Fabrication of a high-resolution mask based on enhanced techniques for line edge roughness improvement with a non-chemically amplified resist and a post-exposure bake

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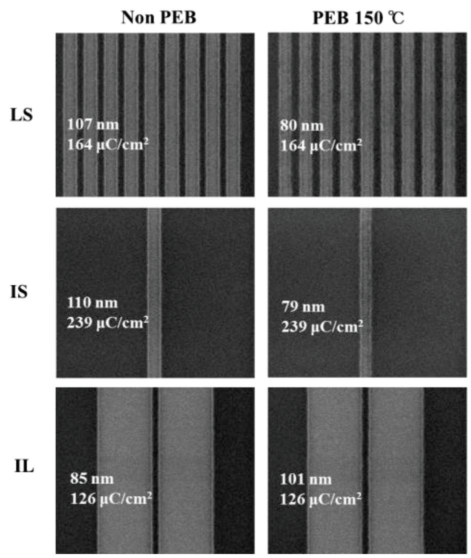
A high-resolution technique has been developed for the fabrication of photomasks for 10 nm half-pitch logic nodes and beyond. Current mask manufacturing techniques use a chemically amplified resist (CAR) material that has a complex mechanism of acid generation; this obscures the criteria for selecting the polymer and the quencher for industrial purposes. It is therefore important to validate non-CAR materials as alternative solutions for mask fabrication. In this research, diluted ZEP520A (Zeon Corporation) was used as a non-CAR material in conjunction with a JBX9000 variable shaped electron-beam lithography tool (JEOL Ltd).[1,2] Additionally, a post-exposure bake (PEB), normally used in mask fabrication, was also used in this research, and we investigated its temperature dependence. In our researches, we applied the PEB method to mask fabrication from non-CAR resists, and we demonstrated its feasibility as a high-resolution technique.

Figure 1 shows top-down SEM images for critical dimension (CD) design values of 100 nm for the line and space (LS) pattern, the isolated space (IS) pattern, and the isolated line (IL) pattern, together with their dependence on the PEB temperature. There was a tendency for the space CD to shrink dramatically at 150°C. Conversely, the IL pattern expanded with increasing PEB temperature. Figure 2 shows the resist sensitivity curves for IL, LS, and IS patterns at a design CD of 100 nm. The resist sensitivity of all the pattern structures gradually decreased with increasing PEB temperature. It appears that space CD shrinkage and line-width expansion as a function of the PEB temperature are optimized at a PEB temperature of 120°C, and that a high PEB temperature of 150°C causes extremely low sensitivity of the resist. Figure 3 shows line edge roughness (LER) for design CD values of 100 nm; a PEB at 120°C seems to be the optimal value for LER improvement. Figure 4 shows cross-sectional SEM images for the best resolution with a PEB at 120°C for each of the pattern structures. Consequently, a high resolution of the order of 20 nm should be achievable by optimizing the PEB temperature.

In summary, the use of PEB with a non-CAR resist helps to suppress the proximity effect, improving LER, and causes an annealing effect, permitting us to demonstrate an advanced fabrication technique for high resolutions of the order of 20 nm.



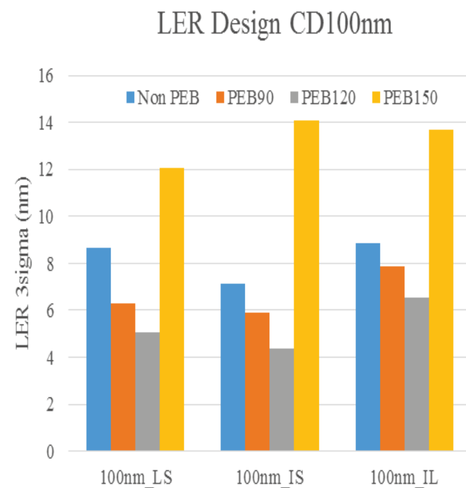


Figure 1, Top-down SEM images showing the post-exposure bake (PEB) temperature dependence for LS, IS, and IL patterns (design CD, 100 nm)

Figure 3, Line edge roughness (LER) for isolated line (IL), line and space (LS), and isolated space (IS) pattern (design CD 100 nm)

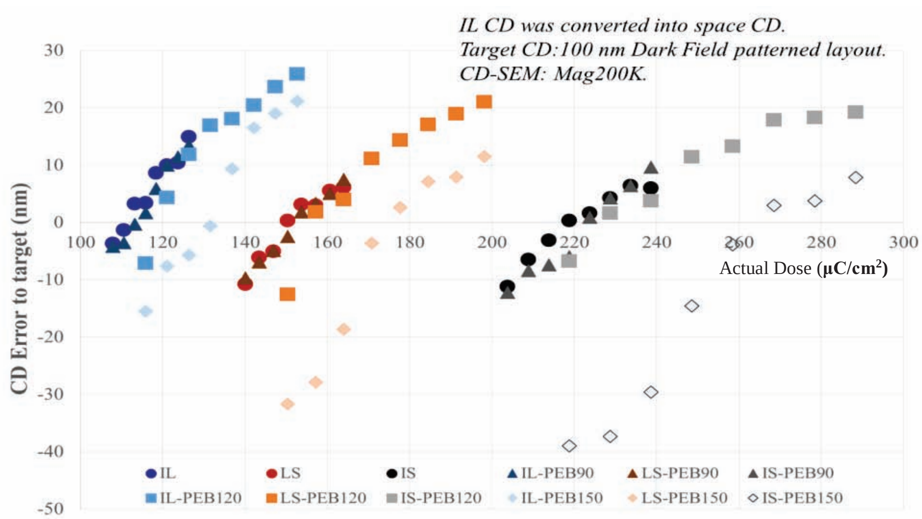


Figure 2, Resist sensitivity curves for isolated line (IL), line and space (LS), and isolated space (IS) pattern (Design CD 100 nm)

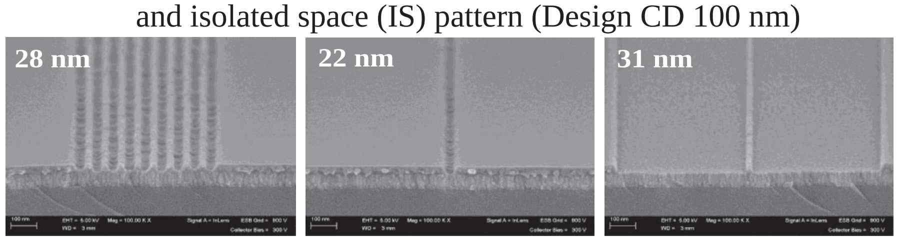


Figure 4, Resolution capability of diluted ZEP520A with post-exposure bake (PEB) at 120 °C

References
[1] ZEON Corp., ZEP520A technical report, Version 2, (2010)
[2] L. Raffaele, C. Pogliania, G, L Cassola, et all. (Proc. of SPIE Vol. 5992 59924W-13)