THE USE OF A WATER SOLUBLE CONTRAST ENHANCEMENT MATERIAL FOR LITHOGRAPHIC IMPROVEMENT

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ABSTRACT

ALTILITH CEM-420WS water soluble contrast enhancement material was used to improve lithographic capabilities of KTI-820 positive photoresist when imaged with a GCA/Mann 4800 DSW g-line 0.28NA Stepper. Improvements in photoresist edge profiles of a two micron line/space pattern were observed using a scanning electron microscope. Experimental data indicated a three fold improvement in contrast and a significant increase in exposure latitude. The experimental results are contrasted with simulated results using PROLITH photoresist modeling software.

INTRODUCTION

Traditional near UV optical lithography has approached its resolution limits. Resolution of an exposure tool is determined as shown in Equation (1).

$$R(min) = K(lambda)/NA \qquad (1)$$

where K is a constant of 0.6, lambda is the wavelength of the exposure source, and NA is the numerical aperture of the exposure tool [1]. For example, a GCA/Mann 4800 DSW g-line Stepper with a NA of 0.28 will have a theoretical resolution limit of 0.93 microns. In order to extend the limit of a lithographic tool, multilayer lithographic schemes have been developed. One such scheme is the use of a contrast enhancement material (CEM) on top of the photoresist layer.

Contrast enhancement lithography was developed in 1982 and has the benefits of extending resolution limits, increasing depth of focus latitudes, increasing exposure and development latitudes, reducing proximity effects, and generating vertical resist profiles with a simple and low defect process [2]. However, early contrast enhancement materials required organic solvents which present health and environmental risks. Contrast enhancement materials also increase the necessary exposure by two to three times, thus decreasing throughput.

100 seconds. Approximately 4ml of Barrier coat CEM-BC5 was applied via static dispense, spread for 2 seconds at 500 RPM, and spun dry for 25 seconds at 4000 RPM to yield 950 angstroms. Approximately 1ml of CEM-420WS was statically dispensed, spread for 2 seconds at 500 RPM, and spun dry for 25 seconds at 4000 RPM to yield 6500 angstroms. No bakes or cures were needed for the contrast enhancement layer. CEM and resist thicknesses were measured using the Nanometrics Nanospec/AFT film thickness measurement system using the program for positive photoresist. An index of 1.66 was used for the CEM [2] and 1.65 for the resist. The barrier coat thickness was measured using ellipsometry. All exposures were done on the GCA/Mann 4800 DSW 0.28NA g-line Stepper. Development was modified such that an added 10 second DI water rinse at 1000 RPM was done prior to development to strip the CEM. The developer used was ZX-934 1:1 with water using a puddle method for 30 seconds. A postbake of 140 degrees Celsius for 120 seconds was done following development.

Once proper focus settings were determined, characteristic curves were obtained by performing a 5 X 5 exposure matrix ranging from 0 to 245 mJ/cm2 of exposure. Thickness measurements were done using a Nanometrics Nanospec/AFT film thickness measurement system. These thicknesses were normalized and plotted versus log exposure. Contrast was calculated using the following equation,

$$\text{Gamma} = 0.6 / \log(E10/E70) \qquad (2)$$

where E10 was the exposure when the remaining resist thickness was 10% of the initial thickness and E70 was the exposure when it was 70%.

Exposure latitude was measured under the same conditions as above using a reticle with varying sizes of line/space patterns. The Nanometrics Nanoline III linewidth measurement system was used to measure the linewidth of a nominal 4 micron resist line for varying exposures at a constant focus setting. The measured linewidth was then plotted as a function of exposure.

Samples from the above procedure were also prepared for SEM analysis using a Cambridge Stereoscan Scanning Electron Microscope. Two micron line/space pairs were analyzed for resist edge profile and sidewall angle.

Both the characteristic curves and exposure latitude results were simulated using PROLITH Photoresist Modeling Software. The ABC parameters used for the contrast enhancement material are A = 6.0 um-1, B = 0.08 um-1, and C = 0.06 cm2/mJ [2,3].

