Resist Trimming Technique in Oxygen Plasma for Sub-30nm Pillar Array

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1. Introduction

The development of large-area, nanostructure patterning with high aspect ratios is a challenging problem that must be addressed for potential applications in high performance nanoscale devices[1]. When negative resist pillar patterns are formed using electron beam lithography, the forward and backward scattering of the electronics limits the resolution and requires that the resist layer be thinner. If the patterned resist pillars were to be used as dry etching masks, the sputtering of the resist polymer during the process requires the pillars to have high aspect ratio. Also, due to chemical processing, high aspect ratio resist pillars has a high probability of falling over due to capillary forces on the pillars [2].

We report on a simple method to overcome the low aspect ratio and collapsing resist problem by using oxygen plasma ashing. Since the barrel-type oxygen plasma ashing results in isotropic etching of polymers, the resist pillars will be etched by twice the thickness laterally as vertically. This means that even if the beginning aspect ratio was 1, after the ashing process the aspect ratio will increase. We used 200 nm thick negative electron beam resist (novolak resin with naphthoquinone diazide/bisazide in propylene glycol monomethyl ether acetate) and patterned 70 nm dot arrays using 80 kV electron-beam (nB3, NanoBeam Ltd.). Oxygen plasma ashing at 100 W power and 0.1 Torr pressure for 10 s resulted in trimming by 15 nm in all direction.

2. Oxygen Plasma Asher process

We used oxygen plasma ashing to increase the resist pillar aspect ratio. The oxygen plasma process was performed at 100 W and 50 W of RF power including reflect power and 0.1 torr of operation pressure. Fig.1 shows a 62 nm diameter and a 170 nm tall negative resist pillar, with an aspect ratio of 1 : 2.82 before ashing. After performing the oxygen plasma ashing at RF power of 100 W for 5 s and repeated 4 times resulted in a 30nm pillar array. The aspect ratio was increased from 1 : 2.82 to 1 : 5.13, which was an increase of more than 80 %.

3. Result and Discussion

Fig.3 shows the thickness reduction in resist polymers depending on RF power and ashing time. It shows that at lower power, 50 W, the polymer burn rate becomes more controllable. Fig.4 shows increasing aspect ratio depending on plasma ashing duration. After ashing at 100W, increased aspect ratio was 36.4% and after ashing at 50W, increased aspect ratio was 70%. Due to the high burn rate of the resist, it was difficult to control the process for the 100 W power.

Fig 5. shows thickness and aspect ratio of the resist pillar depending on the number of 5 s etching. For each step, the ashing was stopped by reducing RF power. The aspect ratio was increased from 1 : 3.03 to 1 : 5.13, when the ashing was performed at 4 steps which was about a 81.9 % increase. Through stepped ashing, we were able to achieve high increase in aspect ratio without resist collapsing or over etching.

4. Conclusion

Through higher rate of decrease in width than the pillar height at plasma ashing experiment of 100 W and 50 W, we achieved a gain in the resist aspect ratio. This method may be used for defining high aspect ratio (1:5) resist pillars with sub 10 nm dimensions without resist collapse.

5. References

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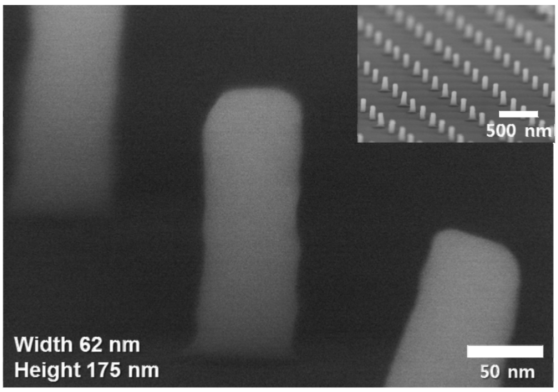

Fig.1. 62 nm pillar array (before ashing).

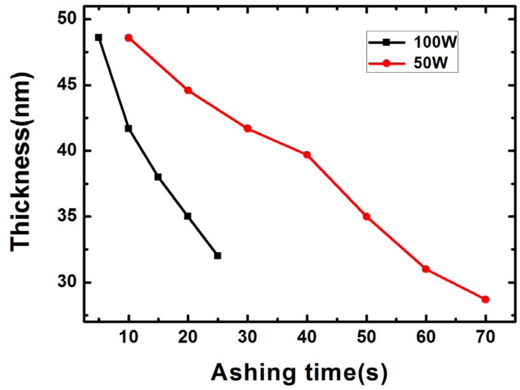

Fig.3. Thickness reduction depending on etching aspect ratio = 1 : 2.8

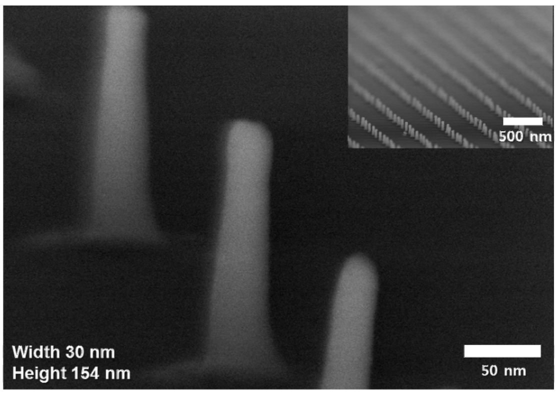

Fig.2. 30 nm pillar array (after ashing) 100W/5 s, repeated 4 times, aspect ratio = 1 : 5.13

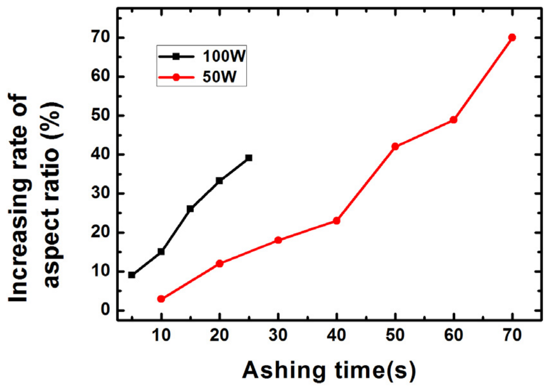

Fig.4. Increasing rate of aspect ratio depending on etching time

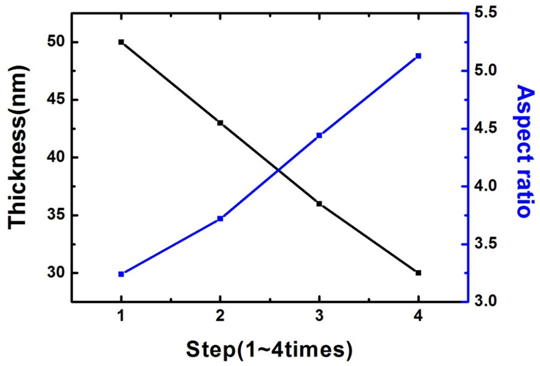

Fig.5. Thickness and aspect ratio depending on number of 5 s etching steps