Line Edge Roughness Reduction Studies Employing Grazing Incidence Ion Beam

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As semiconductor feature sizes and pitches shrink to ever-decreasing dimensions, Line Edge Roughness (LER) becomes and increasing important problem. For the 22nm node, according to the ITRS roadmap CDs, LER will need to be about 10% of this, or about 2nm. The LER is transferred from the photoresist to the substrate through the subsequent processing steps, causing variations in, eg, gate length. This leads to mismatch in device performance and leakage[2]. Thus, an efficient and cost effective way to reduce the LER in the semiconductor photoresist is needed in order to keep the imperfections from affecting processing steps further down the line. We discuss such a LER reduction technique in this paper.

The LER reduction technique under development at CPMI uses an ion beam at a grazing incidence unidirectional with the features. An experimental set-up and the orientation of the ion beam hitting a sample is shown in figure 1.The key potential advantage of this approach over many other smoothing techniques is the ability to smooth LER at relatively long spatial length scales. Ar and Ne Ion beam current densities of various energies of 500 and 1000 eV at various linear distances are measured and reported. Ar and Ne gas species were used in the experiments because they are noble gases and should have few if any chemical reactions with the photoresist. In order to choose processing parameters such as the ion beam energies and angle of incidence, SRIM/TRIM calculations were performed. LER reduction numbers were measured at both short and long spatial wavelengths using Ne, He, and Ar beams. The angle of incidence was varied, as well as ion energy and process time. LER measurements were taken from top-down analytical SEM measurements and Hitachi image analysis software. Line profile data were taken with the SEM in cross-section mode. Results showed a reduction in LER from 6.9±0.47 nm to 3.9±0.61 nm for 90 nm 1:1 lines using an Ar beam at 500eV for 6 s at an 85^{o} angle of incidence. A reduction from 7.9±0.78nm to 4.3±0.70 nm was also measured with an Ar beam at 1000 eV for 4 s at a 60^{o} angle of incidence as shown in Figure 2. The wavelength at which the roughness occurs was analyzed using Fourier analysis on the output of the Terminal PC program. The significant improvement of LWR all across the spectrum from 50 nm on to 1000 nm was observed. Results on the change of CD values while reducing the LER values in a EUV exposed samples will be presented.

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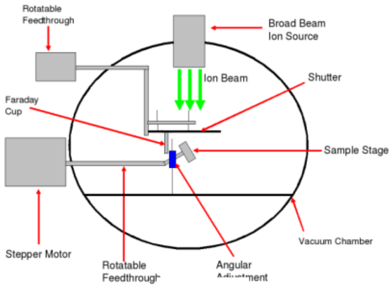
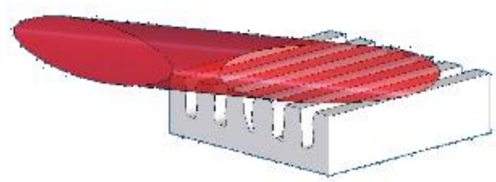
[1]D. N. Ruzic, S. N. Srivastava, Collector contamination: normal incidence (multilayer) collectors, *EUV Lithography*, SPIE Press, Bellingham, WA, 2008. ISBN: 9780819469649

2P. Oldiges et al., Modeling line edge roughness effects in sub 100 nanometer gate length devices, Simulation of semiconductor processes and devices, 2000.

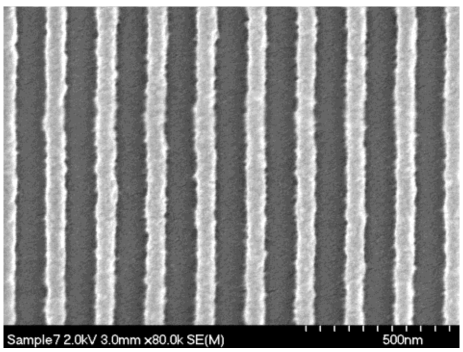


(a)

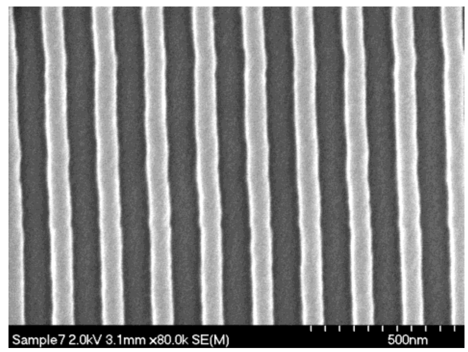


(b)

Figure 1. (a) Schematic of the Illinois experimental LER reduction set-up (b) Ion beam Orientation



(a). unprocessed



(b). processed

Figure 2. SEM image of an unprocessed sample (a) and a processed sample (b). A reduction in LER from 7.9±0.78nm to 4.3±0.70 nm is observed.