DYED RESIST STUDY

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ABSTRACT

Dyed and undyed AZ1512 series resists were characterized for exposure latitude, development rate, and reduction of both notching and standing waves. Uniform and patterned oxidized silicon wafers were coated with aluminum and employed as substrates for all phases of the experiment. The results show that the addition of a dye provided for the reduction of standing waves and an increase in exposure latitude. The control of reflective notching was not verified as collected data proved inconclusive.

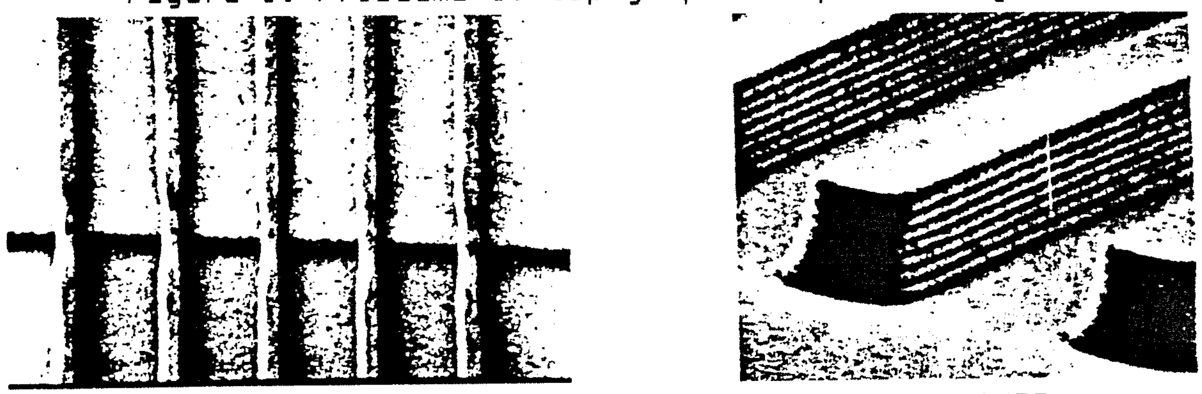
INTRODUCTION

Dyed resist systems provide a versatile approach in the production of high aspect ratio features by reducing notching and standing waves. Notching is the variation in resist linewidth caused by reflection of light from underlying topographical surfaces. Standing waves arise when patterning over a reflective surface, as a result of constructive and destructive interference [1]. Standing waves produce ridges in the resist profile. Both of these elements are detrimental to resist profiles. The individual effects on the resultant resist profiles are illustrated in Figure 1.

The addition of a dye to the resist will allow for a reduction in both standing waves and reflective notching by absorbing reflected and stray light [2]. The implementation of a dyed resist system is an attractive alternative to the many multilayer schemes which have been developed, as its introduction requires little modification of a conventional resist process. Research in terms of dyed resist has shown that while minimizing topographical imaging problems, dyed resist also provides for an increase of exposure latitude [3]. Exposure latitude is represented by the range of exposure energies which will produce an acceptable linewidth. In the dyed resist system stray light is removed, providing greater tolerance to small variations in exposure. As a result, dyed resist systems have been shown to exhibit a greater exposure latitude over undyed resist [4].

Dyed resists also have been found to present inherent disadvantages. As stray light is removed from the imaging system, the required exposure dose in comparison to that of an undyed situation is increased. The increase in exposure dose results with a related decrease in throughput as the overall process time is increased. Also, the increased absorptivity of the dyed photoresist has been observed to relate to a decrease in the resultant sidewall slope as a smaller sidewall angle is produced [5,6].

Figure 1: Problems of topographical patterning [1].



a) NOTCHING b) STANDING WAVES

This experiment dealt with an indepth analysis of the processing applications of a dyed resist system by directly comparing the American Hoechst Corp. AZ1512 and AZ1512-SFD resists. Both are diazoquinone novolac based positive resist systems where the AZ1512-SFD has the addition of an absorbing dye. This non-bleachable dye is most sensitive to the g-line (436 nm) of the mercury vapor spectrum [5,6].

The capacity to reduce standing waves was tested with the Perkin Elmer Development Rate Monitor (DRM) and the application of PROSIM software. The Perkin Elmer DRM provides for the determination of specific resist characteristics including those of contrast, time to clear, and sensitivity by analyzing the resulting resist/developer interactions. Notching was studied through the patterning of resist lines over a previously created aluminum/oxide topography. Finally, exposure latitude for both resists was determined through the application of an exposure matrix and the measurement of the resultant 3 micron lines.

EXPERIMENT

An oxide layer of 4000 A was grown on 8 wafers in a wet oxygen environment. KTI820 resist was used in the transfer of images from the Kodak Exposure Test Mask (ETM) to the wafers. The ETM mask contains structures for lithographic evaluation including various width line/space pairs and focus stars. Once patterned, the wafers were subjected to a buffered HF etch bath to transfer the lithographic image to the underlying oxide surface. The resist was ashed and the wafers underwent a RCA clean. Aluminum was thermally evaporated onto the wafers to produce a coating of 2000 A.

