Journal of Photopolymer Science and Technology
Volume18,Number5(2005)627-630©2005TAPJ

The Need of Top Anti-reflective Coating Materials for ArF Immersion Lithography

Jae Chang Jung, Geunsu Lee, Sung Koo Lee, Keun Do Ban, Cheolkyu Bok, and Seung Chan Moon

Advance Process Dept.2, Memory R & D Division, Hynix Semiconductor Inc, San 136-1 Ami-ri Bubal-eub Ichon-si Kyungki-do 467-701 Korea. (TEL: +82-31-639-1202, E-mail; jaechang.jung @hynix.com)

ABSTRACT

Recently, a new technology called ArF immersion lithography is emerging as a next generation lithography. The first problem of this technology is contamination issues that come from the dissolution of contaminants from the photoresist to the immersion liquid. The second is optical problem that comes from the using hyper NA system. To solve these two problems, we have developed top antireflective coating (TARC) material. This TARC material can be coated on resist without damage to the resist property. In addition to, this TARC material is easily developable by conventional 2.38 wt% TMAH solution. The reflective index of this TARC is adjusted to 1.55, so it can act as an antireflective material. To this TARC material for immersion, quencher gradient resist process (QGRP) was applied also. As a result, we could improve resolution and process margin. However, some of resists showed defects that were generated by this TARC material and QGRP. To solve this defect problem, we introduced buffer function to the TARC material. Thanks to this buffer function, we could minimize defects of resist pattern in immersion lithography.

Keywords: ArF, immersion lithography, top antireflective, defect, quencher

1. Introduction

To accomplish minimizing feature size to sub 60nm, new light sources for photolithography are emerging, such as F2 (λ=157nm), and EUV (Extremely Ultraviolet, λ=13nm). However, these new lithographic technologies have many problems to be solved for real device production. In case of F2 lithography, pellicle issue makes it difficult to use of F2 source in mass production. In case of EUV, light source and mask fabrication issues must be solved for real device application. For these reasons, instead of new light sources, extension of dry ArF lithography has been studied for sub 70nm device production by using Resolution Enhancement Technology (RET) such as using high NA tools, off axis illumination, and phase shift mask.

Recently immersion lithography is also emerging as a potential new lithographic technology for sub 60nm lithography. However, leaching of PAG from resist can make a trouble to the lens of exposure tool. To solve this contamination issue of lens, over-coating material that blocks the leaching of PAG from resist to immersion liquid is under developing by many material companies. [1-3] The resist that has water resistance is under developing also.

In this paper, we will introduce our in-house over-coating material that also acts as a TARC material. In addition to these dual functions, we also added RET function to this over-coating material by using Quencher Gradient Resist Process (QGRP). [4, 5] The performance of our TARC material that has three functions will be evaluated and its defect will be studied also.

2. Experimental

2-1. Materials

For patterning study, commercial ArF photoresist was used. As a Bottom Anti-Reflective Coating (BARC), A25 of Dongjin Semichem was used. The over coating material was made in-house.

2-2. Equipments and process

Received May 9, 2005
Accepted June 10, 2005

The particle was checked by Surfscan. The water resistance of TARC was check by monitoring the increment of particles after water treatment. Water treatment means that water is dropped on the TARC coated wafer that is rotating with 300rpm. The pattering experiments were performed by TEL ACT8 track and ASML PAS5500/1200 ArF Scanner. The illumination condition for L/S pattern was NA=0.85, cross pole (0.92/0.72, 30 degree open). For L/S pattern, a resist film was prepared by spin coating of photoresist solution on an A25 BARC coated silicon wafer and soft baked. On this resist coated wafers, TARC material was coated by spin coating and baked again at 70℃ for 60 seconds. Exposure was carried out on an ArF exposure tool. After exposure, water treatment is performed on the rotating wafer with 300rpm for 60 seconds. Finally, wafer was baked and developed in 2.38 wt% TMAH aqueous solution for 40 seconds.

