A METHOD TO IMPROVE STEP COVERAGE OF CONVENTIONAL POSITIVE WORKING PHOTORESIST

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ABSTRACT

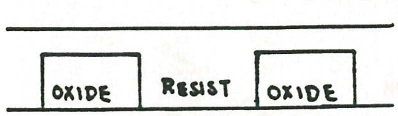
Positive resist coated wafers were immersed in a dilute alkaline base developer, such as 5:1 AZ351, for a short period of time prior to exposure. The purpose of this sequence was to improve development rate discrimination of conventional positive photoresist, which will enhance step coverage. A SEM comparison of a 5 micron line/space pair pattern of AZ1350 resist on a 1.2 micron step, showed this pre-treatment yields improved step coverage compared to a conventional process.

INTRODUCTION

Currently with positive working photoresist, processing difficulties arise transferring an optical image onto a wafer surface with large topographic features (greater than one micron). Multilayer resist schemes have been proposed with the purpose of resolving these problems, but with added expense and technical complexity as well [1,2].

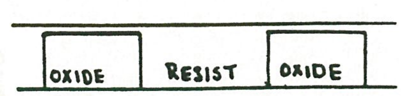
The resist coverage problem can be seen by looking at the cross sectional profile of applied resist, as seen in Figure 1a. During application, the resist spreads out uniformly across the wafer, and areas with large topographic features will have a thinner resist coating. With any resist, a 20:1 development discrimination between the exposed and unexposed areas is desirable [3]. For positive resist, this means the unexposed areas will be reduced an amount equal to one twentieth of the exposed areas when placed in developer. The area of concern is the unexposed region with the thinnest resist coating, since when placed in developer any thickness loss may be significant, as seen in Figure 1b.

FIGURE 1a: Unexposed Resist



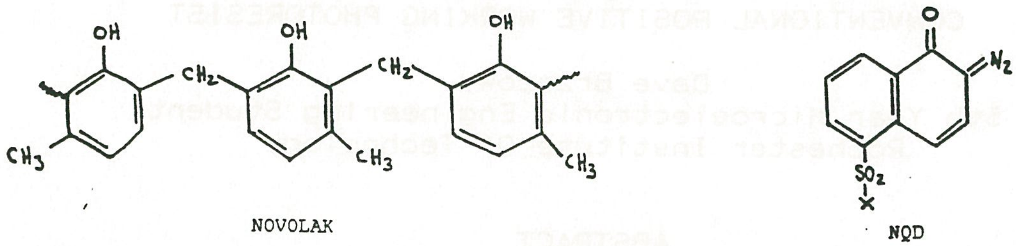
Profile of resist pre-development

FIGURE 1b: Unexposed Resist



Profile of resist post-development

FIGURE 2: Conventional positive resist formulation



For a nominal initial resist thickness of 1.4 microns, and topograghic features on the wafer being in the order of 1.2 microns, the resist thickness coverage will only be 2000 angstroms on top of the tallest features. The development needed to clear a resist thickness of 1.4 microns, results in a thickness loss of 700 angstroms in the unexposed areas using a 20:1 development rate discrimination. In the valleys this is only a 5 percent thickness loss, but on top of the step this amounts to a 35 percent thickness loss. A thinning of resist can lead to masking problems and in extreme cases, there will be a discontinuity over the step.

In order to increase the development rate discrimination, which will reduce the thickness loss in the unexposed areas thus increasing the step coverage, a simple pre-exposure treatment has been proposed [4]. It involves the immersion of a photoresist coated wafer, in a dilute alkaline base developer, such as 5:1 AZ351, for a short time, typically between 15 and 30 seconds prior to exposure.

The theory of the pre-exposure treatment is based on the chemistry which takes place during development. Conventional positive working resists consist of two key components, novolak and naphthoquinone diazide (NQD), as seen in Figure 2. The novolak acts as the binder which controls the resist coating quality. The NQD is the photoactive component which is responsible for the change in solubility of the resist upon exposure.

The exposed areas of the resist undergo a transformation of being a base insoluble sensitizer, to a base soluble acid during exposure [3]. When placed in developer the exposed areas are easily dissolved. A synopsis of the chemistry is shown in Figure 3. The unexposed areas, not altered, still consist of novolak and NQD. Novolak by itself is very soluble in developer and approximately 4000 angstroms per minute can be removed [3]. A slower rate of dissolution in the unexposed areas is believed to be a result of a base induced coupling between the novolak and the NQD. The crosslinking reaction is shown in Figure 4.