RESULTS/DISCUSSION

Figure 3 shows the contrast of KTI-820 positive photoresist with and without using CEM-420WS. PROLITH simulated results are shown along with experimental results. Experimentally, CEM-420WS

Contrast enhancing materials consist of a photobleachable material which is initially opaque to the exposing wavelength but becomes transparent upon exposure. Figure 1 shows the spectral characteristics of typical g-line contrast enhancing material. The key to the CEM is the bleaching dynamics. In order to be effective, the bleaching rate of the CEM must be sufficiently lower than that of the photoresist speed. If the CEM and the photoresist are properly matched, it is possible to completely bleach through the CEM and expose the photoresist in the light areas before the CEM is completely bleached through in the dark areas. In short, an in situ mask is formed during exposure. This in situ mask sharpens the aerial image and will block scattered light thus increasing image contrast. Figure 2 shows a cross-sectional representation of this process [2].

This project characterized ALTLITH CEM-420WS water soluble contrast enhancing material, thus avoiding the health and environmental hazards associated with solvents. Like many multilayer schemes, CEM-420WS requires the use of a barrier coat called CEM-BC5. This is a thin chemically non-interactive layer between the photoresist and CEM that is necessary to prevent interfacial mixing. Interfacial mixing can prevent proper exposure and development of the photoresist. Photoresist contrast, exposure latitude, and photoresist edge profiles were examined with and without the use of CEM-420WS for KTI-820 positive photoresist. The experimental results were compared to PROLITH simulated results.

FIGURE 1:
CEM Spectral Characteristics

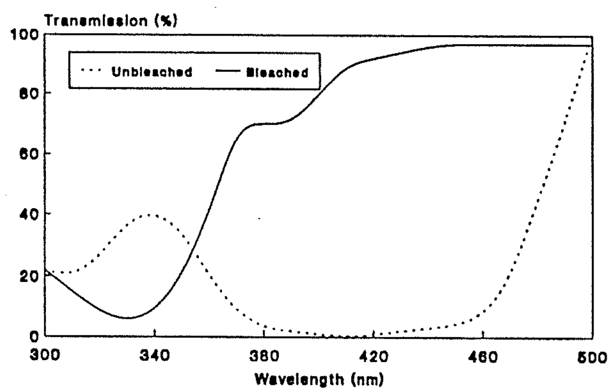
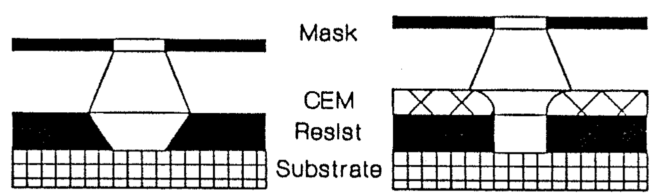


FIGURE 2:
Cross Sections



EXPERIMENT

All photoresist, CEM, barrier coat, and development processing was done on a GCA Wafertrac. Three inch silicon wafers with approximately 5500 angstroms of oxide were used. Adhesion promoter (HMDS) was applied using a static dispense and spun dry at 5000 RPM for 60 seconds. KTI-820 positive photoresist was dispensed statically, spread at 500 RPM for 5 seconds, and spun at 5000 RPM for 20 seconds to yield 1.25 microns of resist. A prebake of 90 degrees Celsius was done for gave approximately a three-fold increase from 1.07 to 3.43 in photoresist contrast. Although simulated results did not accurately predict the experimental results, it did, however, indicate an approximate three-fold increase in contrast as was seen by the experimental results. The photoresist process at RIT is not optimized for process latitude and is probably the reason for poor agreement between experimental and simulated results.

