

BI-LAYER DEEP UV RESIST SYSTEM

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ABSTRACT

A portable conformable mask (PCM) system employing KT1820 as the imaging layer and PMMA, a deep UV sensitive photoresist, as the planarizing layer was investigated. Process parameters of a PMMA prebake at 185°C and methanol soak of 90 seconds achieved a resolution of 2.16 microns. The PCM system was able to achieve better results than a single layer system with regards to resolution and linewidth control.

INTRODUCTION

A bi-layer deep UV system is attractive to the semiconductor industry because it promises higher attainable resolution, reduced proximity effect, and uniform linewidth over substrate topography when compared to a single layer resist[1]. The higher resolution results from two factors. A lower wavelength, as found in the deep UV spectrum (200-260 nm), results in better resolution, and the use of a thinner imaging layer allows for better pattern transfer. Improved linewidth control results from the presence of the planarizing layer, which reduces resist coating thickness variation over steps. Thickness variations would cause pattern width changes as a result of exposure differences in thick and thin resist areas. Proximity effect is the unintended exposure of neighboring resist features due to scattering of energy during prolonged exposures. A thinner imaging layer will reduce exposure time, thus minimizing the proximity effect.

The choice of materials for the top layer resist in a bi-layer system must account for the dual requirement of masking and imaging. The imaging layer and planarizing layer should possess compatible coating and development conditions[2]. One characteristic of this system is the formation of an interfacial layer between the imaging and planarizing layers. This is due to the solvents present in the top layer causing some of the planarizing material to disassociate and mix with the imaging layer. This must be minimized because an interfacial layer that is too thick will inhibit DUV exposure. An appropriate PMMA prebake is a successful way to minimize this mixing.

One bi-layer resist system is a deep UV Portable Conformable Mask (PCM) technique. This system uses a diazo-sensitized and novolac based positive resist as the top layer which serves both as the imaging layer and the subsequent deep-UV mask for the bottom planarizing layer. Conventional positive photoresists are

opaque enough below 250nm to act as an excellent mask for the image transfer exposure of DUV resists. The opaque nature of positive resist results from the presence of novolac resin that has a high optical absorption for deep UV radiation. This allows the bottom planarizing layer to be exposed by a deep UV blanket exposure. The PCM system can be adjusted to achieve a capped or uncapped process. This refers to whether the imaging layer remains for further processing or is removed[3]. Figure 1 illustrates the PCM system.

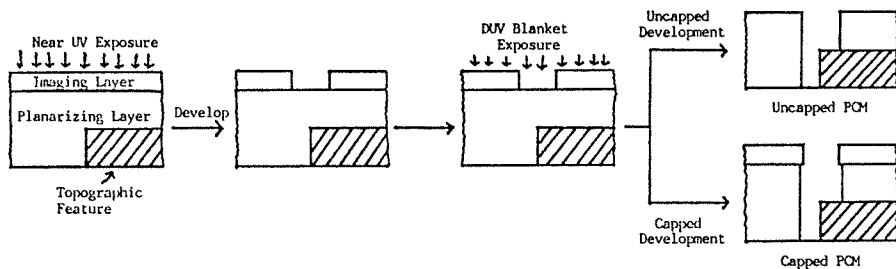


Figure 1 : Schematic illustration of PCM system.

This project uses an imaging layer that consists of KT1820 and a planarizing layer of poly(methyl methacrylate) "PMMA". PMMA is a deep UV resist that has a sensitivity range in the 200-250nm spectral region. Positive images are generated in the PMMA from the deep UV exposure. These images are the result of radiation induced chain scissions in the PMMA layer as illustrated in Figure 2 [4].

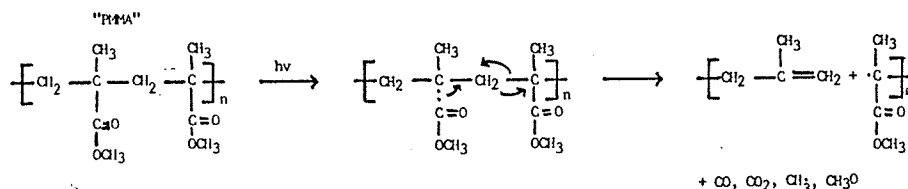


Figure 2 : Radiation induced chain scissions in PMMA.

A design of experiment was employed to aid in obtaining a workable process. It incorporated two factors that will affect the performance of the bi-layer resist system the most. The first is the PMMA prebake that influences the thickness of the interfacial layer generated. The second factor will be a 1:1 methanol:H2O soak before PMMA development. This helps to begin breaking up the cross-links formed in the imaging layer. The soak aids in the removal of the cap and the interfacial layer during the PMMA develop. Poor PMMA development results if the interfacial layer is left intact due to the difficulty of the developer to reach exposed PMMA.

A mercury lamp exposure system that produces a broad spectral output can be used for the deep UV resist exposure. This is possible due to the DUV radiation present in its emission spectrum. A flood exposure with the mercury lamp, using the top

imaging layer as the mask, produces the desired pattern in the PMMA layer. Care must be taken in selecting the piece of equipment to conduct the DUV exposure. The problem is due to the presence of optical lenses that are deep UV radiation absorbing elements. This can be corrected by removing the optics from the system. The low intensities produced at the deep UV spectrum and PMMA's low sensitivity to deep UV exposure requires a long exposure.

