IMAGE REVERSAL WITH AZ5214E PHOTORESIST FOR ETCH AND LIFTOFF

By
Michael A. Ryan
5th Year Microelectronics Student
Rochester Institute of Technology

ABSTRACT

Aluminum pattern definition was evaluated using AZ5214E photoresist in conventional positive and image reversal modes. Wet etch and liftoff strategies were examined for each photolithographic process. Defect density as a function of feature size is given for each process, and yield versus area is projected. It was determined that image reversal processing yielded a lower defect density than conventional resist processing for both etch and liftoff processes.

INTRODUCTION

Image reversal of a positive photoresist has generated much interest among users of optical positive photoresists for integrated circuit fabrication. An image reversal process would facilitate a conversion of light field masks to dark field masks where positive photoresists are being used. Optically, this reduces light scattering, and minimizes image sensitivity to particulate contamination.[1]

Figures 1a and 1b illustrate photoresist imaging with conventional positive photoresist. For some production steps (e.g. oxide, contacts, and implant), the image obtained by using a dark field mask is required. For other processing steps, (e.g. polysilicon and aluminum), photoresist lines are needed to mask the etching process. Imagine several particles scattered randomly on both of the masks shown in Figures 1a and 1b. Clearly, particulate on the light field mask has a higher

FIGURE 1

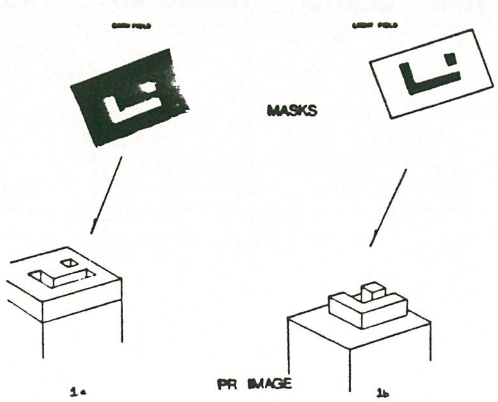
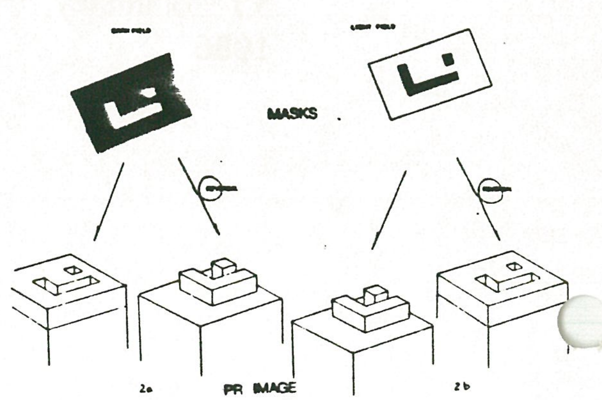


FIGURE 2



probability of blocking light than the same particulate would on the dark field mask. Figures 2a and 2b illustrate how an image reversal process could be used to provide negative tonal images, facilitating a conversion of light field masks to dark field masks.

A second advantage of an image reversal process is the profile control that is available. By choosing process parameters, photoresist profiles of less than 90 degrees, verticle, and greater than 90 degrees may be obtained.[2] It is this latter, 'negative slope' that provides a useful lift-off structure, and is easier to construct than a multilayer resist strategy.