Figure 4 shows the exposure latitude of KTI-820 resist with and without using CEM. A two-fold increase in exposure latitude was seen when using CEM-420WS. Experimentally, a change in exposure of 25% (20 mJ/cm2) would result in a 0.6 change in linewidth for a 4 micron nominal linewidth without the use of CEM-420WS. A 25% (40 mJ/cm2) change in exposure using CEM-420WS would result in a 0.3 micron change in linewidth. As was shown in the previous plot of the characteristic curves, the experimental results did not match that of the simulated results. This again can be explained by the RIT process latitude not being optimized. Despite this, both results indicated an improvement in exposure latitude.

Figure 5 shows SEM photographs of a 2 micron line/space pair without the use of CEM-420WS (Figure 5a) and with CEM-420WS (Figure 5b). The CEM resulted in a much better resist edge profile and an increase in sidewall angle from 70 degrees to 80 degrees. The exposure in Figure 5a was 59 mJ/cm2 and 118 mJ/cm2 in Figure 5b. Using CEM-420WS requires twice the exposure. This, however, should not be a throughput concern in stepper systems since most of the time in these systems is alignment and registration and not in actual exposure time.

FIGURE 3:
Characteristic Curves

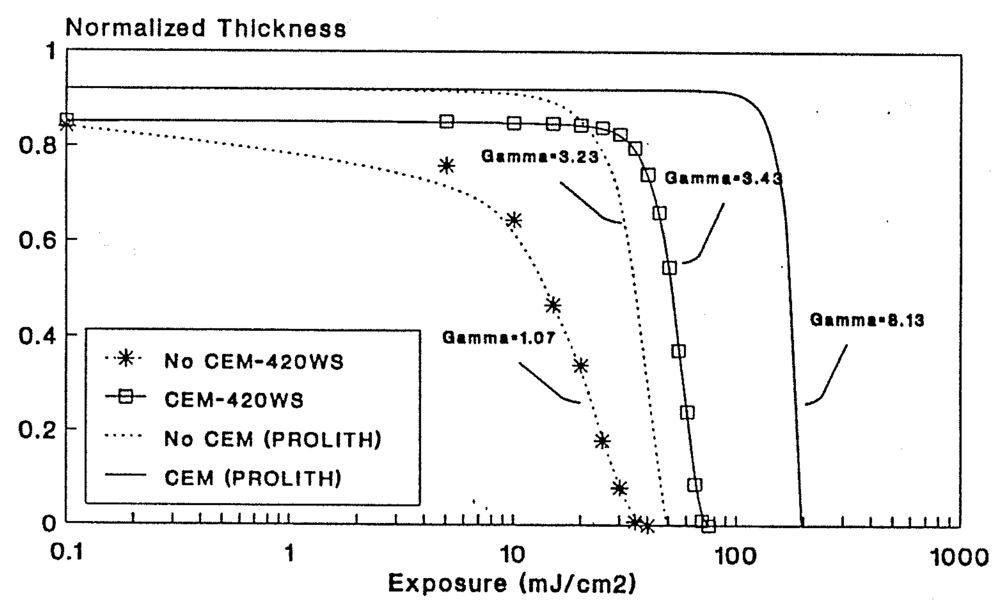
