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E-BEAM LITHOGRAPHY USING PHOTORESISTS FOR IMAGE REVERSAL PROCESS

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ABSTRACT

The AZ5214 positive tone photoresist could be used to obtain negative images by reversal image process in e-beam lithographic technology.

Direct Write on silicon wafers were done to verify the capabilities of this process. We show that this technique could be well suited to obtain useful transferred pattern in microelectronics. Tests with e-beam ZBA-21 Jenoptik system in the laboratory indicated a remarkable advantage when the resist is used in mask making process for image reversal. Exposure time is significantly decreased when device or circuit layouts had a bright or dark dominant area.

INTRODUCTION

In this paper we present some results obtained in image reversal process with AZ5214 (fig. 1), using direct write e-beam lithographic process.

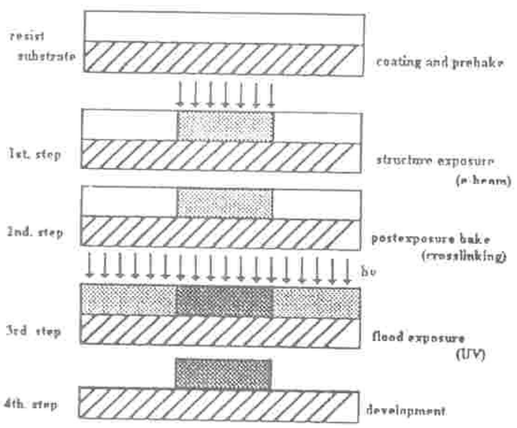

Fig. 1 - AZ5214 image reversal process [1]

The basic principle of image reversal technique using novolak/diazo type resist is well known, although the chemical mechanism of this process in not yet fully understood.

Figure 2 schematically shows a comparison between standard positive tone patterning and image reversal processing.

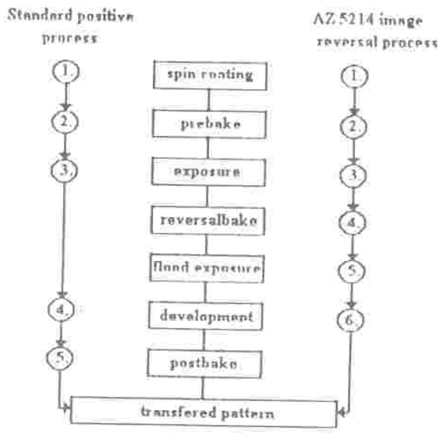

Fig. 2 - Comparison between standard positive and reversal with AZ5214image processing (scheme) [1]

In the search of efficiency of highdensity IC productionthe production using photoactive positive resist, has been recoursed to some modifications as multilayer resist (two or three-layer). The one-layer alternative is the image reversal - with this option the resist may be used as positive or negative [2].

In fact whenever chromium has to be patterned in small and large clear areas, the reversal image process allows a drastic exposure time reduction, because for small exposed areas and after the image reversal, the chromium remains. With this, the filament of e-beam system is preserved, the temperature increase is reached and throughput is increased.

The image reversal process requires a certain amount of basic aditives like imidazole to be added in diazoquinone novolak resin, but it is not always necessary to add base in resist before exposing. Some sulfonic acids produced from arildiazonaphthoquinone can catalize the crosslinking of novolak matrix in the exposed areas permiting another process to image reversal [3], [4].

The AZ5214 resist presents this kind of structure discribed above. The AZ5214 resist, as well as other diazonaphthoquinone resists, were characterized by thermogravimetric and calorimetric analysis, giving a total loss of mass at 300°C and a thermal stability up to 200°C, the temperature of vitreous transition is 480°C and presents a maximum at 171°C [5].

The main change that involves the transformation of positive resist in negative resist is the variation in the solubility of eletron resist after the whole process. To change the positive image (more soluble) to negative image (less soluble), the compound formed after exposing (in exposed areas) has to go through, by some mechanism occurred in the postbaking step (PEB), a transformation to an insoluble derivative in alkaline aqueous solution.

The reaction mechanism of the diazonaphthoquinone compound (PAC) exposed to UV radiation has been discribed in literature. For e-beam exposure, this reaction does not occur in vacuum, without water for the formation of soluble acid in aqueous alkaline solution. In the alternative way proposed by Pacąnski [6], for e-beam exposure in vacuum and room temperature conditions, the Wolf rearrangement does not occur with a ketene formation but a carbene reactive is formed. This carbene attach the C-C and C-H linkage aromatic ring of the resin, forming naphthols soluble in alkaline solution. This was proposed for the formation of positive image.

The chemical formula of the light sensitive compound in AZ5214 resist, it is easily used as a negative resist. When the exposed film is baked the crosslinking mechanism of the resin occurs catalized by arildiazonaphthoquinone sulfonic acid resulting in insoluble compound.

As described by other authors and in our former paper [7], when the resist is exposed to e-beam radiation and subsequently developed with a developer based on alkaline solvent (AZ400K dilute), one can get a positive image, that is, the exposed region is dissolved. Meanwhile, when the film of exposed resist is submitted to postbaking during a short time, the irradiated region remains more resistent to dissolution than there original resist. This will be sufficient to get a negative image, but a subsequent UV exposure increases the resist contrast [8].

