CONTRAST ENHANCEMENT MATERIAL EVALUATION FOR A MICRALIGN PROJECTION SYSTEM

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ABSTRACT

Contrast Enhancement Material (CEM-388) was to be evaluated for a Perkin Elmer Micralign Projection System by comparing the contrasts for Kodak 820 positive photoresist with and without the use of the CEM. The contrast curve was determined from thickness versus log exposure graphs for various development times. A correlation between exposure dose and carriage speed of the Micralign System was investigated.

INTRODUCTION

The dimensions of Integrated Circuit designs are rapidly approaching the resolving power of optical projection exposure tools used in the industry.(1) Various multilevel resist systems have been developed to extend the resolutions obtainable with the current tools. One of these systems, Contrast Enhancement Lithography (CEL), is said to 'improve' the contrast of the aerial image from the exposure tool to the photoresist, therefore permitting smaller linewidths and greater packing densities.

Contrast Enhancement Lithography uses a thin photo-bleachable layer on top of a conventional positive photoresist.(2) The CEM bleaches slowly compared with the underlying photoresist and forms an "in situ" contact mask over it. A schematic of the CEM process is shown in figure 1. Once portions of the CEM are bleached through, the photo-resist is exposed with a relatively uniform intensity. Only the highest intensity portions of the projected image are transmitted to the underlying photoresist, thus creating near vertical photoresist profiles.(3)

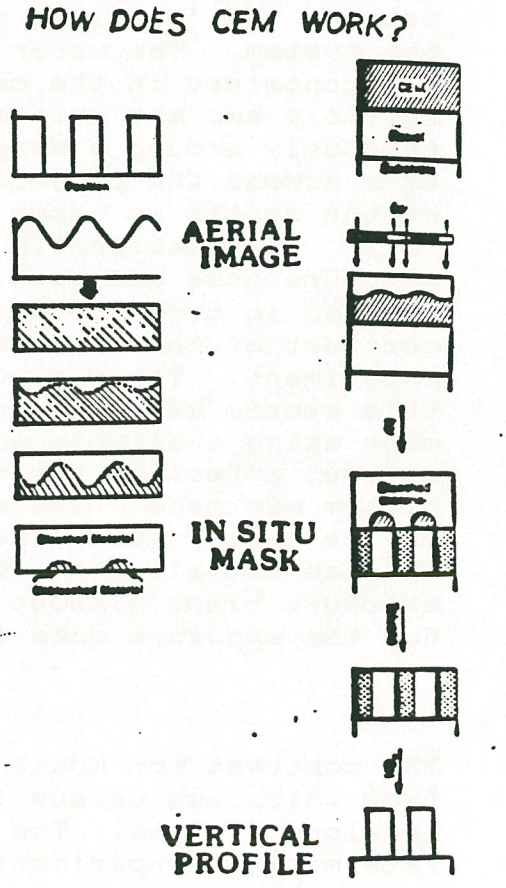
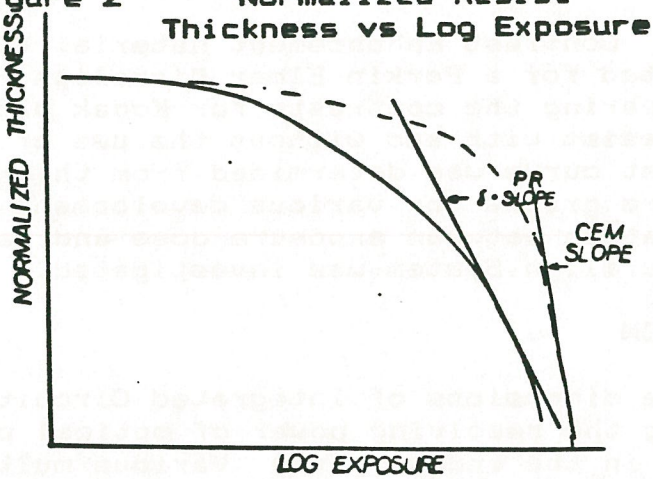