3. Results and discussion

3-1. Design concept of TARC material

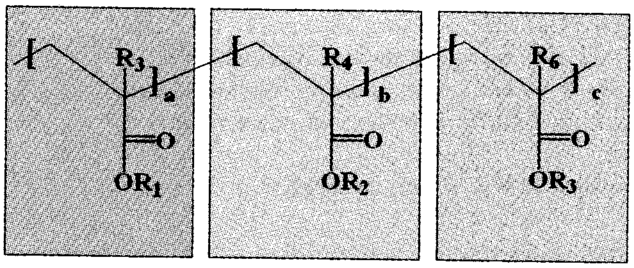

Figure1. The polymer structure of TARC

The polymer structure of TARC for immersion lithography is shown in figure 1. For the solubility to organic solvent that does not dissolve under layer resist, fluorine containing methacrylate monomer is introduced. This fluorine monomer also decreases reflective index of over-coating material so that over-coating material can have anti-reflective coating property. Acrylic acid is introduced for the solubility to 2.38wt% TMAH developer. To increase water resistance, the third methacrylate ester is introduced. To this TARC material, quencher gradient resist process (QGRP) was used.

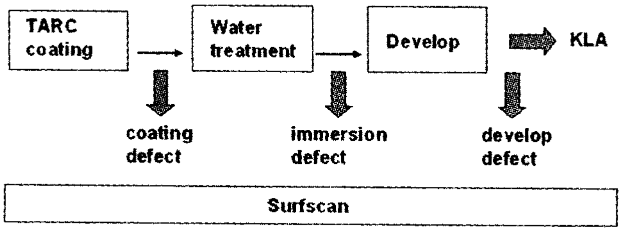

Figure 2. Defect monitoring method by KLA and Surfscan.

The concept of QGRP and its result were demonstrated in our previous studied. [4, 5] In our previous study, we could confirm that resolution and exposure latitude were increased enormously by QGRP.

3-2. Defect study of TARC

The development of defect free TARC material for immersion lithography is very important for the using immersion TARC in real device fabrication, so we tested defect of TARC as the scheme shown in figure 2. With the Surfscan, we counted the number of particles at each step as shown in figure 2. To check the water resistance of TARC material, we counted particles before and after water treatment. To check the develop property, we counted particles after develop. The results were shown in figure 3. As can see, there are some particles after TARC coating but these particles come from manual coating. Generally particles are increase in case of manual coating to compare with in-line coating. If in-line coating is performed, particles will not be increased. After water treatment, particles are increased much more. This means that water affects the TARC surface. However, in our experiment, as the water treatment is performed on the rotating wafer with 300 rpm, this condition is stronger than real immersion process. From this, we can guess that TARC material has enough water resistance. The most important thing is that all these particles that were generated by water treatment are disappeared after develop. From this, we can conclude that our TARC has no critical particle issues.

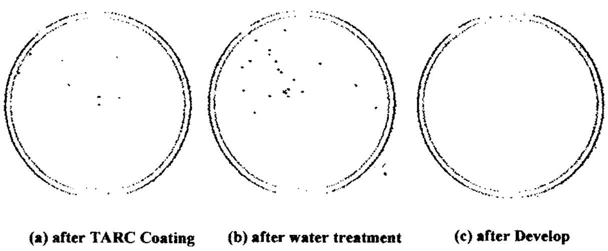

Figure 3. Number of particles by Surfscan

3-3. Defect after patterning

As we have no immersion illumination tool, the patterning experiment was tested by the scheme as represented in figure 4. Instead of exposure in immersion liquid, the patterning experiment was performed by flowing procedure. First the resist was coated on a BARC coated silicone wafer and TARC

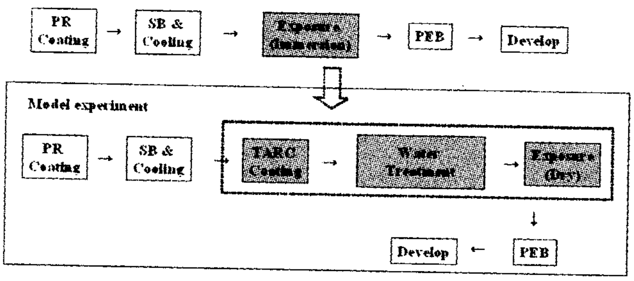

Figure 4. Process scheme for immersion experiment

was coated on this wafer. After coating and soft baking, to make immersion environment, water treatment was performed on the rotating wafer with 300rpm for 60 seconds. After water treatment, exposure was performed and then exposed wafer was baked and developed. As mentioned in our previous paper [5], our TARC had weak quencher in its composition. This means that QGRP was also applied in our experiment. The 80nm gate line and space pattern was obtained by this method. However, the scanning result of defect at 80nm gate line and space by KLA made us disappointed. The total defects were 5,000 or more and the defect number increases as the CD of line increases. The shapes of defects are shown in figure 5. Most of defects are bridge type.