EXPERIMENTAL

It has already been described on a previous paper [7] the stages concerning cleanliness and wafer drying, the application of resist layer and film thickness measurement. The next stage will be described as follows:

The low adhesion of the organic film on semiconductor made the utilization of silicon wafer with resist difficult on the conditions above.

As the thickness of the film is reduced, the adhesion is damaged. The aim of reduced thickness of film is the image resolution improvement after development step. [9]. With the purpose of obtaining the best results, a previous step was introduced before the application of the resist. This step consists on apolar layer formation on wafer surface, that occurs by spinning the organic solvent of resist and a subsequent drying in oven during 10 minutes at prebaking temperature (80°C).

The prebaking temperature was maintained at 80°C during 5 minutes. The thickness of the film remained constant in 0.5 μm. and alternativity in 1.35μm.

The exposure was carried out with e-beam lithography system ZBA-21 Jenoptik with 20 keV energy. The flood U.V. exposure was done by using Kulicke and Soffa model 686B.

The post exposure bake (PEB) was processed on a hot plate. Several temperatures were used between 80°C and 125°C and at times up to 3 minutes.

The exposed wafer was developed by immersion in diluted developer with slight agitation and rinsed in deionised water.

The developer system (AZ400K) was used in different concentrations varying between 0.20 and 0.30N.

RESULTS AND DISCUSSION

The procedures to obtain the image reversal involves the following steps after e-beam exposure:

Post Exposure Bake (PEB)

This step is crucial to obtain the image reversal process. During the baking, resin crosslinking (hardening) occurs, and the resin becomes more soluble. The best adequate time and temperatures confirm the data reported elsewhere in the literature [10], i.e., 125°C and 1 minute.

Using more time, the development process after U.V. flood exposition was delayed and the unexposed e-beam resist apparently becomes hardened, and as a result, the development was not homogeneous.

Decreasing temperature does not permit the negative image to be fixed. This is a similar effect caused by low exposure on e-beam.

Flood Exposure U.V.

Experiments were performed at different U.V. exposure time (various doses) - ranging form 6 to 15 seconds. In this interval, no appreciable influence in final image was observed.

Developing

With 0.26N solutions of AZ400K, the developing time was of 45s at 22°C. This developing time was enough to remove the resist in no e-beam exposure regions. The edges of the layout are more resistent to removal and this resistence is greater with closer lines.

E-Beam Exposure

The structure tests had different shapes and dimensions. The dose of each exposure was maintained constant and the dose interval varied from 25 to 70μC cm^{-2}. For a smaller dose, the negative image was partially dissolved, the film thickness was reduced from 0,5μm to 0.3μm. The areas smaller than 1μm had to be developed, were dissolved but the edges were not well difined. For greater dose, the resist contrast were good, the edges were well difined but the small structures that had to be dissolved were damaged by backscattered electrons. It was noticed that the layouts of 4μm lines width were extended (see figures)

It is possible that for greater doses, the resist undergoes a heating in regions closer to the exposed lines. The crosslinking of photoactive component (PAC) with resin causes a decrease in solubility. When the PAC is thermolytically degraded in the absense of water, it forms a linkage with a molecule of the carrier resin causing an increase in molecular weight with a corresponding decrease in solubility. This effect acts in the same direction as the proximity effect. This heating produces the resist hardening in these areas and causes the developing time to increase. This heating is different than PEB when the PAC thermolytically decomposes in short intervals on hot plate baking because there is a larger concentration of water in the surrounding.

Experiments were perfomed with 1.35μm films and doses varying from 25 to 60μC.cm^{-2}. The interproximity effects are easily observed in the pictures below. Equal lines/space of 4μm are used. For isolated lines, the line width does not change. But when it is closer, the negative image becomes larger (see fig. 3 to fig. 4).

The problems in using this resist on silicon wafer are the same for positive tone and negative tone pattern. The advantage in its dual use is remarkable when the resist is used in mask making, where, depending on the desirable structure we can choose the process without changing the material.

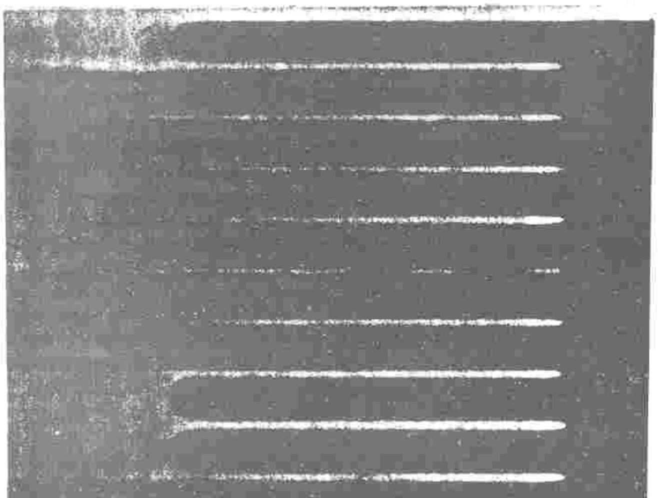

Fig. 3 - AZ5214 Image reveral patterning on silicon wafer with ZBA-21 Jenoptik e-beam lithographic system dose 25μC cm^{-2} - 1.35μm resist thickness - 4μm lines and spaces.