Figure 1 Use of Contrast Enhancement Material

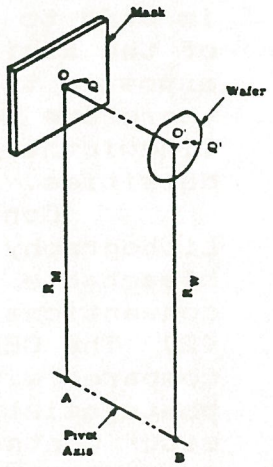
The Contrast Enhancement Material (CEM) was evaluated for a Perkin Elmer Micralign Projection System by comparing the contrasts for Kodak 820 positive photoresist with and without the use of the CEM. The contrast of a photoresist is one of the characteristic properties of the material and may be determined from the slope of the flat line portion of a graph of resist thickness versus the log of the exposure dose for various development times. A CEM should increase the slope, i.e. the contrast, of this curve as shown in figure 2.

Figure 2 Normalized Resist Thickness vs Log Exposure



The Micralign Projection System allows for changes in exposure dose by varying the scan rate or the 'carriage speed' of the system. The wafer and mask are contained in the carriage assembly and are rotated simultaneously around a single, fixed axis across the projection optics of the system as shown in figure 3.

Figure 3 Nominal Scan Geometry



A relationship between exposure dose and scan speed was desired in order to determine the contrast of the materials for the experiment. The exposure dose for this system was difficult to determine using available equipment without affecting the machine, so an approximation to another system was made. The exposure dose for a Kasper Mask Aligner may be easily determined using a radiometer. The Micralign set up does not allow for the placement of the radiometer at the exposure plane without bypassing safty mechanisms. The equation for the exposure dose is:

Dose = Intensity * Time

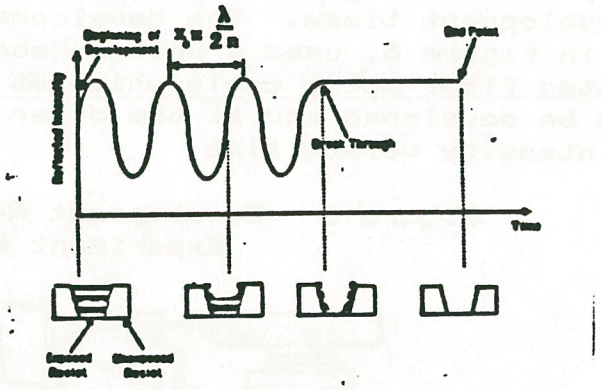
The contrast for Kodak 820 positive photoresist was determined from thickness versus log exposure graphs for a particular development time. The graphs were obtained from a development rate monitor experimental set up. This set up used a monochromatic light source and a bifribricated fiber optic cable which at one end is attached to a wafer to be developed and at the other end to a plotter of relative intensity versus time.

The resist thickness, Xpr, remaining after a particular development time was determined from the following equation:

$$Xpr = N * lambda / 2n$$

Where lambda is the primary wavelength of the light source, n is the index of refraction of the photoresist, and N is the number of cycles that the development has gone through. A sample of a relative intensity versus development time plot is given in figure 4.

