PERFORMANCE CHARACTERIZATION OF A GCA 4800 STEPPER

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ABSTRACT

Characterization of a GCA 4800 stepper was done in order to assess the system capability for image quality and overlay. This was achieved through running stepper jobs two or three times per week. Data was statistically analyzed and the results showed good agreement with accepted values with the exception of system registration [1].

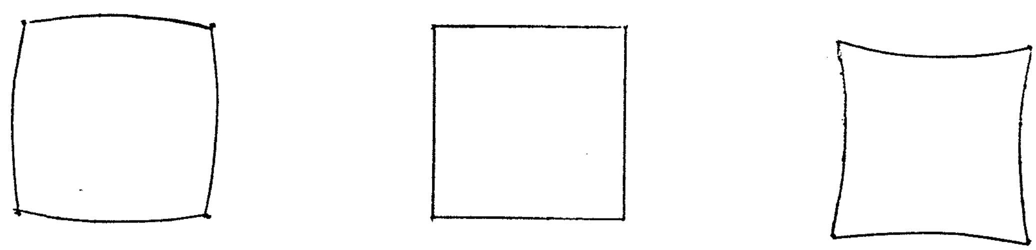
INTRODUCTION

Step and repeat photolithographic imaging tools are currently the exposure system of choice for VLSI and ULSI applications. This is for several reasons: 1) ability to print submicron geometries, 2) lower cost than non-optical systems, 3) reasonable throughput. Geometries in production of 1 and 4 megabit DRAMs are in the .7 to 1 micron range, with plans to run at or below .5 micron for the next generation or two of DRAMs. The only feasible way to achieve this is with steppers. This partially stems from economics and the reduction capability of the stepper. Designs on the reticle can be made anywhere from 4 to 10 times larger than will be printed on the wafer. Therefore, reticle designs are not limited by current maskmaking technology.

The GCA 4800 stepper operates with a g-line exposure source to reduce the reticle image ten times in size. This image is exposed over the entire wafer in a predetermined array by the stage moving from exposure site to exposure site. Therefore, the control over stage motion and quality image reproduction are the most serious challenges for the stepper.

One area of concern in stepper performance is image quality. Perhaps the most familiar criteria evaluated is system focus. The image, in order to be properly resolved, must be correctly in focus. Optimum system focus is determined through a focus array whereby the stepper increments focus over several predetermined rows. The optimum focus is found through microscope evaluation of the sample. The row with the best resolution corresponds to a focus value from the array, which is the best system focus.

Two other image quality concerns are with image reduction and image distortion. Reduction is the actual ratio of the reticle image to the aerial image. Ideally, it should be 10:1, but testing can determine if the image is excessively or insufficiently reduced. Knowing the true reduction ratio will determine if design changes need to be made to account for this error. Distortion is a measure of how much the sides of the image deviates on the sides from an ideal rectangle. It is classified as barrel or pincushion as shown in Figure 1. There is no way to correct for this as it is dependent on the quality of the lens.



Barrel Ideal Pincushion

Figure 1: Barrel and Pincushion Distortion

A second set of criteria is related to the stage motion. Correct stage motion is critical, especially for second level exposures and beyond. Submicron lithography is useless if tight control of overlay cannot be realized. The first concern is precision, or the ability of the stage to repeat its own motions within the same exposure level. It measures how accurately the stage moves from die to die. A second concern is die rotation, or how much the second level exposure has been rotated about its center with respect to the first level. This usually results from a reticle alignment error and is uniform across the wafer. The second measure made by the die rotation verniers is the amount of variation in die rotation across the wafer. This is caused by twisting of the optical column between exposures or rotation of the stages. It is corrected only with a hardware manipulation. A third concern is with stage orthogonality. This is a measure of how close the stages move to perfect when the second level has been rotated by ninety degrees from the first. Any angle other than ninety degrees obtained can be accommodated with a software correction. A fourth concern is trapezoid, or the amount of planar non-parallelism between the reticle and the wafer. In a system equipped without a Z-axis correction on the platen, this error cannot be corrected.

Two final criteria are somewhat related. One is registration and the other is baseline correction. Registration is the ability to overlay a second level onto a first level. It is perhaps the most important quality of a stepper, a higher priority than resolution. Associated with registration is the baseline correction. This is due to the indirect alignment method of the stepper. Alignment is made under an alignment microscope and the stages then move the wafer under the optical column. The baseline is the distance the stages are supposed to move from alignment to exposure. The error is the difference the stages move from their ideal position. This difference can be accounted for with a software correction.