Four wafers were hand coated with AZ1512 applying a 4kRPM spin speed. A prebake of 30 minutes in a convection oven at 90 C followed. A resultant resist thickness of 1.2 microns was measured. One wafer was exposed with the application of a focus-exposure matrix on the GCA 4800 Mann stepper in order to determine the optimum focus and exposure. Once determined, these values were applied as the basis of the notching test exposures. These exposures included both that of nominal exposure and that of 33 percent overexposure. Once determined, both test wafers were exposed on the GCA and developed for 1 minute in AZ312MF (1:1.2) developer. In each case, the ETM mask was shifted to create regions where the resist lines crossed over the underlying topography. This was was used to visually examine the wafers for evidence of notching. This process was then repeated with the application of dyed resist, AZ1512-SFD.

In the experimental analysis of standing waves, bare silicon and aluminum coated wafers were employed as substrates. In both cases, the resist was hand coated applying a spin speed of 4kRPM followed by a 90C/30 minute convection prebake. A Perkin Elmer DRM was set up for testing as per the operating instructions. The AZ312MF developer's bath temperature was 20C. Each wafer was exposed applying the GCA six zone exposure pattern with a starting exposure of zero and exposure increments of 35 mJ/cm2. Once patterned, the development rate information was collected through the DRM. Once completed, the data was analyzed and the PROSIM software package was applied to achieve a profile simulation. Both resist types and the various underlying substrates were modelled.

Finally, in the analysis of exposure latitude uniformly coated aluminum substrates were employed. The given substrate was hand coated with AZ1512 resist with a spin speed of 4kRPM and followed by a 90C/30 minute convection prebake. The wafer was exposed on the GCA 4800 Mann stepper with a matrix which varied exposure from 87 to 170 mJ/cm2 with an incremental exposure of 12.5 mJ/cm2. After development for 1 minute in the recommended AZ312MF developer, the resulting linewidths of the three micron line/space pairs were measured with the stage micrometer. The relation of linewidth versus exposure energy was determined and exposure latitude was calculated as shown in Equation (1). The limitations of 3.0 um. +/- 0.1 um. were determined acceptable in the calculation of the exposure latitudes. This process was then repeated for the dyed resist.

$$\text{Exposure Latitude} = [(\text{EXP max} - \text{EXP min})/\text{EXP optimum}] \quad (1)$$

RESULTS/ANALYSIS

The optimum exposure of the dyed resist was observed to be greater than that required with the undyed resist. Therefore, a decrease in throughput would result as a larger exposure energy would be required. A variation of approximately 20% was observed with the undyed resist averaging an optimum exposure of 125mJ/cm2 and the dyed averaging 150 mJ/cm2. The results from the calculation of the exposure latitude for both resists are summarized in Table 1.

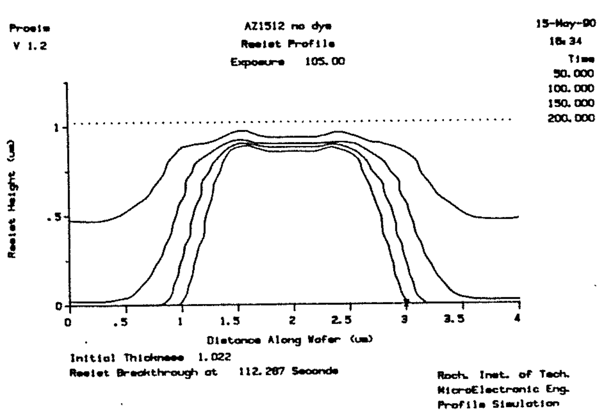
Table 1: Exposure latitude. Note: Tabulated exposures are expressed as a percentage of the maximum exposure.

	AZ1512	AZ1512-SFD
EXP max	84.62	100.0
EXP min	73.08	84.62
EXP opt	76.92	92.30
LATITUDE	15.0%	16.7%

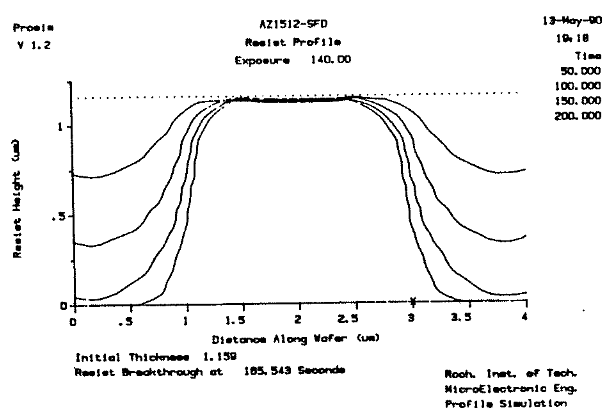
In accordance with earlier research, an increase in exposure latitude was observed with the dyed resist. As expressed as a percentage of the applied range of exposure, the resultant exposure latitude increased from 15% for the undyed resist to 16.7% for the dyed resist.