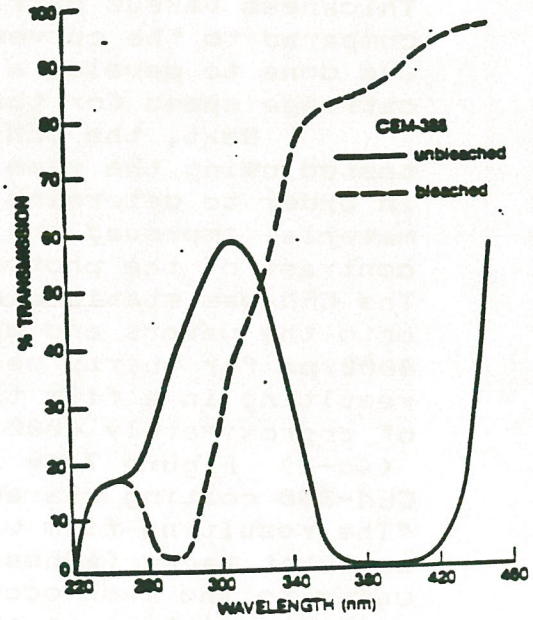
Figure 4 Intensity Plot and Thickness Determination



The development of several different exposure doses must be done in order to create the curves. Wafers were then exposed with varying carriage speeds on the Micralign Projection System. The thickness remaining points for each curve were marked on the thickness versus log exposure dose graphs and a correlating exposure dose was determined.

The CEM-388 material is designed for use with 405 nanometers of illumination although significant contrast enhancement is said to be obtainable with the broad band Perkin Elmer projection system. (4c-3) Figure 5 shows the spectral properties of a 4000 angstrom CEM-388 film.

Figure 5 CEM-388 Spectral Characteristics

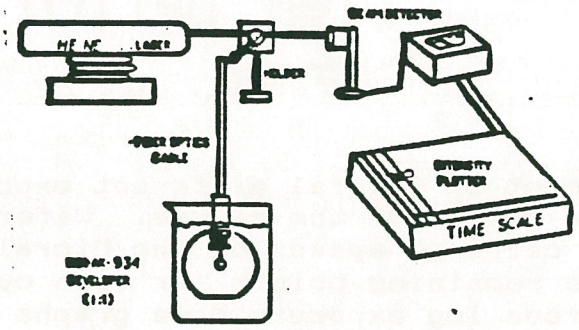


EXPERIMENT

It was first necessary to determine the exposure focus of a five inch by five inch mask plateholder in order to make an RIT/AMI test mask for the Micralign exposure tool. This was accomplished by doing a 'step' exposure on the GCA Photorepeater across a photographic plate. The step exposure involved changing the focus after each exposure.

After development, the images were evaluated to determine the proper focus setting for that particular plateholder. The Micralign projection system allows for changes in exposure dose by varying the 'carriage speed' of the system. The exposure dose for this system is difficult to determine so an approximation to another system was made. (Note: This is an approximation only. The spectral output of the two lamps differs as well as the method of exposure - contact versus projection.) The dose for the mask aligner was determined using a radiometer to measure the intensity of the lamp output and multiplying that by the exposure time. (The Micralign set up does not allow for the placement of the radiometer at the exposure plane without bypassing safty mechanisms.) A determination of the contrast for Kodak 820 positive photoresist was made by completeing thickness versus log exposure graphs for various development times. The development rate monitor set up, indicated in figure 6, used a Helium-Neon laser and a bifribricated fiber optic cable which at one end is attached to a wafer to be developed and at the other end to a plotter of relative intensity versus time.

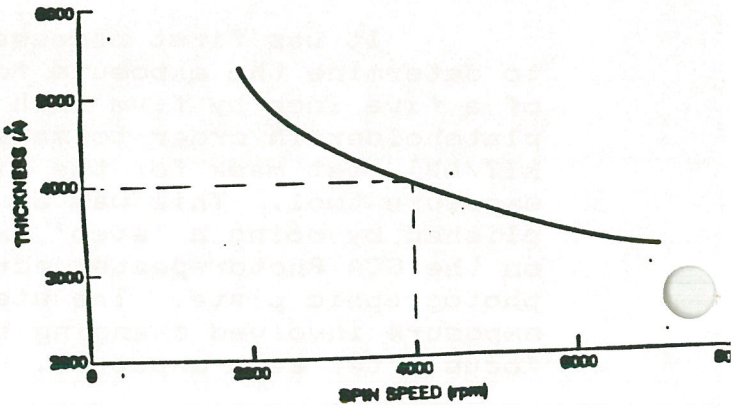
Figure 6 Development Rate Monitor Experiment Set Up