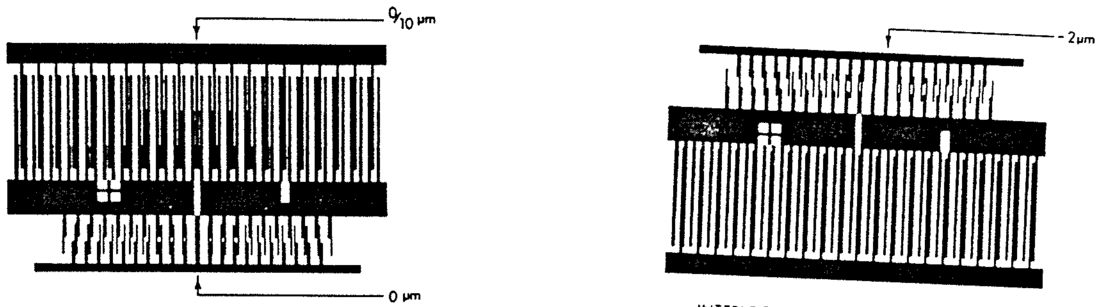
This project was to understand the normal system performance of these parameters and be able to compare the actual capabilities to the expected system capabilities and determine deficiencies. This consisted of performing monitoring experiments to gather a large enough data base to make a statistical analysis of system capabilities.

EXPERIMENT

The GCA Universal Vernier Test Target [1] was utilized to evaluate all criteria (baseline, precision/registration, reduction/distortion/rotation, and orthogonality) except focus. Focus evaluation utilized a lithography evaluation reticle which contained a focus star as shown in Figure 2. The focus star is read from the outside inward, starting at 2um and radiating inward, with markers at every .5um. The best focus is the row in a focus matrix that has the best resolution of the star.

Figure 2: Focus Star

The GCA reticle utilizes interlocking verniers for measurement. The verniers consist of a male and female portion that are overlaid on top of each other, as shown in Figure 3. The amount of registration error defined by the vernier overlay is achieved through microscope examination. The vernier scale consists of two arrays of parallel structures: coarse and fine verniers. The measurement difference of the coarse array is 1 micron, while the fine array measurement difference is .1 micron. When the two vernier halves are interlocked, the coarse verniers can measure errors from -10 microns to +10 microns with a 1 micron least count. The fine vernier scale is capable of measuring errors from -1.0 micron to +1.0 micron with a .1 micron least count. Due to the non-cyclic nature of the verniers, errors over 1 micron in magnitude are of integer value only [2].



INTERLOCKED VERNIER PATTERN INDICATING PERFECT REGISTRATION

INTERLOCKED VERNIER PATTERN INDICATING -2µm

Figure 3: Interlocking Verniers

Stepper jobs for(precision/registration and reduction/ distortion/rotation) were created while an existing orthogonality job was modified to remove all software corrections. Data was collected 2-3 times per week. The three inch silicon wafers had 5300 angstroms of oxide grown on them and were coated with 1.3um of KTI 820 resist prior to exposure. The resulting data was statistically analyzed to assess system capabilities and compare with accepted values [1].

RESULTS/DISCUSSION

Table 1 shows a listing of tool specifications and the parameter results obtained from the experiment.

Table 1: Tool Specifications and Test Results

PARAMETER	SPECIFICATION [1]	TEST RESULT	3 SIGMA VALUE
Precision	+/- .2um	X= +.01um Y= +.06um	X= .24um Y= .17um
Registration	+/- .35um	X= +7.21um Y= -.98um	X= 9.88um Y= 3.42um
Distortion	+/- .2um	X= -.06um Y= +.02um	X= .20um Y= .22um
Reduction	+/- .2um	X= +.29um Y= +.43um	X= .32um Y= .30um
Trapezoid	+/- .35um	X= -.09um Y= -.09um	X= .29um Y= .29um
Die Rotation	<= .1um	.08um	.19um
Orthogonality	+/- .5arc-sec	-.53arc-sec	4.65arc-sec

It can be seen from the data that most parameters are reasonably close to the specifications set up by the manufacturer.

There appears to be no problem with stage precision, image distortion, reduction, trapezoid or die rotation. The stage orthogonality is a minor problem, only in controlling the amount of variation, not in the overall mean value.

The most serious problem resides with the system registration. As seen by the data in Table 1, the registration is orders of magnitude higher than the tool specification. This may be directly related to fluctuations with the baseline correction. Data collected over a six month period shows assignable cause variation for the X stage, as indicated by Figure 4.

