Soft Defect Printability: Correlation to Optical Flux-Area Measurements

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ABSTRACT

Soft defects on photomasks have, historically, been difficult to measure, and predict how the measured size of a soft defect will correlate to what prints, if at all. Over the past few years KLA-Tencor STARlight surface inspection has become the inspection of choice for soft defects. Though the capture rate of this tool is exceptional, the defect sizing capability has lacked in accuracy. Customer specifications have traditionally been built around defect size and transmission. If a given defect cannot be accurately sized then it cannot be accurately dispositioned. In this study we are attempting to show a correlation between the AVI defect measurement tool sizing and what actually prints on the wafer. We will show defect sizing both from the KLA-Tencor STARlight and pattern tools, the AVI tool, AIMS and VSS printability data.

Keywords: photomasks, soft defect, STARlight, AVI, AIMS and VSS, flux-area

1. INTRODUCTION

A photomask vehicle was chosen. The patterns were an internal Photronics design. Polystyrene spheres were then attached. The plate was run on a KLA-Tencor SL300HR, a KLA-Tencor 363, and a KLA-Tencor SL300. Pictures were obtained from the inspection tools. Although these tools have a very similar defect sizing strategies, they did not agree on the sizing of each defect. The AVI Photomask Metrology tool was used to obtain accurate size measurements. Pending wafer measurements, defect printability was assessed with the Zeiss AIMS tool and the NTI Virtual Stepper Software (VSS).

The AVI measures the total flux absorbed by a defect, and then reports the defect's "effective size", the diameter of a chrome spot that would absorb the same flux. This "effective size" measurement yields the same results at different wavelengths and magnifications.

For this study several defects were selected, three calibrated polystyrene sphere defects and one randomly occurring contamination defect. Zeiss AIMS data was taken using the locations provided by the inspection tools. The AIMS tool has the capability to perform aerial imaging for predictability of printing. The parameters used were chosen to match an ASML PAS5500/750, a 248nm high NA scanner. Printability analysis was also performed on the NTI VSS using a model with the same setup parameters. The data from AIMS and the Virtual Stepper are detailed.

2. EXPERIMENT RESULTS

The photomask was ran multiple times on several KLA-Tencor pattern and STARlight tools. The defect locations were matched and the results of the defect sizing from both pattern and STARlight are shown in Table 1. As shown in the table a given defect captured at different pixel sizes show to be very different sizes. The AVI measurements were done on two separate tools. The AVI numbers shown are taken from a blue-light SL300. The same measurements were taken from a 365 nm UV KLA-Tencor pattern tool with the AVI tool and the variance was less than 20nm.

Defect #	AVI Measured Size *from SL300	.186 um KLA363 Pattern		.25 SL300 STARlight		.375 SL300 STARlight		.5 um SL300 STARlight	
	effective diameter	x	Y	x	y	x	y	x	y
9	.802	0.558	1.116	0.75	0.75	1.125	0.75	1.00	1.00
56	.545	2.232	0.744	2.50	1.75	2.25	1.50	3.00	2.00
64	.542	0.930	1.116	1.00	1.00	0.75	0.75	1.00	1.50
79	.383	0.558	1.116	0.75	1.00	1.125	0.75	0.50	0.50

Table 1.

The inspection results as measured by the AVI tool on the SL300 are shown below. Defects 56,64,79 are shown in full screen shots from the AVI tool. The measurements in the table above are an average of three measurements taken on the tool. This can be seen in the screen shots: In the left-middle headings "History" and "Average of Three".