The photoresist was coated at 5000rpm for thirty seconds and convection baked at 85C for twenty minutes for all experiments. Wafers were also processed at the same time using the Micralign projection aligner with varying carriage speeds. Thickness versus carriage speed curves were completed and compared to the curves obtained with the mask aligners. This was done to develop a relationship between the exposure dose and carriage speed for the Micralign system.

Next, the CEM-388 was tested using the same method in order to determine if the material improved the measured contrast of the photoresist. The CEM was static dispensed onto the wafers and spun at 4000rpm for thirty seconds resulting in a film thickness of approximately 4000 angstroms. (4c-3) Figure 7 is a graph of CEM-388 coating characteristics. "The resulting film will be somewhat tacky (adhesion of the wafer to the mask occurs if contact printing is attempted), but the wafer must not be baked further while the CEM-388 is on the photoresist." (4c-3)

Figure 7 CEM-388 Coating Characteristics

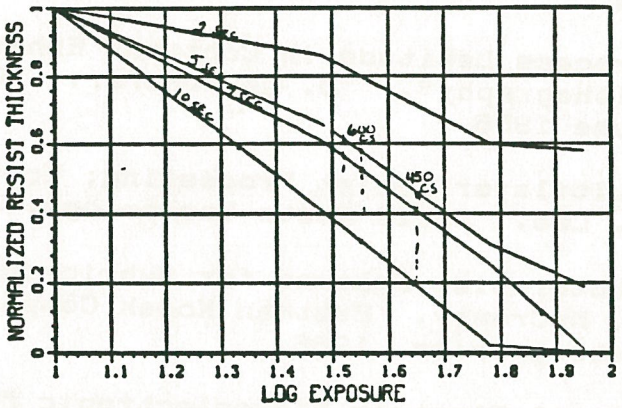


RESULTS/DISCUSSION

Difficulty was encountered in determining the focus for plateholder #309561 on machine #1795-07. The projection assembly was not seating properly in the column during the step exposure of the mask. This was overcome and the focus was determined to be .081625.

Thickness versus log exposure curves for Kodak 820 positive photoresist are plotted in figure 8.

Figure 8 Resist Thickness versus Log Exposure for Varying Development Times



Notice, all of the curves have approximately the same slope at the flat line portion of the curves. The intersection points of the normalized thickness for each carriage speed were marked on the graph and a correlation between two carriage speeds with an exposure dose was determined as follows:

carriage speed	log exposure
600	1.55
450	1.65

A similar experiment was attempted with the CEM-388 and using Kodak 820 photoresist without CEM as a control. At this time, the micralign system was not functioning so only the 'contact' mask aligner was used. Since contact of the mask to the CEM would result in adhesion, the wafers were not exposed through a clear mask but placed on top of the mask holder and exposed directly.

The CEM-388 donated was dated 11/85. The guidelines for use of the material (4c-3) state a shelf life of three months at room temperature. High humidity and high temperatures may create a loss of contrast enhancement effectiveness, while at low temperatures, a precipitate will form. (4c-3)

Another adverrsity was encountered with the unavailability of the 934 developer which had been used up to this point to develop the Kodak photoresist. A Shipley developer was substituted in an attempt to salvage the experiment. Gross lifting of the resist occurred and none of the relative intensity versus time plots were of use.

SUMMARY

Sufficient testing of the Contrast Enhancement Material could not be made at this time. A method of determining the exposure dose of the micralign system is required. Fresh CEM material should be obtained and the patterning of a positive resist system with the CEM could be compared with a 'control' (without the CEM) by evaluation of the resulting profiles under a scanning electron microscope.

ACKNOWLEDGEMENTS

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