Process Dependence of Line Width Roughness in Electron Beam Resists

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I. Intorduction

As the dimensions of resist patterns have been reduced, nanoscale resist topographies such as line edge roughness (LER) or line width roughness (LWR) become a priority issue in lithographic processes because they affect the fidelity of pattern transfer and result in greater variation in device performance. It has been suggested that LWR is caused by the chemical inhomogenity at the boundary between patterns and spaces. The chemical inhomogenity of chemically amplified resists is caused by the stochastic effect of incident electrons and subsequent chemical reactions. In this work, the stochastic effect of incident electrons was investigated by changing process conditions. A non-chemically amplified resist was used to eliminate the effect of chemical reaction. The formation mechanism of LWR is discussed based on radiation chemistry.

II. Experimental

Poly(methylmethacrylate) (PMMA) was used as a positive-type resist. Propylene glycol monomethyl ether acetate (PGMEA) was used as a casting solvent. Two kinds of developer were used. One is the developer 1(H_2O:2-propanol=1:1). The other is developer 2 (methyl isobutyl ketone (MIBK):2-propanol=1:3). The wafers were primed with BARC. PMMA solutions were spin-coated onto silicon substrates at 3000 rpm for 30 s and baked at 110.0 ˚C for 90 s to form thin films. The resist samples were exposed to 75 keV electron beam. The exposure doses ranged from 400 $\mu C/cm^2$ to 1200 $\mu C/cm^2$. They were immersion-developed in developer 1 or developer 2 for 30s and rinsed in water before drying. Resist patterns were recorded with a Hitachi High Technologies S-5500 SEM. LWRs (3-sigma) were estimated by analyzing SEM images.

III. Results and discussions

Figure 1 shows the SEM micrographs of line-and-space resist patterns with 150 nm pitch. The resist patterns obtained using developers 1 and 2 are shown in Fig. 1(a) and (b), respectively. The sizing doses were 1200 and 400 $\mu C/cm^2$ for each developer. LWR of the resist patterns obtained using developer 1 was higher than that of the resist patterns obtained using developer 2 in spite of the low sensitivity. Figure 2 shows the relationship between LWR and the line width of the resist patterns with 60, 90, and 150 nm resist film thickness. The exposure dose was 400 $\mu C/cm^2$. LWR decreased with the increase of resist film thickness. The estimation of the density of main chain scission points is ongoing. In conference, the formation mechanisms of LWR will be discussed in detail by comparing the experimental LWR with the distribution of main chain scission points.

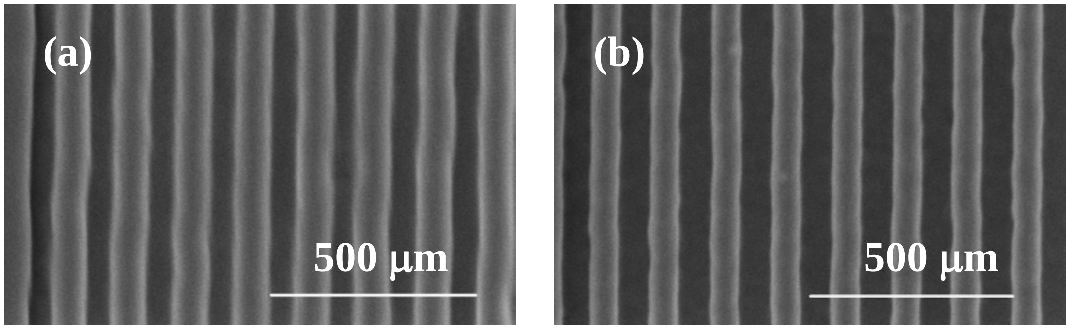

Figure 1. SEM micrographs of PMMA resist films after development using (a) $H_2O$and 2-propanol and (b) MIBK and 2-propanol.

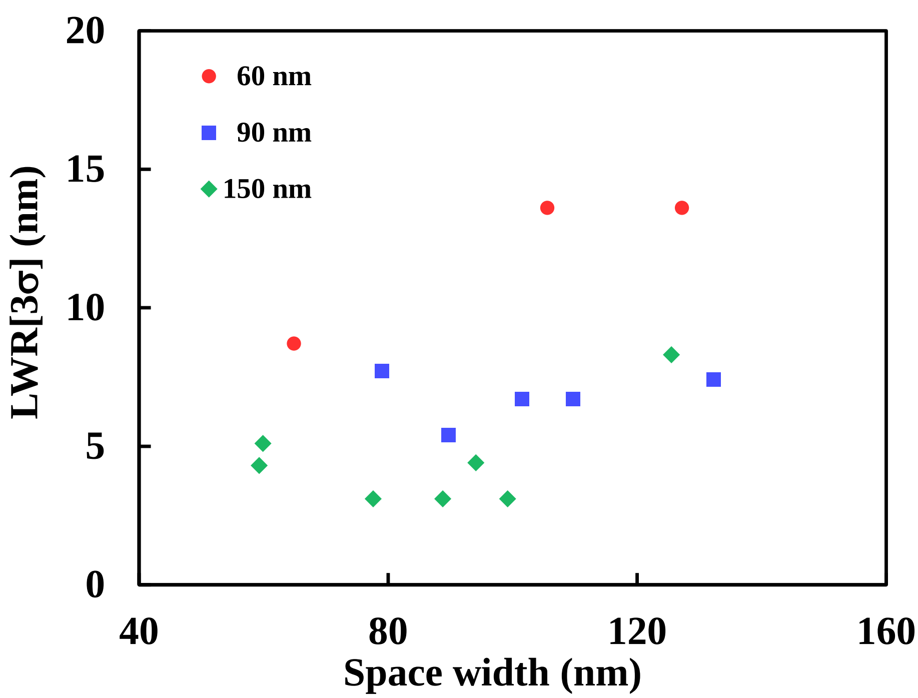

Figure 2. Relation between LWR and the line width at 60 nm and 90 nm resist film thickness. The exposure dose was 400 μC/cm^2.