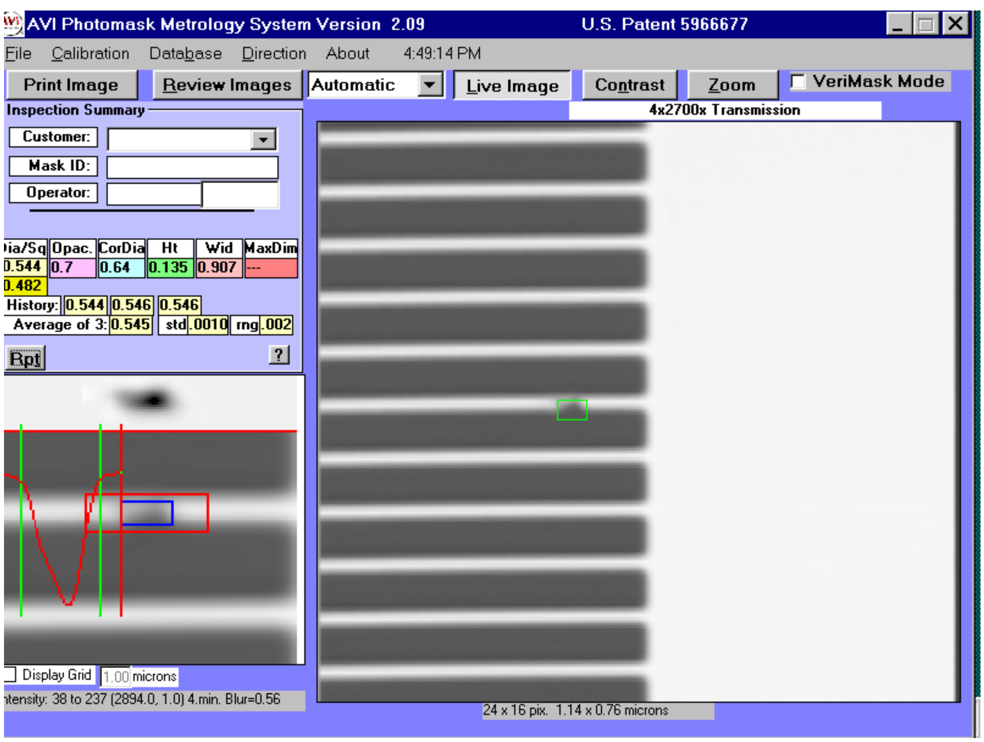


Image 1. Defect 56 AVI image

Defect 56 is a naturally occurring contamination type defect bridging two leads in a metal like structure. This defect appears to be darker than the polystyrene spheres. This defect would normally be cleaned off before a pellicle is affixed to the plate. However, for the sake of this study, during the fabrication process several instances of this type defect were intentionally left on the photomask.

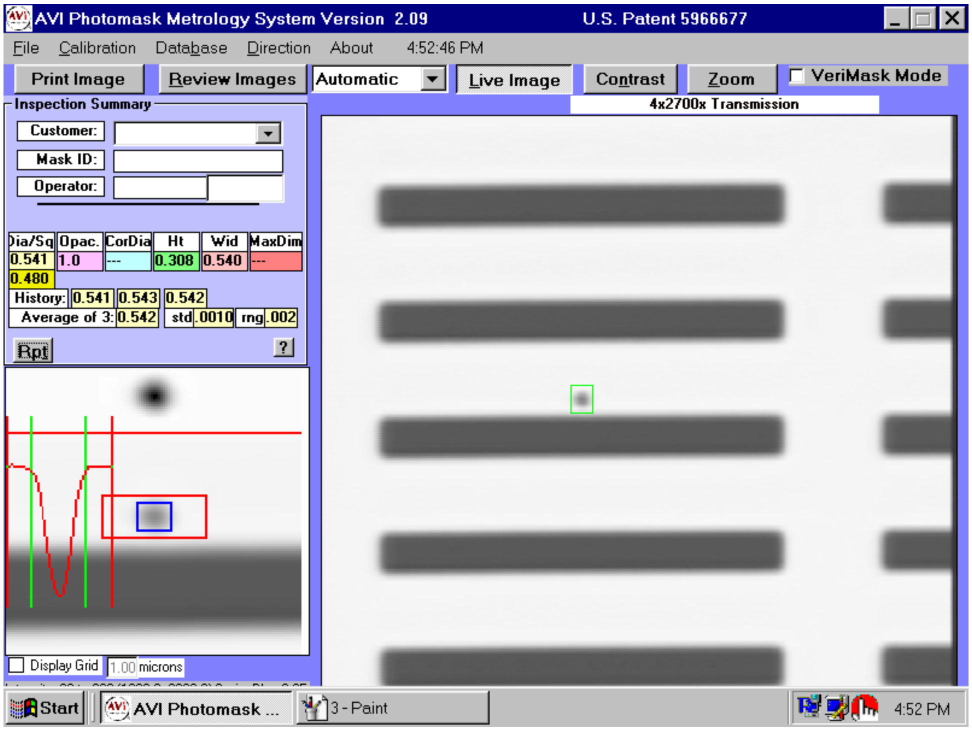


Image 2. Defect 64 AVI image

Defect 64 is a polystyrene sphere approximately 1 um off of a line edge. This defect was used to see if the line cd would be significantly changed with a semi-transparent type defect.