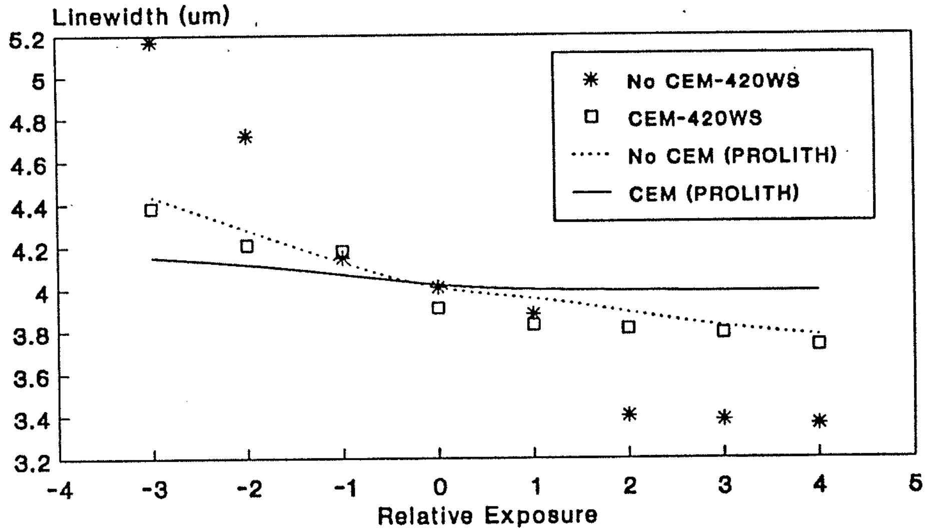
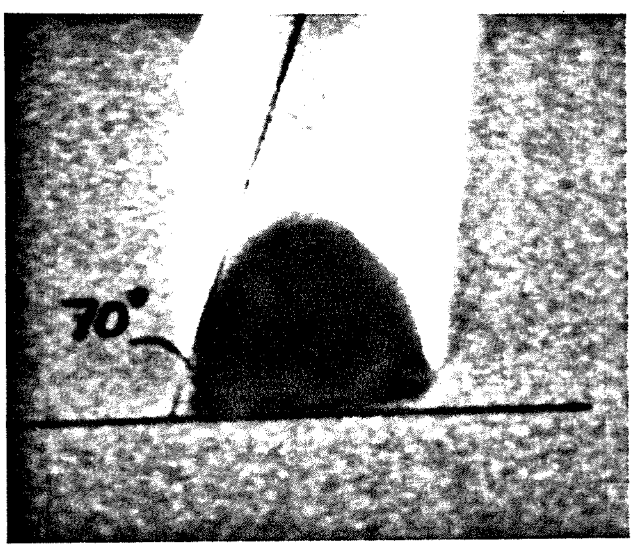
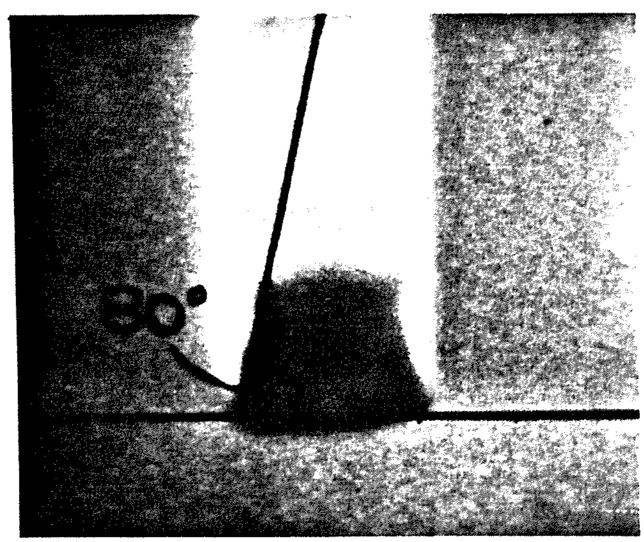


FIGURE 4:
Exposure Latitude
4 Micron Nominal Linewidth





5a: Without CEM-420WS



5b: With CEM-420WS

FIGURE 5: 2 um Photoresist Lines

CONCLUSION

The use of a water soluble contrast enhancement material such as ALTILITH CEM-420WS is a very simple process which yields a significant lithographic improvement. CEM-420WS gave a three-fold increase in KTI-820 photoresist contrast, which agreed with PROLITH predictions. Exposure latitude was doubled using CEM-420WS. PROLITH also predicted an increase in exposure latitude but it wasn't as significant. An improvement in photoresist edge profiles was seen using scanning electron microscope. An increase in sidewall angle from 70 degrees to 80 degrees was seen when using CEM-420WS.

Future work in characterizing CEM-420WS would be to study development latitude, focus latitude, and proximity effects. Experimental determination of the ABC parameters for CEM-420WS and KTI-820 to better match the simulated results to the RIT process is also recommended. Development rate monitoring would also be valuable in verifying the results obtained in this project.

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