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The Effects of Contrast Enhancement Material over an Image Reversal Resist System

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Abstract - As computer chips get smaller and the number of devices on them increases, the requirements for lithography reduction becomes more significant. One way to improve resolution and contrast of sub-micron features is to use an Image Reversal(IR) resist system. Further improvement can be obtained using a Contrast Enhancement Layer (CEL). The CEL provides a contact mask for the underlying resist system. The CEL allowed for the IR resist to produce better defined lines and spaces. Resolving 1 μm lines was possible. However, the 1 μm spaces were not. Overall, the contrast enhance material did improve resolution and contrast of the larger features (>2μm), however, when the experiment was replicated, the same results were not seen. There was some adhesion problems with the IR resist, and there was still some difficulty in removing all of the CEL.

I. Introduction

The image reversal resist processes are used to improve the resolution over other conventional resist systems. By introducing a post exposure bake (PEB) and a low energy flood exposure, the image reversal resist cross links in the exposed areas and takes on the properties of a negative acting resist. During the PEB, a "monazoline process" occurs. Which means, that the monazoline amine causes a thermal decarboxylation of the base soluble DQN photoproduct (indene carboxylic acid). This causes the resist to become base insoluble. The flood expose step causes all other areas to become soluble.

AZ5214 (AZ Products), an image reversal resist, was used in this experiment because it needs no pre- or post- chemical treatment and does not require a high flood exposure dose. It also allows for high resolution, high contrast, and is thermally stable.

The contrast enhancement material used in this experiment was CEM-420 (MicroSi). A photochemical isomerization of diarylnitrones to oxaziridines occurs when exposed to wavelengths of 365nm-436nm. This means that a non-transparent material under goes a bleaching process, rendering it transparent in only the exposed areas. In turn, this material can be used as a contact mask over any existing resist system.

In the initial experiment, the CEL thickness was to be varied along with the exposure dose and the depth of focus in order to achieve an optimum process for <1μm features. However, it was seen that there was an interaction between the layers, and the water soluble CEM with barrier coat would not come off the IR resist. Several new process steps were taken to solve this problem. It was determined that the barrier coat was the material causing the problems, and this step was removed.

II. Chemical Structures

AZ5214 is a diazonapthonuinone (DNQ) base image reversal resist. When the DNQ is exposed, it changes to an indene carboxylic acid (Figure 1).

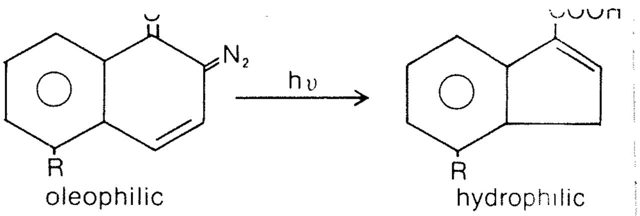


Figure 1

It then undergoes a chemical reaction with the help of an alkyl amine, forming an unstable amine salt of the carboxylic acid (Figure 2).

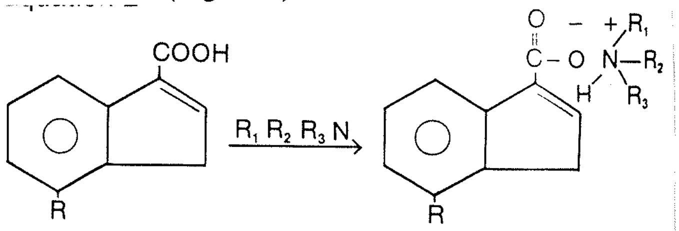


Figure 2

To successfully transform this material into a negative acting resist, decarboxylation of the carboxylic acid must take place. This is done using a post exposure bake step. Along with this bake, a catalyst is added to speed up the reaction. In turn, the amine salts are changed into an aqueous alkali insoluble indene (Figure 3).

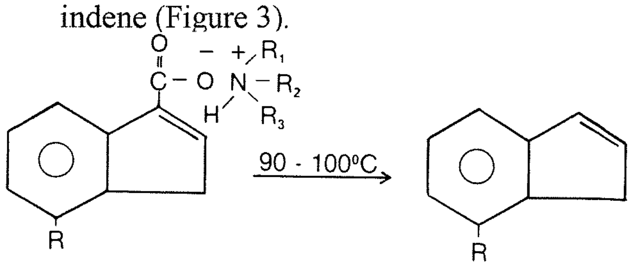


Figure 3

CEM-420ws is a photochemical material which bleaches, or becomes transparent in exposed areas. It starts out as an opaque nitrone. When it is exposed, it undergoes a chemical reaction which transforms the nitrone into a transparent oxaziridine (Figure 4).