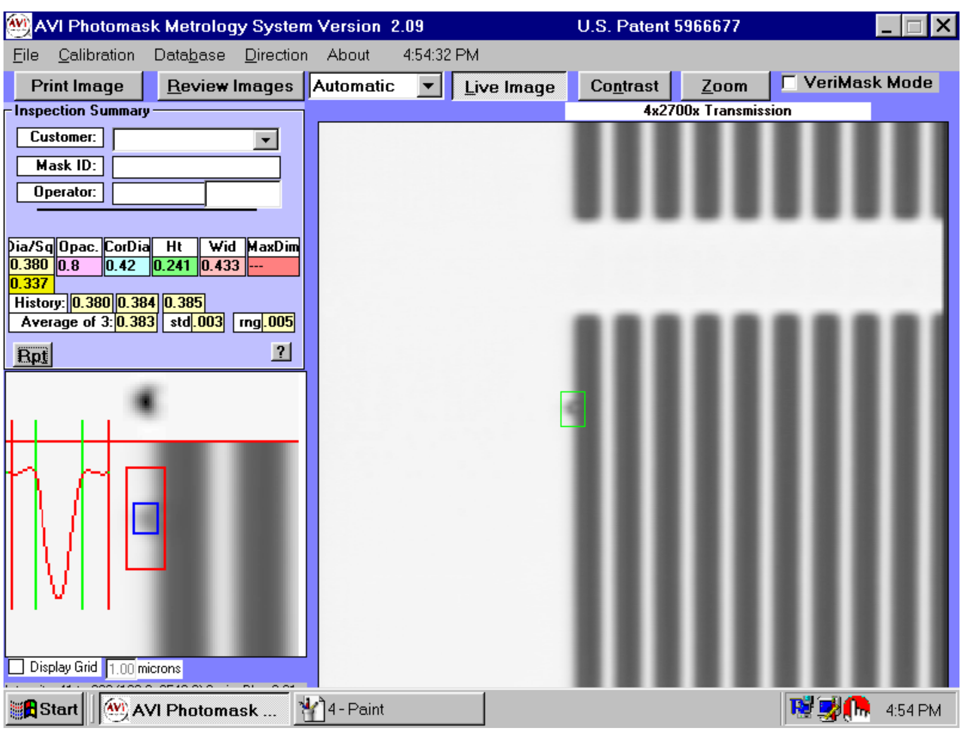


Image 3. Defect 79 AVI image

Defect 79 is a polystyrene sphere laying on the edge of a line. The measurement from the AVI tool will only show the part of the defect exposed.

The following images are AIMS and VSS comparisons of the two different approaches to simulation.

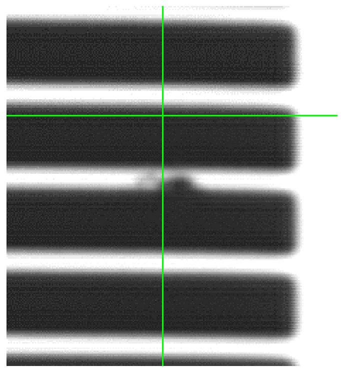
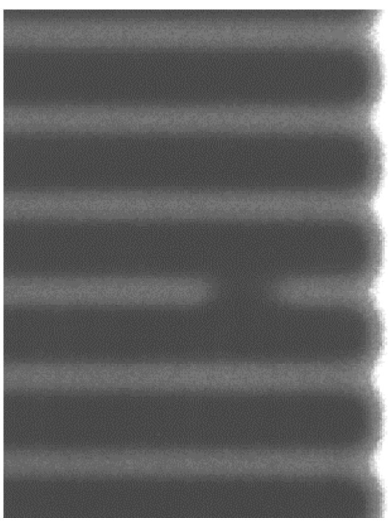


