

## Second Level Alignment of the PE MODEL 140

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### ABSTRACT

The Perkin Elmer Model 140 was investigated for second level alignment. Using a photolithographic evaluation mask, inspection of six wafers yielded overlay errors. The average x-translational error was  $-1.95 \text{ } \mu\text{m}$ , the average y-translational error was  $-.4 \mu\text{m}$ , and the average rotational error was  $-.0005$  uradians.

### INTRODUCTION

In the photolithographic process of the microelectronic industry there are three major tools of optically transferring a pattern on a mask to a photoresist coated wafer. These methods are contact printing, proximity printing, and projection printing.

Contact printing was the earliest method used to produce patterns on silicon wafers. The mask is first aligned to the wafer. It is then clamped to the resist coated wafer (while maintaining alignment), and exposed with ultraviolet light. This form of printing yields the most faithful image transfer and best resolution, but there are a couple of major disadvantages. Defects in the mask are generated from the constant mask-to-wafer contacting process. These defects are then printed on all subsequent wafers. If these defects cannot be removed by cleaning, the mask must be replaced, involving added cost. Another problem is particles that get between the mask and the wafer preventing intimate contact which reducing resolution [1].

In proximity printing the mask and wafer are placed close to one another during exposure, but do not make contact. By introducing this gap, the defect problem of contact printing should be avoided, but as the gap size is increased, the resolution rapidly degrades. The equation for minimum resolution in proximity printing is given by [2]:

$$b_{\min} = 1.5 * (s \lambda)^{**1/2} \quad (1)$$

where  $b_{\min}$  is the minimum resolution,  $s$  is the size of the gap, and  $\lambda$  is the exposure wavelength.

In projection printing, lens elements or mirrors are used to focus the mask image on the wafer surface, which is separated from the mask by large distances. Several types of projection printing techniques have been developed, including: a) reduction step and repeat aligners; b) non-reduction step and repeat

aligners; and c) 1:1 projection scanners. The reduction steppers use refractive optics to project the mask image onto the wafer. Since the image projected is stepped and repeated across the entire wafer, the wafer size is no longer a problem. The ultimate advantage of stepper technology over scanner-type aligners is higher image resolution and the possibility of greater overlay accuracy [3]. The major disadvantage of steppers compared to scanners is a lower throughput. Scanners can have a throughput of 100 wafers/hr, where steppers can only output about 10-15 wafers/hr.

Projection printing is used almost exclusively for VLSI fabrication [4]. In the 1:1 projection scanner, the wafer and mask are scanned through a narrow arc of UV radiation by means of a continuous scanning mechanism. The minimum resolution of this type of system is given by:

$$w = k * \lambda / NA \quad (2)$$

where  $w$  is the minimum feature size,  $k$  is a constant that depends on photoresist parameters,  $\lambda$  is the exposure wavelength, and  $NA$  is the numerical aperture of the optical system [5].

This experiment consists of performing a second level alignment on a Perkin Elmer Model 140 Micralign series projection scanner. The 1:1 wafer scan system uses a reflective spherical mirror to project the image onto the wafer surface [6]. Chrome plates will be used to make the masks involved in this process. Chrome plates are used because they have better resolution capabilities than emulsion masks. The standard ETM mask will be used for the alignment targets. This mask has a number of optical verniers, resolution targets, and alignment targets. A figure of this mask can be seen in Appendix 1. Comparisons of alignment overlay between aligners can then be performed at different linespace dimensions.

## EXPERIMENT

The first step in this project was to select which type of alignment targets to use, from cross hairs, verniers or any others and select a minimum resolution. When this was decided, the entire alignment site and the mask can be designed. The Kodak Exposure Test Mask (ETM) was used. The four inch wafers were first put through a full RCA clean. The exposure doses were then optimized. The lamp was characterized by taking irradiance readings at different scan speeds. The following equation was then used to determine exposure dose:

$$E = I * (100) / \text{Sensitivity Factor} \quad (3)$$

where  $I$  is the irradiance reading in  $\text{mw}/\text{cm}^2$  and the sensitivity factor is .00175. The wafers were coated on the GCA wafertrac. Line program number 9, which uses a spin speed of 5000 rpm, was used. KTI820 positive resist and KTI934 developer (1:1) were used. The exposure dose used was 57  $\text{mj}/\text{cm}^2$ . The development

time associated with this exposure was 10 sec. The first masking level was then imaged onto the wafers. They were then etched in a buffered HF dip for 7 min. The etch rate determined for the buffered HF bath was 750A per min. The remaining photoresist was then ashed off. The wafers were then put into a RCA clean. Photoresist was then recoated onto the wafers. The second masking level was aligned and exposed. The same processing parameters were used for the second level that were used for the first level. The wafers were then developed and finally inspected. The process used for aligning a second level on the scanner was then documented for further use by the RIT facility. This documentation can be found in Appendix II.