FIGURE 3: Exposure chemistry

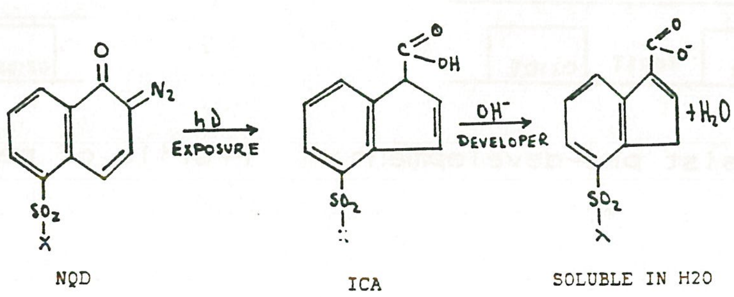
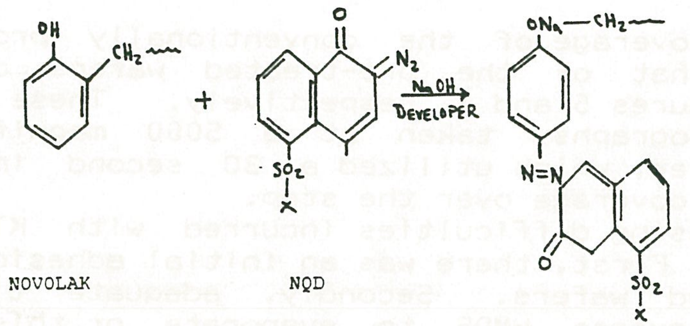


FIGURE 4: Development chemistry of unexposed areas



In conventional developing it is believed this coupling reaction does not happen to completion, due to the developer being amply used in developing the exposed resist. Thus fresh developer is not locally available to the unexposed areas so the coulping can not effectively take place. The pre-treatment allows adequate time for the crosslinking to take place on the surface, thus reducing the solubility of the resist at the surface, while the bulk still retains its photoactive characteristic. The result is increased development discrimination, which stated earlier, will preserve the resist coating on top of large topographies.

This study is an investigation on the effect of a pre-exposure treatment on step coverage. KTI 820 and Hoechst AZ1350 resists were examined.

EXPERIMENT

Large topographies were created by thermally growing a 1.2 micron layer of silicon dioxide, masking a 5 micron line/space pattern and utilizing a wet etch to create the step. After a plasma ash and subsequent clean the wafers were ready for further processing.

The wafers were primed with HMDS and coated with Hoechst AZ1350 photoresist with an nominal thickness of about 1.4 microns. A prebaked at 90 degrees celcuis was carried out for 30 minutes in a convection oven. At this point the wafers were divided into two groups. One group of wafers were immersed in 5:1 AZ351 developer for a time varying between 15 and 30 seconds, rinsed in DI water for 2 minutes, air dried and then were selectively exposed. The other group went directly to exposure.

A Kasper contact mask aligner was used for exposure, which emits strongly at the G,H, and I lines of the ultraviolet light spectrum. The wafers were exposed using a 5 micron line/space pair mask, which was aligned perpendicularly to the oxide steps. The wafers were developed in 5:1 AZ351 developer for 60 seconds. The exposures needed were approximately 90 mj/cm2 for the pre-treated wafers, and 80 mj/cm2 for the standard group. A scanning electron microscope was used to evaluate the resulting profiles.

A similar procedure was done with KTI 820 coated wafers, but

processing difficulties precluded the completion of this study.

RESULTS/DISCUSSION

The step coverage of the conventionally processed wafers compared to that of the pre-treated wafers can be visually examined in Figures 5 and 6 respectively. These are scanning electron micrographs, taken at a 5000 magnification. The pre-treated wafer, which utilized a 30 second immersion time, shows a better coverage over the step.

The processing difficulties incurred with KTI 820 resist were two fold. First, there was an initial adhesion problem with the pre-treated wafers. Secondly, adequate time should be allotted for excess HMDS to evaporate or this could lead to process deviations. In this case the resist sensitivity fluctuate depending on the amount of HMDS applied. It should also be noted if KTI 820 were used, the viscosity would have to be adjusted so that the difference in resist thickness to oxide height is in the order of 2500 angstroms or less so that a noticeable difference in step coverage can be more readily be seen.

CONCLUSIONS

A pre-exposure treatment using a dilute alkaline base, such as AZ351, was shown to improve the step coverage in AZ1350 resist. The enhanced step coverage is believed to be a result of increased development rate discrimination between exposed and unexposed areas of the resist.

ACKNOWLEDGEMENTS

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FIGURE 5: Resist processed in a standard manner

FIGURE 6: Resist processed with a pretreatment