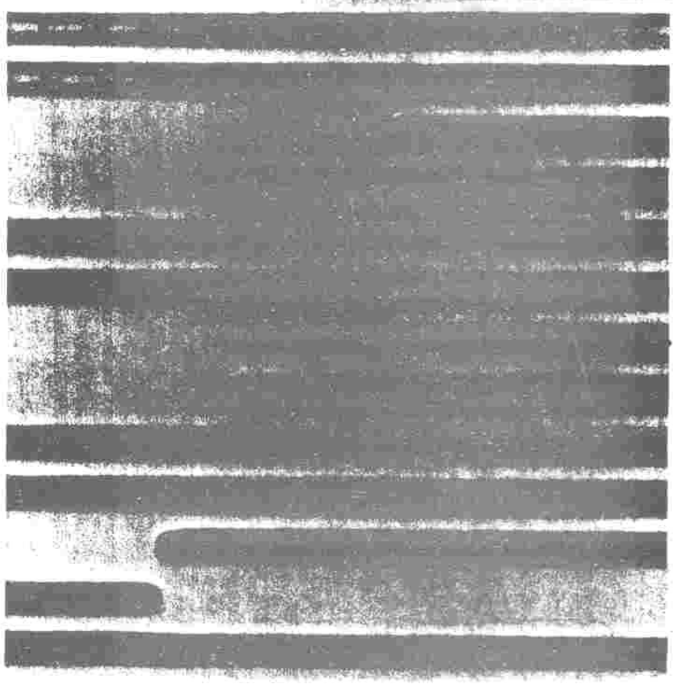

Fig. 4 - AZ5214 Image reversal patterning on silicon wafer with ZBA-21 Jenoptik e-beam lithographic system dose 70μC.cm^{-2} - 0.5μm resist thickness - 4μm linesand spaces

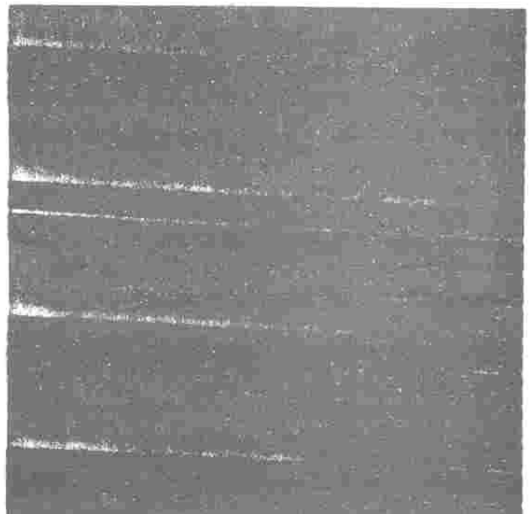

Fig. 5 - AZ5214 Image reversal patterning on silicon wafer with ZBA-21 Jenoptik e-beam lithographic system - dose 50μC.cm^{-2} - 0.5μm resist thickness - 4μm lines and spaces.

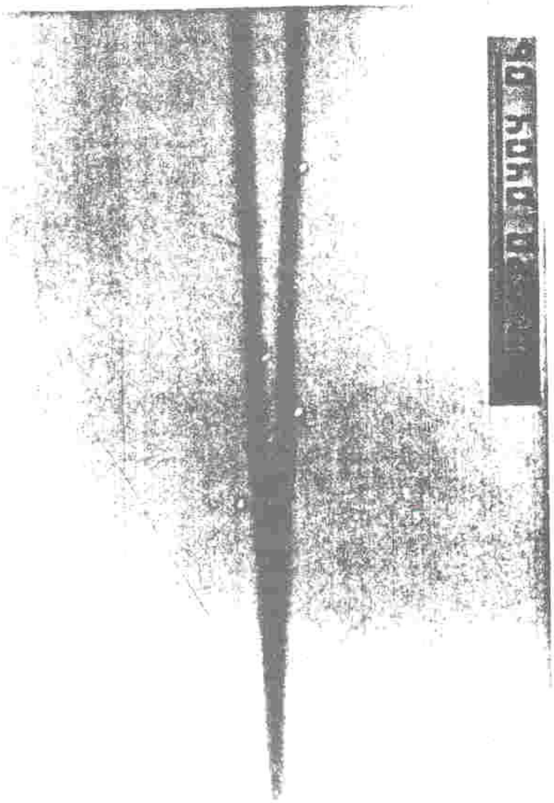

Fig. 6 - AZ5214 Image reversal patterning on silicon wafer with ZBA-21 Jenoptik e-beam lithographic system dose 50μC cm⁻² - 0.5μm resist thickness - Electrooptical device mask - light power divider, minimum linewidth of 4μm and angle less than 1 degree between branches (SEM photo)

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