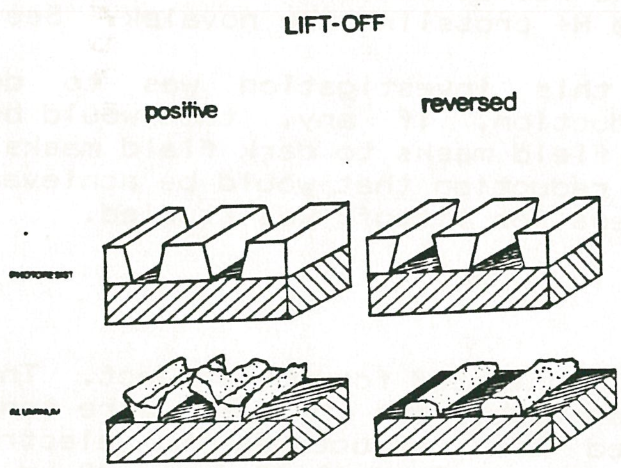


FIGURE 3

Photoresist profiles for lift-off

Figure 3 illustrates the photoresist profile for positive and reversed positive resist. Note that for the positive process, the profile angle is less than 90 degrees. During aluminum deposition for liftoff, aluminum may deposit on the resist sidewall, leaving residual material after the resist has been dissolved away. The reversed process can yield a profile angle which is greater than 90 degrees. The sidewall is then shadowed from metal deposition, resulting in a cleaner liftoff. However, an image reversal liftoff process uses a light field mask, and defect density attributed to contamination on the mask is expected.

Currently three methods for image reversal of conventional positive photoresist are used in industry. The monazoline process[3] is realized by dissolving monazoline into photoresist prior to coating. Ammonia vapor priming may also be used following exposure. Both these processes are used to induce a decarboxylation of the exposed areas of the film, yielding a non-photosensitive indene of low solubility in developer. Additional equipment and chemicals are required for both of these processes.[4]

Image reversal may also be achieved by employing AZ5214E positive photoresist. AZ5214E can be used in an image reversal mode by treating the resist with a bake following exposure. No flood exposure is required; no additional chemicals are required. The mechanism for image reversal in the 5200 series appears to be one of crosslinking rather that decarboxylation. For the base induced decarboxylation mechanism, the dissolution rates of unexposed positive resist and decarboxylized resist are relatively the same; a flood exposure is used to provide an appropriate solubility ratio. The exposed regions of the 5200 series, when given a heat treatment, become much less soluble than the unexposed regions of the same material. This suggests a dramatic increase in molecular weight in the 'reversed' areas, probably due to crosslinking. An additive, similar to malamine, is most likely in the resist formulation. The additive, in the presence of heat and H+ crosslink the novalak. See Figure 4.

The purpose of this investigation was to determine the defect density reduction, if any, that would be achieved by conversion of light field masks to dark field masks. Secondly, the defect density reduction that would be achieved by using an image reversal process for liftoff was studied.

EXPERIMENTAL

Two masks were fabricated for the project. The layouts of the masks were identical, but the masks were tonal opposites. The masks patterned test structures to electrically probe aluminum linewidth for 3,5,10,15,20, and 30 um lines. Also, test structures for each of these linewidths, (feature sizes) to determine a defect density for electrical shorts and opens, were included. See Figure 5. The areas for each of these test structures are given in Table I.

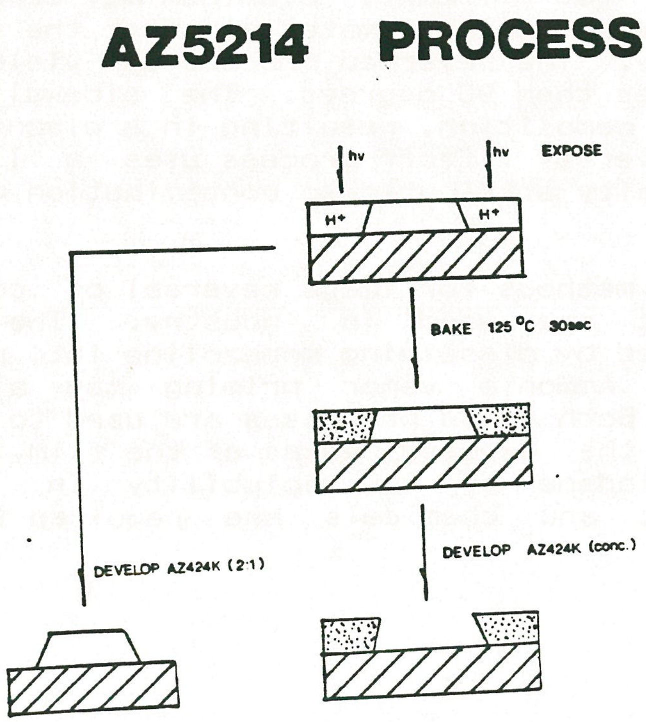


FIGURE 4

The AZ5214 process for positive (left) and negative (right) images.