## RESULTS

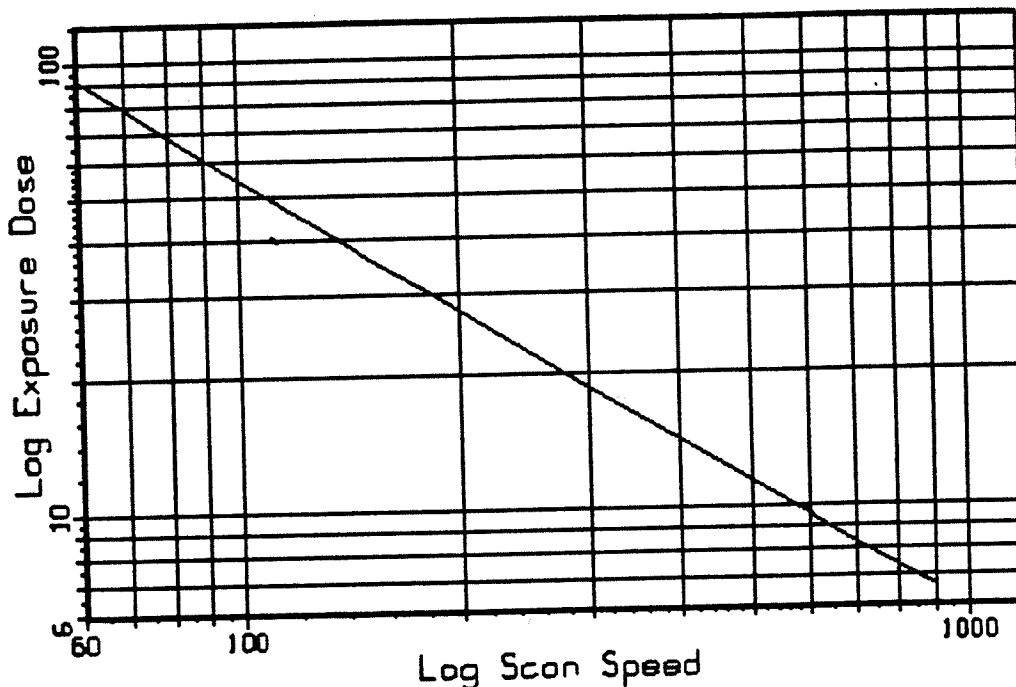
Using the GCA wafertrac a resist coating of 1.26  $\mu\text{m}$  resulted with a uniformity of 99%. This value was found by taking five thickness readings across the wafer and dividing the range by the mean. The optimum exposure dose was determined to be 36mj/cm<sup>2</sup> with a development time of 20 sec. The developer was diluted 1:1 (dev:H<sub>2</sub>O). This may still be too strong. Diluting the developer 2:3 (dev:H<sub>2</sub>O) would give a better process. This would result in a longer development time which in turn would result in a more uniform development. The exposure dose was found by using the plot of Log Exposure vs. Log Scan Speed obtained by taking irradiance readings over a wide range of scan speeds and using Equation 3. This plot can be seen in Figure 1.

Inspection of the second level alignment included determining the translational and rotational alignment errors. For four oxide wafers the data obtained is in Table 1. The x and y translational errors are read directly off of the optical verniers on the ETM mask. The numbers in Table 1 are actually an average of five sites around the wafer. The rotational errors are found by averaging the top and bottom y errors and dividing by the diameter of the wafer. What this actually obtains is the tangent of the angle, but since the angle is so small they are approximately the same.

Wafer#	Ave x ( $\mu\text{m}$ )	Ave Y ( $\mu\text{m}$ )	Ave Rotational (urad)
1	-1.2	1.0	-.019
2	-1.6	-1.8	.011
3	-2.2	-0.8	.009
4	-2.8	0.0	-.003
Ave	-1.95	-0.4	-.0005

Table 1: Overlay Results

Log Scan Speed vs. Log Exposure Dose  
Perkin Elmer Model 140



**FIGURE 11: Log Scan Speed vs. Log Exposure Dose**

**CONCLUSION**

Scan speed was correlated to exposure dose for the Perkin Elmer 140. Process parameters were determined for exposure and development of KT1820 positive photoresist and KT1934 developer. First and second levels were aligned and exposed on the scanner for the first time at RIT. The scanner is now ready to be used for four inch wafer fabrication. Hopefully this will make the conversion of the RIT factory from a three inch line to a four inch line easier.

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## REFERENCES

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- [2] L. F. Thompson, C. G. Willson and M. J. Bowden, Introduction to Microlithography, (American Chemical Society, 1983.) p.19
- [3] Ibid., Ref 1., p.472.
- [4] Ibid., Ref 1, p. 468
- [5] Ibid., Ref 3., p. 20
- [6] Ibid., Ref 1, p. 468

## APPENDIX I