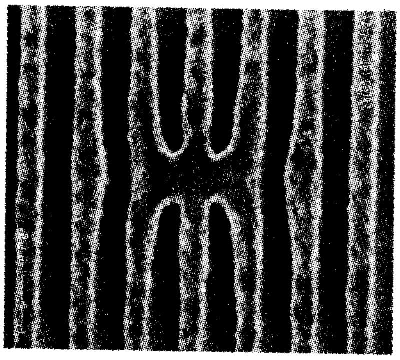

Figure 5. SEM pictures of defect

3-4. New design concept of TARC material.

To get rid of bridge defects that might come from QGRP, we introduced the forth monomer to the figure 1 polymer. TARC for QGRP has weak quencher in it composition. As explained in our previous work [5], the concept of QGRP is that quenchers diffuse through the resist and generate quencher concentration gradient at the resist. At the top region of resist, the concentration of quencher is higher than the bottom region of resist. As a result, the resolution and process margin increase. However, this weak quencher may act as a bridge source at the top region of resist. To solve this defect problem, the forth monomer that had strong acid function was introduce. We guess that the forth monomer that has strong acid may reduce bridge type defect of resist pattern as shown in figure 5. The important thing is that strong acid is directly attached to main TARC polymer resin so that the neutralization of weak quencher by strong acid restricts only at the top region of resist. Though the neutralization of weak quencher by strong acid restricts only at the top region of resist, weak quencher diffuses to the bottom region of resist. The process scheme of QGRP is shown in figure 6 and that of new concept is shown in figure 7. As the same patterning method used in previous section, the defect after patterning was tested and its result is represented in figure 8. As can see, the number of defects are 500 but many of them are repeating defect not bridge defect. By introduction of forth monomer that has strong acid, we can make a defect free TARC and we call this new system to "Buffer-QGRP".

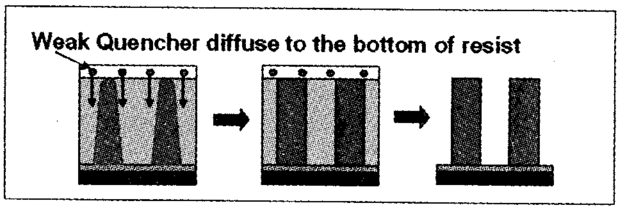

Figure 6. The process scheme of QGRP

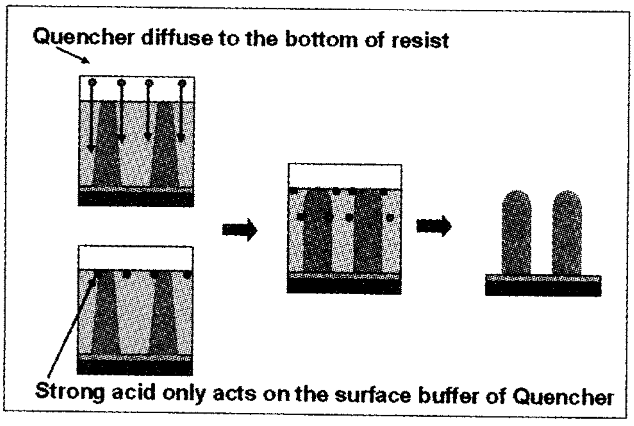

Figure 7. The process scheme of Buffer-QGRP

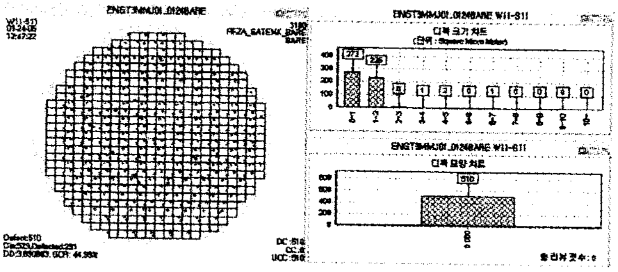

Figure 8. The numbers of defect scan by KLA

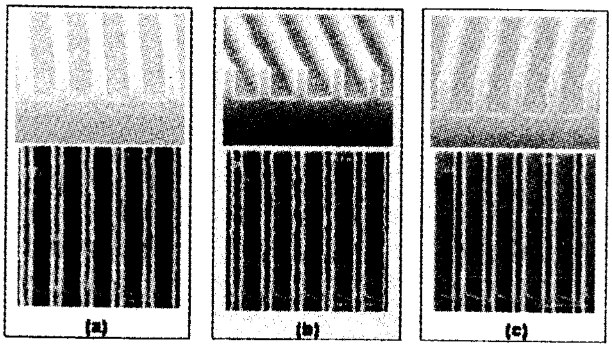

Figure 9. SEM pictures of 80nm line and space pattern was obtained with the optimum exposure energy by the method of (a) normal dry, (b) immersion QGRP, and (c) immersion Buffer-QGRP