Figure 4: Baseline X Value Versus Time

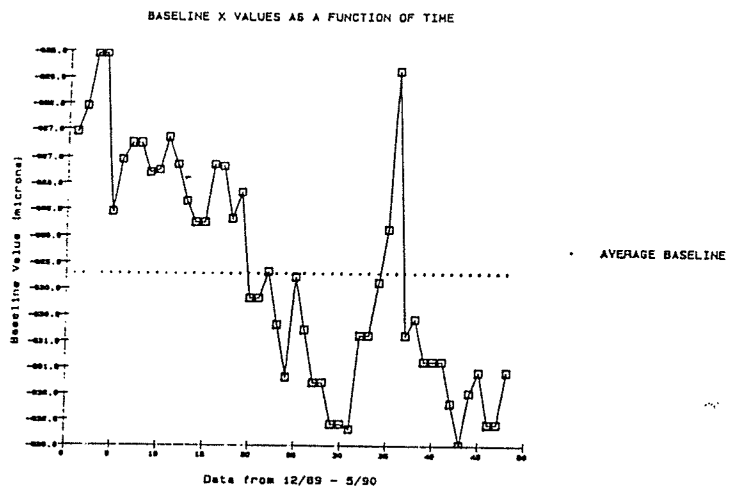
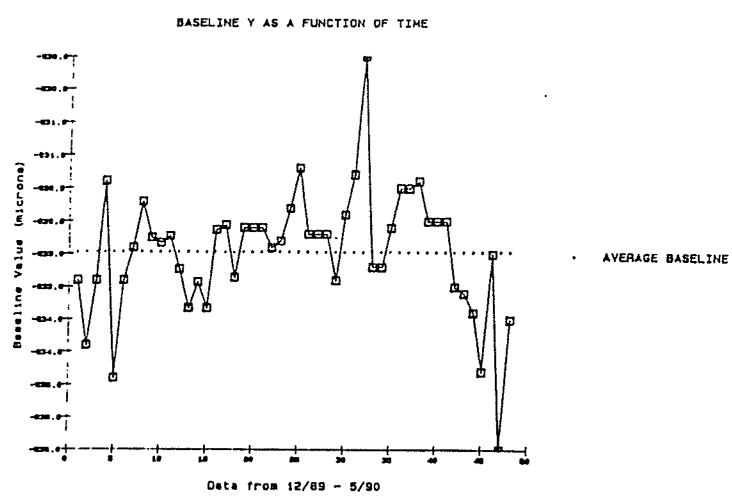


Figure 5 shows the Y baseline fluctuation. It is more random and has less average variation than the X but it also needs tighter control.

Figure 5: Baseline Y Value Versus Time



Since there is no significant problem with the image quality due to lens aberrations or the precision of stage motion, the only problem existing is with level to level overlay. Erratic values obtained from registration monitoring give no confidence in being able to run a multi level process for small geometries. The minimum geometry that is normally run in production is governed by Equation 1.

$$GR = 3\{(2)^{.5}\} \cdot R \qquad (1)$$

where GR is the ground rule or minimum geometry and R is the 3 sigma value of the registration [3]. With the tool specifications for the GCA 4800, the R value is .35um. This yields a minimum geometry of 1.48um, consistent with the resolution limit of 1.25um. With the values obtained for registration, processing will be limited due to the variability of the registration.

Recommendations for future work would be to determine conclusively if a direct correlation exists between the baseline correction and the amount of registration error in back to back runs. If so, correcting the baseline problem, which likely needs a hardware manipulation, would automatically generate tighter control over registration. Better registration control would enable better usage of the resolution capability for multilevel processing.

CONCLUSION

The RIT GCA 4800 stepper is close to the specifications for precision, reduction, distortion, die rotation and trapezoid errors. Results from these tests showed good agreement with reference [1]. Results for orthogonality need tighter control for overall variance. Registration and baseline need hardware manipulations and maintenance to bring the variation and control to a level where the full resolution capability of the stepper can be utilized.

ACKNOWLEDGMENTS

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REFERENCES

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[2] Schneider, William C. "Testing the Mann Type 4800 DSW Wafer Stepper". SPIE, Vol.174, 1979, pg. 6-14.

[3] Harald Bohlen and Werner Kulcke. "Evaluation of Level-to Level Overlay in Lithography Systems". Solid State Technology, February 1990, pg. 59-61.