Figure 2a represents the profile which resulted with the undyed AZ1512 resist. It displays a loss in thickness along with defined standing wave ridges. In comparison, Figure 2b presents the profile created with the dyed AZ1512-SFD resist. It shows minimal thickness loss and a reduction of the ridges which result from standing waves in its profile. These basic profile characteristics were created at many exposure energies and were observed to present little variation between exposures. From observation of the DRM development rate data, both resist produced similar resist characteristics with the exception that the dyed resist displayed a lower sensitivity.

Figure 2: PROSIM Profile



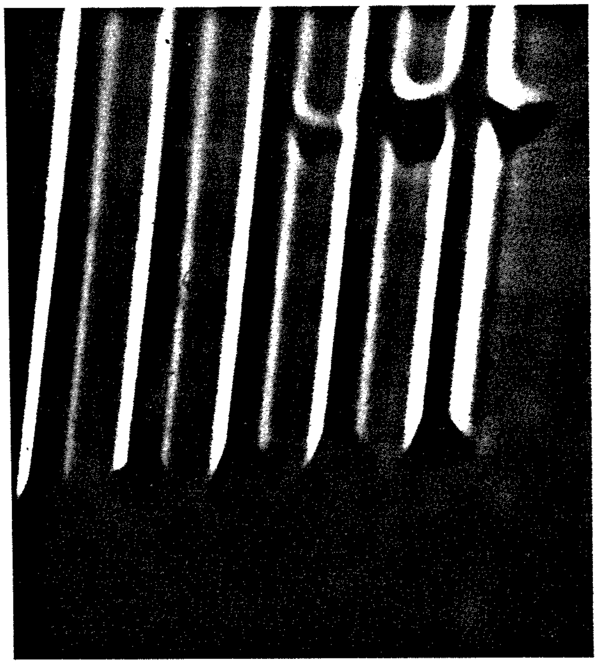
a) AZ1512



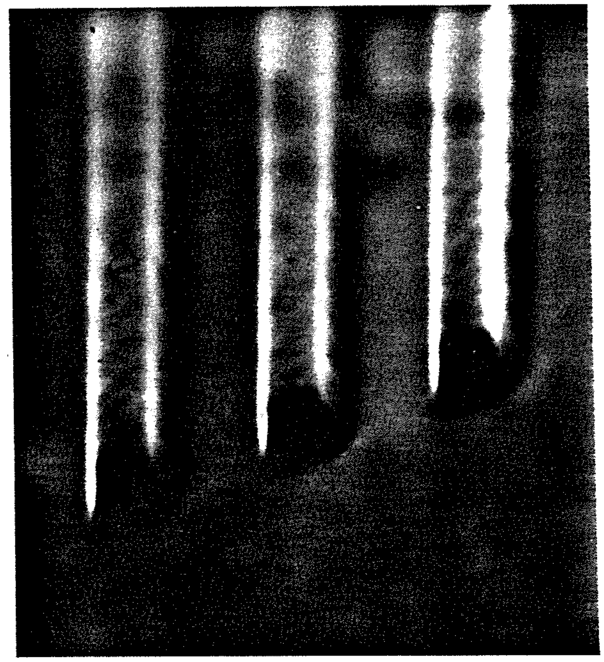
b) AZ1512-SFD

In order to verify the accuracy of these computer profile simulations, Scanning Electron Micrographs (SEM) were taken of actual 2 micron line/space pairs which were patterned using the optimum exposure doses for both the undyed and the dyed resist. Although the quality of the SEM's were far from ideal, a definite improvement in the resist profile was observed with the application of the dyed resist. These micrographs are displayed in Figure 3.

Figure 3: SEM of 2um resist profiles.



a) AZ1512



b) AZ1512-SFD

Both the dyed and undyed resists produced similar results with minimal notching occurring at all of the exposure doses. As a result, no conclusive evidence in terms of the reduction of notching was observed. In terms of further experimentation in this particular area of study, one suggestion would be to observe the effect of coating resist thinner. This may help to enhance the notching which does occur and provide for better comparison between the two resists.

CONCLUSIONS

The exposure energy required for AZ1512-SFD dyed resist was observed to be greater than that required by the undyed AZ1512 resist. A variation of approximately 20% was determined with the undyed resist averaging an optimum exposure of 125 mJ/cm2 and the dyed averaging 150 mJ/cm2. The exposure latitude was observed to increase from 15% to 16.7% with the addition of a dye into the AZ1512 resist system. The capacity of dyed resist to provide for the reduction of standing waves was displayed with the application of PROSIM. These simulations were verified through SEM's of actual resist profiles. Finally, the results from the study of reduction of reflective notching were determined to be inconclusive as no variation was observed between the dyed and the undyed resist.

ACKNOWLEDGMENTS

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