EXPERIMENT

Oxide topography of 5,000 Angstroms was generated on eleven wafers. The topography consisted of 5, 10, and 20 micron lines and spaces in separate parallel lined grids. Olin Hunt's MEAD PMMA 495K Mol. Wt. with 7.5% solids was applied to nine of the wafers. The wafers were cleaned and dehydration baked prior to HMDS application. All the resist coating was accomplished on a Headway spin coater. To maximize resist uniformity, care was taken in the coating step to include equal amounts of resist applied for spinning (2ml), and using the same spin speed and time. A 2 micron layer of PMMA was used as an efficient planarizing layer. The application occurred in two 1 micron steps. The 1 micron thickness was achieved with a spin speed of 2000 RPM for 35 seconds. A prebake was required following each one micron application of PMMA. Three wafers each were prebaked at 145°C, 165°C and 185°C. The prebake occurred in the convection oven for a bake time of 30 minutes. The resist applications were verified by ellipsometer and Nanospec readings.

A 0.45 micron thickness of KTI 820 at 23% solids was applied to the nine wafers and one control. A 1.2 micron layer of KTI820 at 27% solids was applied to a second control. The spin speeds for the 23% and 27% solids were 6,000 RPM and 5,000 RPM respectively for 30 seconds. The resist was prebaked at 85 °C for 30 min in a convection oven. The 23% solids KTI820 was exposed at 28mJ/cm² and the 27% solids exposed at 56mJ/cm² using a Kasper aligner. An ETM mask, consisting of an array of lines from 10 microns to 0.1 micron, was used by rotating 90 degrees to the oxide pattern on the wafers. A 30 second develop in KTI developer diluted 1:1 with DI water. Since an uncapped process was being pursued, no post exposure bake of the developed KTI820 was performed.

PMMA blanket exposures of the initial nine wafers occurred with the mercury vapor bulb. An exposure time of 2 hours and 15 minutes was used. Following the PMMA exposure the wafers were soaked in 1:1 methanol:H₂O. Three soak times of 30, 60, and 90 seconds were conducted on each of the different prebake conditions. The PMMA was developed in PMMA developer for 105 seconds and rinsed in PMMA rinse for 60 seconds, both developed by Olin Hunt. The wafers were then blown dry. Optical and SEM images were used to measure the resulting resolution and linewidth variation (Nanoline). A comparison to the single layer resist coated wafers will also be performed.

RESULTS/DISCUSSION

The initial investigation observed the characteristics of the PMMA layer and its interaction with the imaging layer. This included the determination of the PMMA index of refraction to be 1.46 and observations of any interfacial layer formation. Observing the interfacial layer was accomplished by coating a layer of KT1820 ($n=1.65$) onto PMMA for exposure and development. The PMMA index of refraction was then remeasured and determined to be 1.52. The increase in refractive index displays changes in the optical characteristics of the PMMA layer. This is the result of interfacial layer formation.

A simple deep UV exposure system was incorporated into the experiment. It consisted of 250 watt mercury bulb removed from a GCA contact reticle mask maker, and placed into a black box configuration. This set up displayed inherent problems of exposure uniformity and low lamp intensity in the DUV spectrum. To aid in the energy incident on the wafers the back side of the box was lined with aluminum foil. However, this was still inadequate and resulted in exposure times of two hours and fifteen minutes to be effective in flood exposing the PMMA layer. This exposure was still a little low so the PMMA development time had to be increased from 90 seconds to 105 seconds to adequately remove all the exposed PMMA.

Observations of the 1:1 methanol/H₂O soak were made during the PMMA development process. This included a comparison between soaking and not soaking the wafers prior to PMMA develop. The wafers that were not soaked formed a residual film on the surface. The film is believed to be remnants of the KT1820 imaging layer, as a result of observations made of the wafers that were soaked. This is because it was easy to identify the imaging layer developing off of the wafer surface while immersed in the PMMA developer. It was also noted that the longer soak time of 90 seconds was better at removing the KT1820 than the lower time of 30 seconds. This is expected due to the prolonged exposure time required for the PMMA layer that resulted in more KT1820 crosslinking. The increased crosslinking enhances the adhesion of the KT1820 to the PMMA layer. Failure to remove the KT1820 imaging layer displayed poor development of the PMMA. It must also be noted that the lower prebake temperatures of the PMMA layer were also observed to exhibit poor KT1820 removal.

Further investigation with Nanoline measurements and SEM analysis shows a PMMA prebake condition of 185°C and a 90 second methanol soak achieved the best results. A minimum resolution of 2.16 microns was obtained along with good linewidth control over the oxide topography down to 3.0 microns. This can be compared to the single layer resist systems. The 0.45 micron layer of KT1820 achieved minimum resolution of 2.2 microns but exhibited very poor step coverage. The 1.2 micron layer improved the step coverage so that its linewidth control was almost comparable to that of the PCM. However, the resolution dropped to 2.9 microns.

It was observed that some wafers exhibited resist adhesion problems due to the long develop time required for the low exposure dose. This indicates that the dehydration bake at 90°C for 30 minutes maybe insufficient and that a higher temperature could be required. The other alternative would be to obtain a better exposure source so that lower develop times will be needed to develop the exposed images.

The values achieved for minimum resolution and linewidth control could be improved. This is evident from the loss in dimension of the line space pairs. These line space pairs display an inefficient DUV exposure dose. Once again the mercury lamp exposure system can be linked to the problem due to its inability to produce high dosages in the DUV spectrum.

CONCLUSION

A PCM process consisting of KT1820 and PMMA was developed. It achieved a minimum resolution of 2.16 microns and exhibited good linewidth control over oxide topography down to 3.0 microns. This was achieved by the process parameters of PMMA prebake and methanol soak equal to 185°C and 90 seconds respectively. However, the PCM system has been limited by the DUV exposure source used in the experiment. An improvement in the exposure system will greatly enhance the PCM capabilities. The improvements of the exposure source could come in the form of acquiring a Perkin Elmer 500 or excimer laser exposure system.

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