Image 4. Reticle image of Defect 56



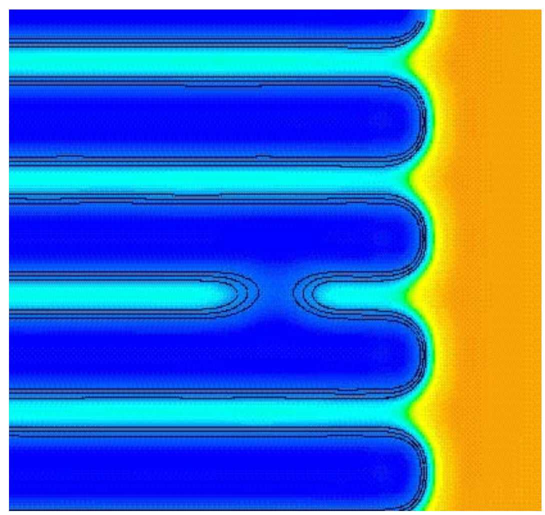


Image 5. AIMS image of Defect 56

Image 6. VSS image of Defect 56

As shown above the defect plainly prints under both simulations. The apparent difference in linewidth between the two simulations is from the scale of the images not exactly matched. Image 7 below is a further AIMS 3D image.

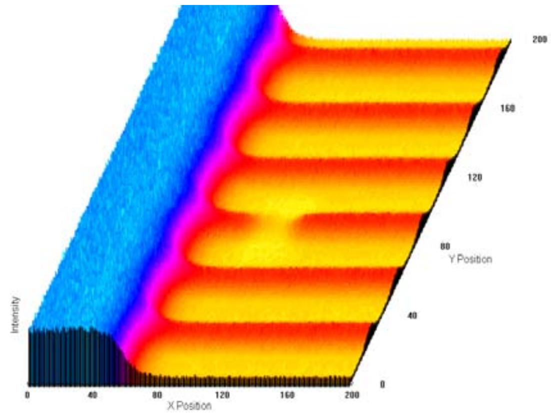


Image 7. AIMS 3D image of Defect 56

Defect 64 (shown below) shows the effect of a semi-transparent defect away from the edge of a line.

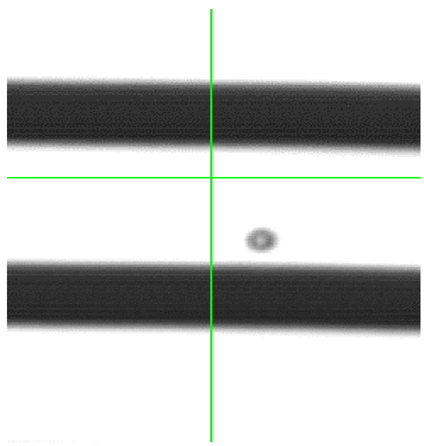
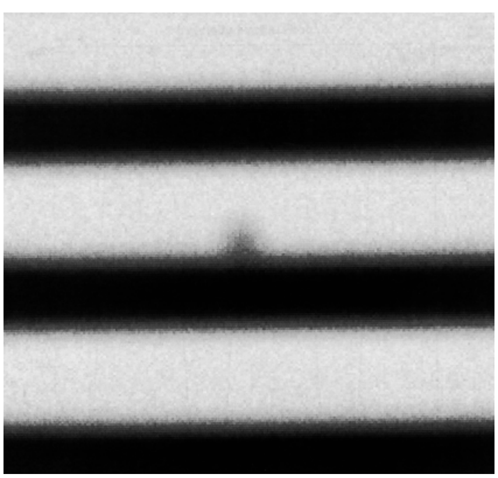


