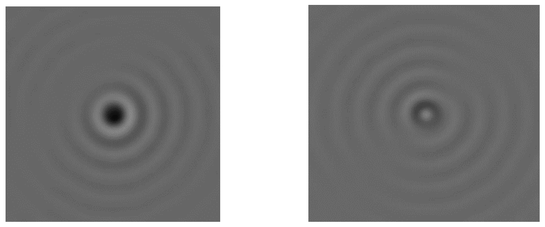

Fig. 3 Aerial image of bumps and pits defect

The aerial image of the mask can be simulated by taking the reflected field as a light field input through an infinite ideal lens. Because the comparison of small size defect images after lens imaging is too low, there will be missed detection, so this paper designed a set of detection algorithm based on defocus imaging and template matching. The defocus imaging method is shown in Fig.4.

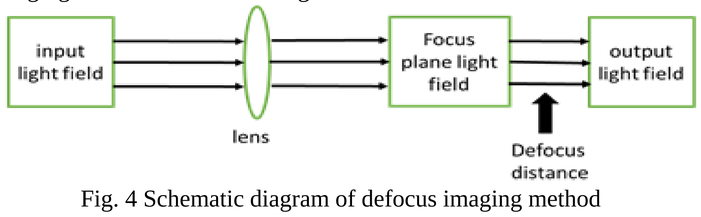

Fig. 4 Schematic diagram of defocus imaging method

Defocus-based image to be tested, detecting defects algorithm includes three steps:

- **Universal template matching**
- **Redundant test box to remove**
- **Specific template matching**

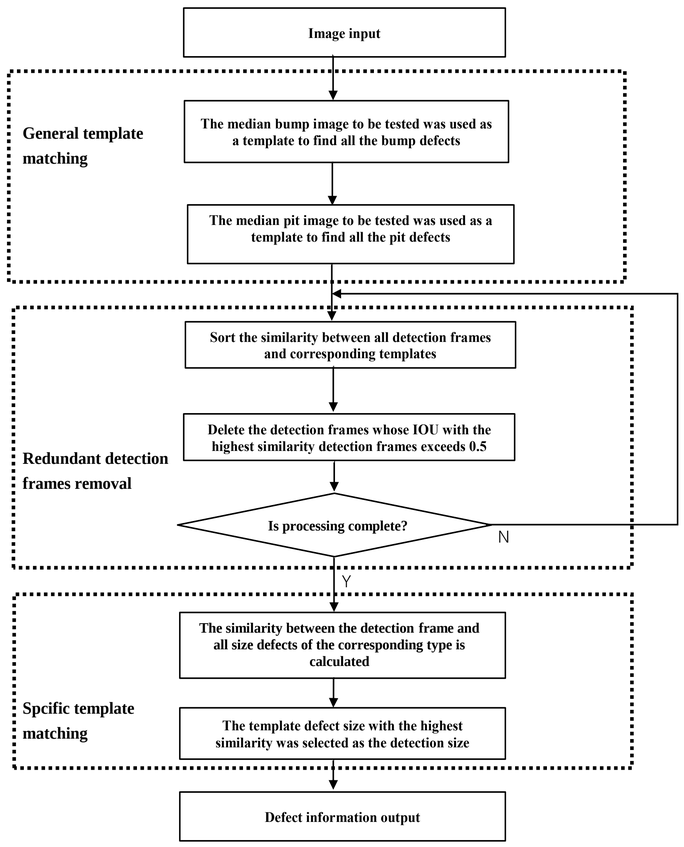

Fig. 5 Image processing flowchart

The detection results after the above three steps are shown in fig.6. The pit defect is marked in green, the raised defect is marked in red, and FWHM of the defect is marked above the detection box.

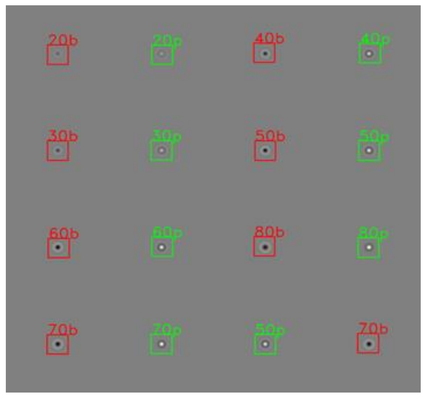

Fig.6 Defect detection results of template matching algorithm

RESULTS

In order to verify the effectiveness of the algorithm, the defects with a FWHM of 20 to 80 nm are randomly stitched to obtain some large-size mask blank images. The statistically detected defect information is shown in the Table 2.

Table. 2 Defect detection result

	bump	pit
20nm	100%	100%
30nm	100%	100%
40nm	100%	100%
50nm	100%	100%
60nm	100%	100%
70nm	100%	100%
80nm	100%	100%

It can be seen from Table 2 that the detection effect of defocus imaging combined with template matching algorithm is very good, which can achieve 100% detection rate in the size range of 20nm to 80nm, and the accuracy of defect size determination is also up to 100%.

CONCLUSIONS

Based on the holistic characteristics of white board structure and phase mask defect, access to mask the reflected light field using FDTD method simulation, combined with the ideal lens and Fresnel diffraction propagation theory of far field space, like, according to the space like on the focal plane image contrast of low situation put forward based on the confocal imaging and phase defect detection and template matching method of Realize the detection of defect type, location, size and other information. Good results are obtained, which has good application value for actual EUV mask blank defect detection.