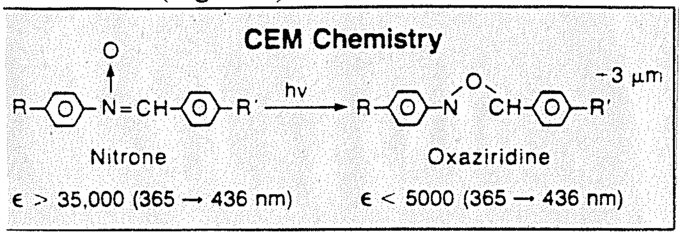
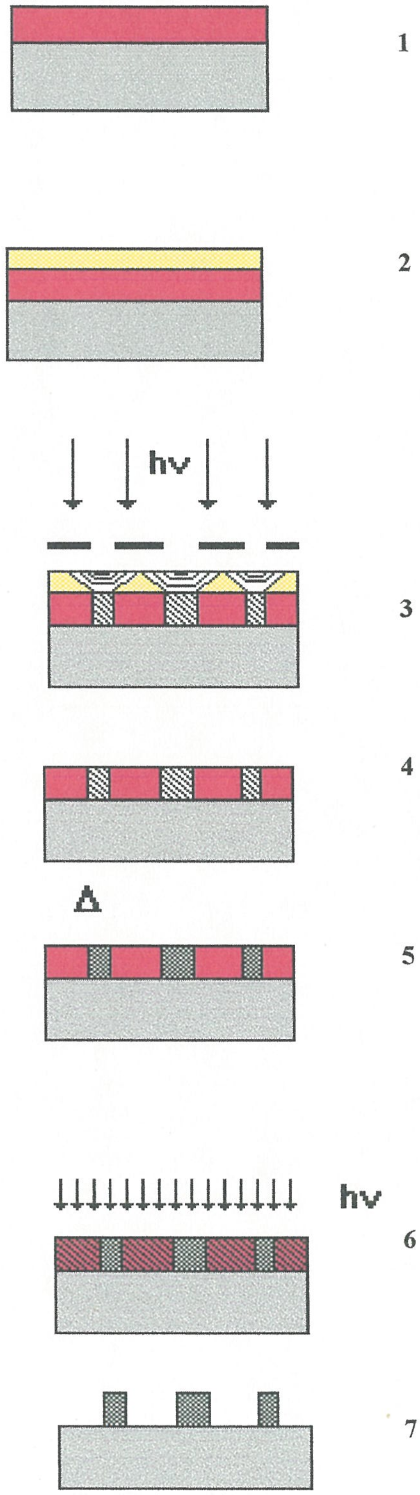


Figure 4

III. Experimental Procedure (Final)

-Dehydration Bake 10 minutes 100 °C hotplate
-Spin on HMDS 4500 rpm 30 seconds
-(1)Spin on AZ5214 4000 rpm 30 seconds
-Prebake 100 °C 45 seconds hotplate
-Measure resist thickness on Nanospec AFT thickness measurement tool
-(2) Spin on CEM-420ws 6000 rpm 30 seconds
-(3) Expose using a projection lithographic tool (GCA 6700 wafer stepper
Dose = 450 mJ/cm^2
-(4) Rinse CEM
Place in petri dish with DiH_2O
Agitate
-(5) Post Exposure Bake 115 °C 90 seconds hotplate
-(6) Flood Expose using g-line exposure tool (Kasper Aligner) 30 seconds
-(7) Develop 4 : 1 DiH_2O : 351 Developer, Until cleared

III A. Cross-Sections



IV. Results and Discussion

There were some problems in the actual processing of these two materials. First, there were some adhesion problems with the AZ5214. A dehydration bake and an HMDS coat was added to the original process, this seemed to solve this problem. Second, the CEM was not rinsing off of the AZ5214. The original method was to spray and spin the material off. It was also seen that the CEM-420ws had some type of interaction with the AZ5214, causing an interfacial layer, which also prevented the material from being removed. To solve this problem, a higher spin speed was recommended, changing it from 4500 rpm to 6000 rpm. This stopped the two materials from adhering. Then it was seen that if a soak was used instead of an aggressive rinse, the CEM-420ws was removed, but process time increased a great deal.

An Exposure matrix was run to determine the optimum exposure dose to successfully image with and without CEM. For AZ5214 dose = 385 mJ/cm^2, for AZ5214 with CEM-420ws dose = 450 mJ/cm^2. It was seen that in the overexposed regions, the CEM improved the resolution of the AZ5214. (Figures 5A & B)

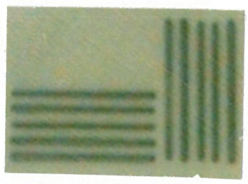


Figure 5A
1 μm lines AZ5214 with CEM
500 mJ/cm^2

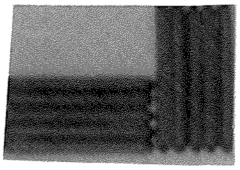


Figure 5B
1 μm lines AZ5214 without CEM
500 mJ/cm^2

In conventional positive and negative resist systems, exposure dose with CEM is twice that without CEM. AZ5214 image reversal resist is a very slow resist, and only needed 14.4% more exposure dose to produce an image.

A focus matrix was also performed to show how CEM improves DOF over AZ5214, but none of the images were clear or measurable. However, the CEM did moderately improve depth of focus, visually, over AZ5214 for lines > 2 μm.

V. Conclusions

CEM-420ws marginally improved 1 μm resolution of AZ5214. The performance of AZ5214 and CEM-420ws were very dependent of age and storage conditions. Because of the inconsistency of the materials, this process was not repeatable. Even though resolution was improved in this experiment, this would not be a better alternative because of low throughput due to added process steps. Finally, although this experiment didn't completely fulfill the primary objectives, much was learned about material performance, experimental research and procedures, and the various equipment used. Overall, this experiment could help one understand the perils involved while performing a research project, and the satisfaction one can get when the results of the experiment are helpful for further research.

VI. References

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