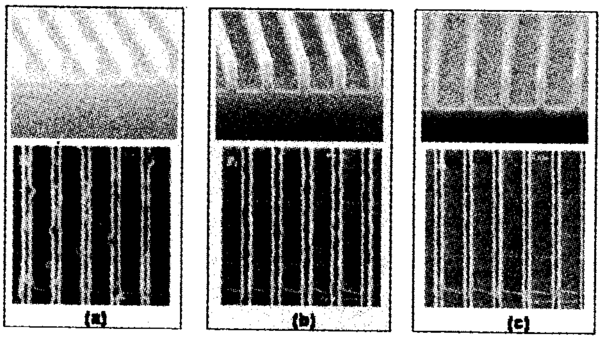

Figure 10. SEM pictures of 80nm line and space pattern was obtained with the over exposure energy by the method of (a) normal dry, (b) immersion QGRP, and (c) immersion Buffer-QGRP

3-5. Lithographic Performance

The SEM pictures of figure 9 and figure 10 were obtained by the patterning methods of normal dry case, immersion QGRP case, and immersion Buffer-QGRP case. Figure 9 was obtained with the optimum exposure energy of 80nm line and space pattern. As can see in figure 9 (a), that was obtained by normal dry exposing method, we get the 80nm of slope and top loss profile. With immersion QGRP as explained of section 3.3, as can see in figure 9 (b), we get the vertical profile pattern but there is roughness that comes from quencher of QGRP. As explained 3-3 section, this roughness might be a bridge defect source. In case of immersion Buffer-QGRP, as can see in figure 9 (c), we could get the vertical profile and slightly top rounding profile as expected in figure 7. The patterns of 80nm line and space that were obtained with over exposed case were shown in figure 10. As can see in figure 10 (a), in case of normal dry exposing method, we get serious slope and top loss profile. The pattern is so deformed that there are many particle defects that are generated by tearing of deformed resist. On the contrary, for immersion QGRP case as explained at section 3.3, we get the vertical profile pattern as can see in figure 10 (b). However, there is some roughness that comes from quencher of QGRP. In case of immersion Buffer-QGRP, as can see in figure 10 (c), we could get the vertical profile and slightly top rounding profile as expected in figure 7. As can see in figure 10, the important thing is that, with immersion Buffer-QGRP, we get smaller size of pattern without pattern collapse to compare with immersion QGRP.

4. Conclusions

We have developed TARC for immersion lithography. Generally, immersion TARC has two functions. One is blocking the leaching of contaminants from resist. The other is anti-reflective function. In addition, our TARC has unique third function that is resolution enhancement function. This third function was achieved by QGRP. However, QGRP makes bridge defect. To solve this defect problem, we modified chemistry of our TARC and we called this system to "Buffer-QGRP". By Buffer-QGRP, quenchers that are at resist surface could be neutralized. As a result, we could solve defect problems of our TARC system.

References

1. W. Hinsberg, G. Wallraff, C. Larson, B. Davis, V. Deline, S. Raoux, D. Miller, F. Houle, J. Hoffnagle, M. Sanchez, C. Rettner, L. Sundberg, D. Medeiros, R. Dammel, and W. Conley, *SPIE*, **5376** (2004) 21.
2. J. C. Taylor, C. R. Chambers, R. Deschner, R. J. Lesuer, W. Conley, S. D. Burns, and C. G. Willson, *SPIE*, **5376** (2004) 34.
3. S. Kishimura, M. Endo, and M. Sasago, *SPIE*, **5376**. (2004) 44.
4. J. C. Jung, S. L. Lee, W. W. Lee, C. Bok, S. C. Moon, and K. S. Shin, *SPIE*, **5376** (2004) 63.
5. J. C. Jung, et. al, *SPIE*, **4690** (2002) 212.