10 nm node pattern transfer development using an EUV, DUV and electron beam sensitive acrylate-based resist

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As feature pitch scaling continues to push the limits of immersion 193nm lithography, increasingly complex patterning schemes have been implemented including double exposure/double etch and pitch splitting techniques.[1] The advent of EUV lithography should enable a return to a more conventional single exposure/single etch pattern transfer scheme.[2] Recent work on EUV resists and their performance during pattern transfer has been reported for 22 and 14 nm node dimensions.[2] However, it is likely that EUV will not be ready for manufacturing until the 10 nm node. In this work, we assess the performance of an acrylate-based EUV resist with a polymer-bound photo acid generator (PAG)[3] at 10 nm node dimensions, targeting a minimum feature pitch of 40 nm.

Exposures were performed using 100 keV electron beam lithography (EBL) combined with 248 nm photolithography (for pattern loading), to simulate full field EUV exposures. Both exposures were performed in a common layer of 50-nm thin resist. The EBL printing contrast of the material used in this study was characterized as a function of post apply bake (PAB) and post exposure bake (PEB). Best results were observed for a PAB of 115 °C and a PEB of 90 °C (Fig. 1). The critical dimension (CD), line edge roughness (LER) and line width roughness (LWR) characteristics as a function of pattern pitch are shown at varying exposure doses (Fig. 2). The data demonstrates that a clear modulation of the CD from 18 - 35nm is achieved for the target pitch range by varying the base dose from 80 to 120uC/cm^2. In tandem, LER and LWR values increase only slightly, ranging between 3-4nm and 6-8nm, respectively.

We evaluated the pattern transfer performance of the material used in this work by measuring the evolution of CD, LER and LWR throughout the pattern transfer process using reactive ion etching (RIE). For this experiment a trilayer resist stack consisting of a 20 nm-thin hard mask (HM) and a 65 nm-thin organic planarizing layer (OPL) was used. Results are shown in Figure 3. Successful pattern transfer into 50 nm of a silicon-based oxide was obtained for the target 40 nm pitch. The measured CD, LER and LWR results for the images shown in Figure 3 are presented in Table 1. LWR is slightly improved through the pattern transfer process. However both LER and LWR remain higher than the projected need for 10 nm node patterning.[3] Despite this fact, these results show that pattern transfer at 10 nm node dimensions is possible with the evaluated resist system.

[1] B. Haran, IEEE Proc. of IEDM, 625 (2008)
[2] O. Wood, et al, Proc. of SPIE **7636,** 76361M ((2010)
[3] C. Koh, Proc. of SPIE **7636,** 763604 (2010)
[4] M. J. Rooks et al, J. Vac. Sci. Technol. B **23** 2769 (2005)

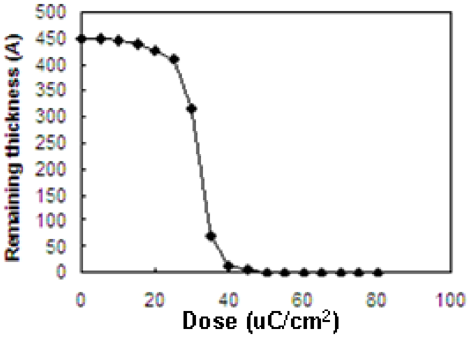

Figure 1: Contrast curves for EBL exposure. Large area patterns at varying dose were exposed and developed using an aqueous solution of 0.26*N* tetramethyl ammonium hydroxide (TMAH) for 30 sec. The remaining thickness of the material was measured using an optical interferometer.

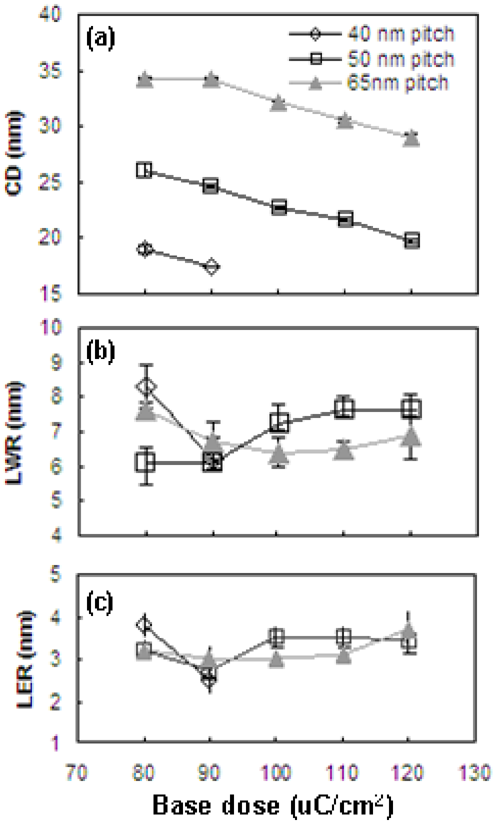

Figure 2: (a) CD (b) LWR and (c) LER for patterns at 40, 50 and 65 nm pitch as a function of varying base dose. All patterns were exposed using a single pixel exposures with a 5 nm pixel size. Patterns were proximity effect corrected using the method presented by Rooks, et al[4].

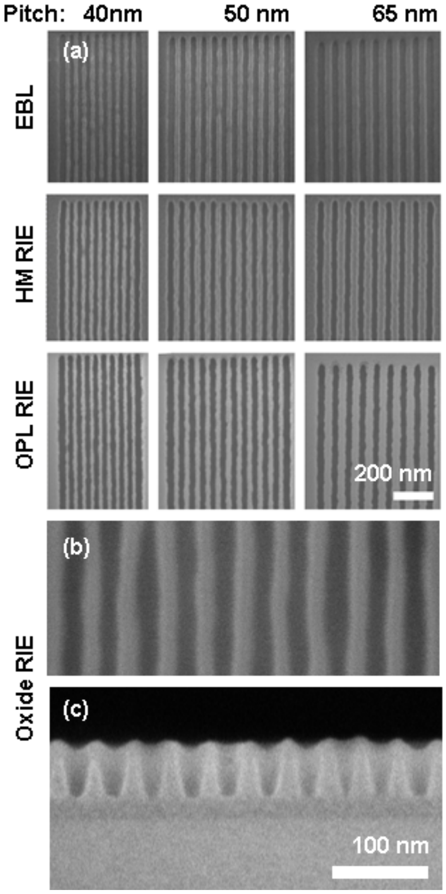

Figure 3: (a) SEM images obtained after EBL, HM RIE and OPL RIE are shown in figure 3. Successful pattern transfer was obtained for all CD and pitch combinations. (b) Top down SEM image of 40 nm pitch pattern transferred into 50 nm of a silicon-based oxide material. (c) Cross sectional SEM image of (b).

	CD(nm)		LWR(nm)		LER(nm)	
Pitch	HM RIE	OPL RIE	HM RIE	OPL RIE	HM RIE	OPL RIE
40nm	19.4±0.11	15.6±0.19	6.5±0.23	6.4±0.11	4.1±0.14	3.9±0.11
50nm	26.9±0.16	21.6±0.16	5.4±0.15	5.9±0.22	3.7±0.10	3.7±0.10
65nm	38.1±0.14	35.3±0.12	5.5±0.18	6.2±0.14	3.6±0.13	4.1±0.10

Table 1: CD, LWR and LER data for the images shown in Figure 3. LWR is slightly improved through the pattern transfer process. However both LER and LWR remain higher than the projected need for 10 nm node patterning[3].