Image 8. Reticle image of Defect 64



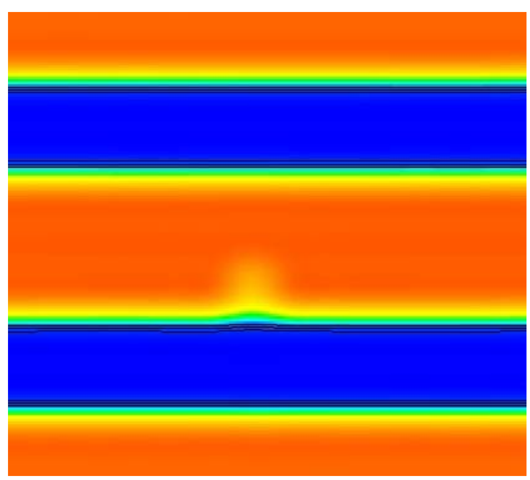


Image 9. AIMS image of Defect 64

Image 10. VSS image of Defect 64

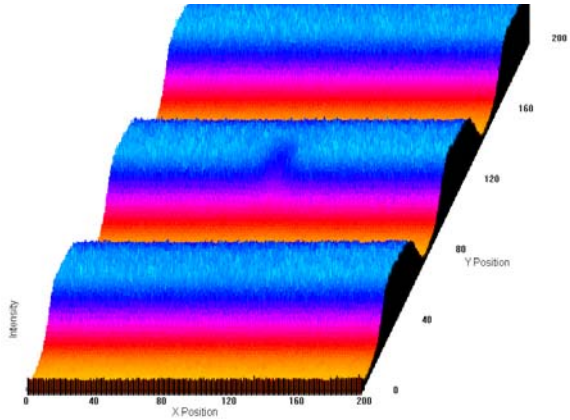


Image 11. AIMS 3D image of Defect 64

Image 79 is an example of a semitransparent defect laying on the edge of a line. The STARlight tool would naturally show the size of this type defect to be larger than the transmitted light image of either a pattern tool or the AVI tool, which uses transmitted light to do the flux area measurement.

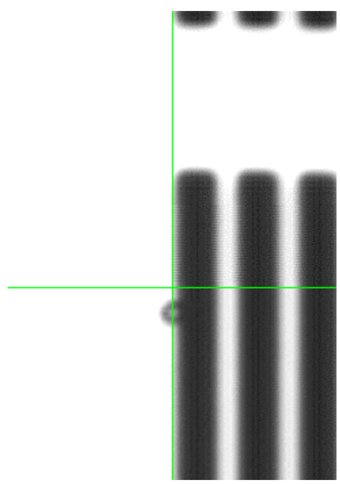


Image 12. Reticle image of Defect 79

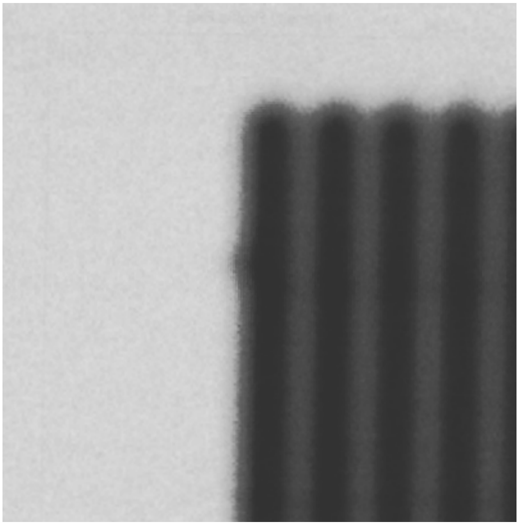


Image 13. AIMS image of Defect 79

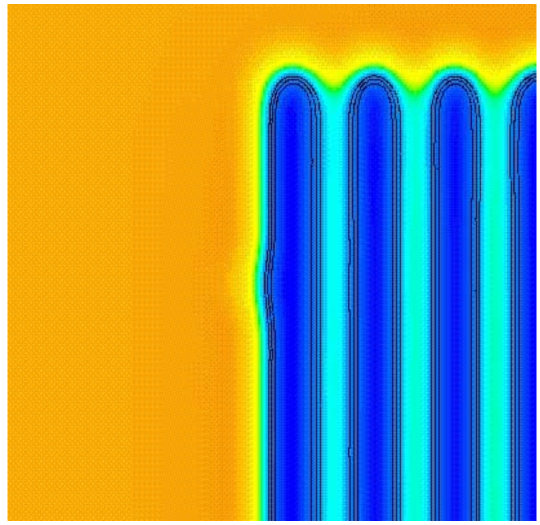


Image 14. VSS image of Defect 79

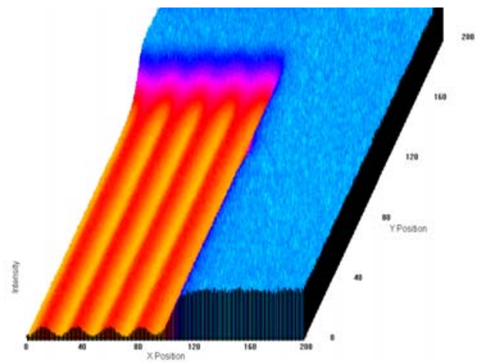


Image 15. AIMS 3D image of Defect 79

Defect 9 is an example of a semi-transparent defect between the ends of two lines.