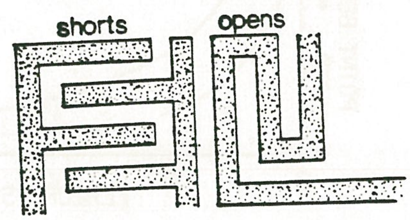
TABLE I

Feature Size Test Area For WILMA Test Chip

Feature size	Test	Area (um^2)
3	short	5,100
	open	5,850
5	short	21,875
	open	32,025
10	short	52,200
	open	101,900
15	short	61,875
	open	77,700
20	short	50,000
	open	84,600
30	short	122,400
	open	230,700

FIGURE 5

TEST STRUCTURES



Once the aluminum had been patterned using positive and reversed resist, several die were probed to determine defect density for each feature size. Knowing defect density as a function of feature size, Yield vs Area curves may be obtained using Murphy's expression:

$$Y = (1/(1 + A*D))**N \quad \text{where } A=\text{chip area} \quad [5]$$

D=defect density

N=number of mask levels

A wet silicon dioxide was grown 5000 A thick on 3 inch (100) silicon wafers, n type. Four processes, listed below, were used to pattern aluminum on the substrates. Full process details are found in Appendix A. Three (3) wafers were used for each process.

1. Positive wet etch (light field mask)

2. Reversed wet etch (dark field mask)

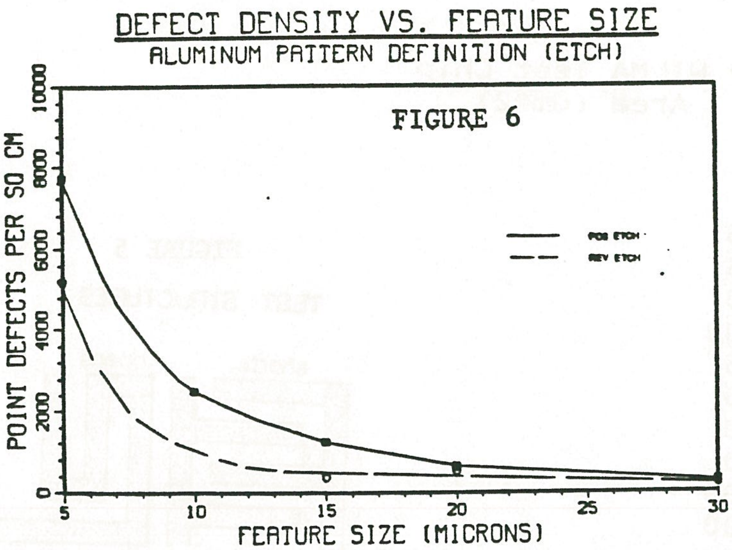
3. Positive lift off (dark field mask)

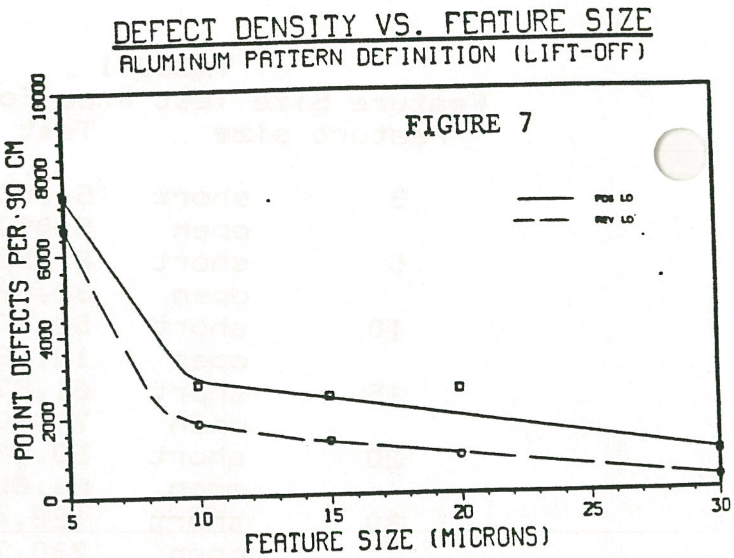
4. Reversed lift off (light field mask)