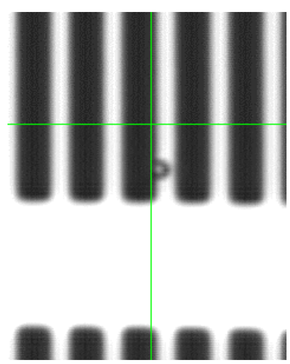


Image 16. Reticle image of Defect 9

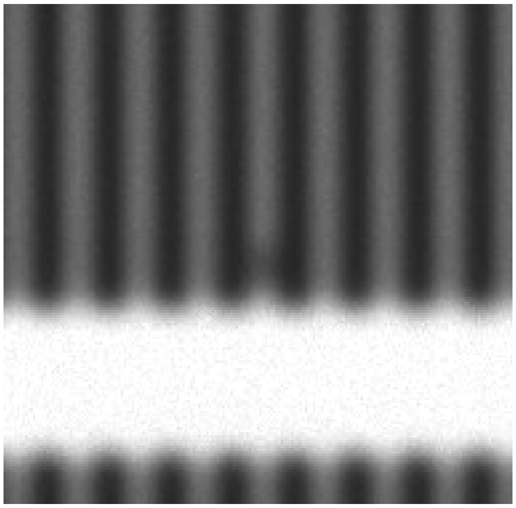


Image 17. AIMS image of Defect 9

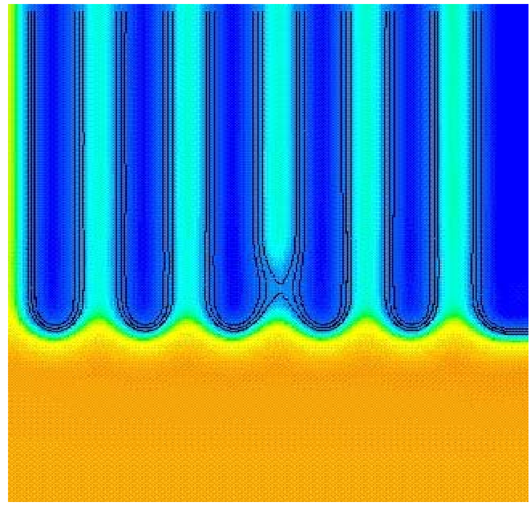


Image 18. VSS image of Defect 9

3. CONCLUSIONS AND FUTURE WORK

It is generally accepted that defect printability depends on the (effective) defect size and its distance from nearby edges. Most processes already call for separate edge- and isolated defect specs. With the availability of "effective" defect sizing, even soft defects can be accurately dispositioned with the same rules as hard defects. The "effective" size takes into account the total light absorbed by the defect. This is the result of the defect's area and its opacity.

The aerial images from both the AIMS and VSS simulations show good agreement on the shape and size of a given defect.

The KLA-Tencor tools, both pattern and STARlight, while very good at locating defects are not reliable in absolutely sizing those defects. The same defect, at different pixel sizes, show to be a different measured size from the tool.

The AVI defect sizing tool proved to be very adept at measuring the effective size of defects[2]. The reliability and repeatability of this tool is ideal for defect size "binning". The data from this tool definitely can and needs to be used in proving that there is an absolute size cutoff for printability.

This work is being carried on through the wafer printing process. The photomask are in the process of being printed on wafers. That work will be published at a later date.

Some future work that needs to be performed is to repeat this study to try to find out if there is an absolute size cutoff for printability. This needs to be performed with multiple size defects. These were not readily available for this study. With this sort of data in hand, some specifications could be modified allowing a faster flow to the wafer fabs from the mask shop.

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REFERENCES

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