Following processing, twenty dice were sampled from each process. The defect density was then determined for each feature size.

RESULTS

Defect density vs. feature size for wet etch is plotted in Figure 6. The image reversal process, by employing a dark field mask, yielded as much as fifty percent fewer defects than the conventional positive process. In Figure 7, defect density vs. feature size for the lift-off process is plotted. Once again, the image reversal process had a lower defect density than the positive tone process, most likely due to the profile angle.





Overall, the reversed wet etch process was the cleanest. The image reversal lift-off process had similar defect density to the positive tone etch process. It is believed that this defect density is driven by the use of light field masks on the contact printer. The image reversal process exhibited better resolution; three micron lines were imaged with difficulty. The conventional positive process could not resolve three microns.

CONCLUSION

For pattern definition of aluminum and polysilicon, an image reversal process using AZ5214E photoresist, employing dark field masks was shown to produce fewest defects. As much as fifty percent fewer defects were found at 5 micron feature sizes, which may aid in reducing geometries using silver halide masks.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Mark Spak of AZ Photoresist Products, Dr. Lynn Fuller and Mr. Michael Jackson of Rochester Institute of Technology for their assistance with this project.

REFERENCES

[1] M. Long, Image Reversal Techniques with Std. Positive Photoresist, SPIE Vol469, p189, 1984

[2] H. Klose, et al, Image Reversal of Positive PR, Char and Modeling, IEEE Trans on Elect Dev, Vol ed32, No9, Sept 85

[3] S. MacDonald, et al; Image Reversal, IBM Research Lab, San Jose, CA, undated.

[4] M. Spak, et al; Mechanism and Lithographic Evaluation of Image Reversal in AZ5214 Photoresist, presented at 7th Int. Tech. Con. on Photopolymers, Ellenville, NY

[5] J. Lee; Multilayer Resist Processing: Economic Considerations, Solid State Tech., June 1986, p143

APPENDIX A

PROCESS DETAILS

Positive Etch

1. Dep 1500A Aluminum
2. Coat 1.4 um AZ5214
3. Softbake 90C 45 sec
4. Expose 30mJ/cm^2
5. Develop AZ424K (2:1) 30 sec
6. Measure/Inspect
7. Hardbake 140C 45 sec
8. Aluminum Wet Etch 35C
9. PR Strip

Negative Etch

1. Dep 1500A Aluminum
2. Coat 1.4 um AZ5214
3. Softbake 90C 45 sec
4. Expose 45mJ/cm^2
5. Post Exp Bake 125C 30 sec
6. Develop AZ424K (conc) 30sec
7. Measure/Inspect
8. Aluminum Wet Etch 35C
9. PR Strip

Neg Liftoff

1. Coat 1.4 um AZ5214/Bake
2. Expose 45mJ/cm^2
3. Post Exp Bake 125C 30 sec
4. Develop AZ424K (conc) 30 sec
5. Measure/Inspect
6. Deposit 1500A Aluminum
7. Liftoff (AZ1500 Thinner)

Pos Liftoff

1. Coat 1.4um AZ5214/Bake
2. Expose 30mJ/cm^2
3. Develop AZ424K (2:1) 30sec
4. Measure/Inspect
5. Deposit 1500A Aluminum
6. Liftoff (Acetone)