Sub-10nm lines using PMMA and HSQ Double Patterning

Li Fan, Leo T. Varghese, and Minghao Qi*

School of Electrical and Computer Engineering, and Birck Nanotechnology Center
Purdue University, West Lafayette, IN 47906

HSQ is a popular resist for electron-beam lithography (EBL). High resolution down to 4.5 nm half pitch was achieved with tuning of the development of HSQ [1]. However, such narrow lines were achieved in thin resist and the contrast was low, and successful pattern transfer into underneath structures was limited to 15nm half pitch [2]. Part of the requirement for high-quality pattern transfer is the thickness of resist, which may place the limit on the resolution, unless a thick sacrifice layer is placed underneath a thin imaging layer.

Here we propose a method to achieve high resolution and thick resist using a bi-layer resist approach and spatial frequency doubling. The process flow of halving the pitch and reducing the line width is shown in Figure 1. We first spun ~30nm thick HSQ on a silicon wafer. 60nm-pitch gratings with 40nm wide teeth were written using the Leica VB6 High Resolution EBL system. The pattern was developed using 25% Tetramethylammonium Hydroxide (TMAH). Next, PMMA resist of ~70nm thickness (molecular weight 950K) was spun on the wafer and it was placed in vacuum to ensure that PMMA completely filled the HSQ trenches. Gratings of 20nm line width and 60nm pitch were written in PMMA with EBL. The PMMA gratings were aligned to the HSQ gratings and shifted by half the pitch (30nm) using pre-patterned gold alignment marks. Cold development at 6°C was adopted for PMMA development to achieve a clean profile [2].

To achieve spatial frequency doubling, RIE with CF_4/Ar chemistry was employed to etch HSQ using PMMA as an etch mask. Fig. 2 shows an SEM micrographe of the initial results. HSQ lines of 40nm were thinned down to a line width of ~10nm while the pitch was halved from 60nm to 30nm. To get even thinner lines, we will carefully optimize the PMMA writing and etch conditions. Our method has the potential of getting extremely narrow lines in a relatively thick HSQ film (30nm), *e.g.* high aspect ratio, since the capillary force associated with wet development can be avoided in our dry-etch process.

Our initial demonstration here achieved a pitch of 30nm with a starting pitch of 60nm. We are able to write 26nm pitch gratings in HSQ, and hope to achieve pitches down to 15nm with reasonable thickness.

* corresponding author: Minghao Qi, 1205 W. State St, Rm 1297, West Lafayette, IN 47906

Email: *mqi@purdue.edu*

References

[1] Yang, J. K. W. *et al* J. Vac. Sci. & Technol. B **27**, 2622 (2009) and D. Morecroft *et al* J. Vac. Sci. & Technol. B **25**, 2837 (2007)
[2] Hu, W et. al, J.Vac.Sci. & Technol. B **22**, 1711 (2004)

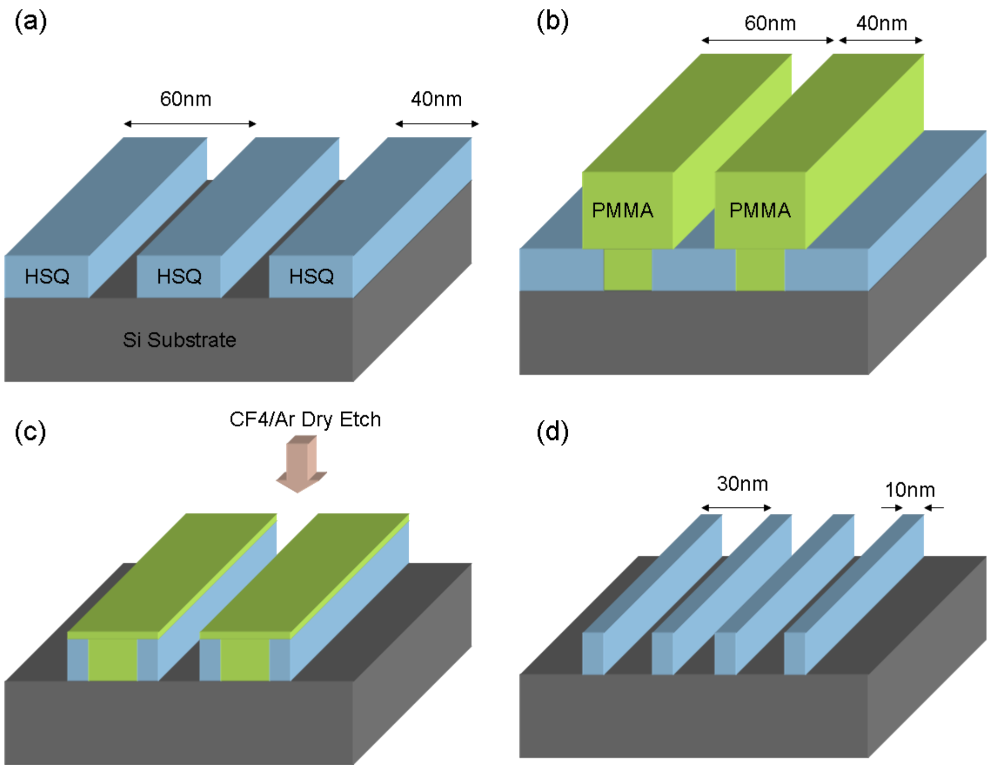

Figure 1. Schematic of the process flow: (a) Negative resist HSQ gratings were patterned with EBL; (b) Positive resist PMMA gratings were aligned and written with EBL; (c) Patterned PMMA is used as an etch mask to etch HSQ using RIE; (d) PMMA is removed to get10nm HSQ lines with 30nm pitch gratings.

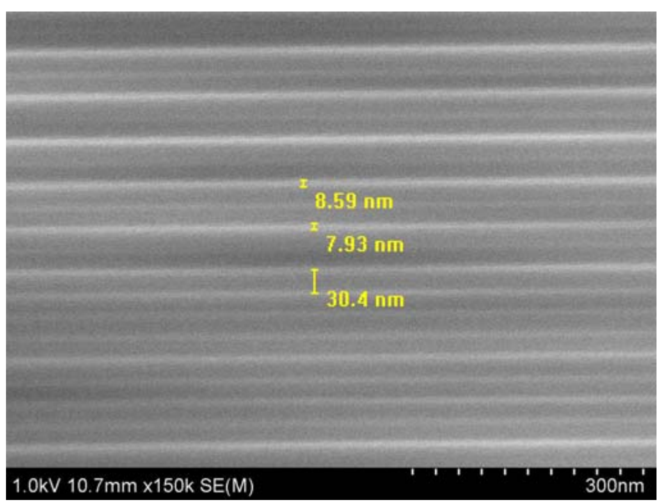

Figure 2. SEM micrographs of sub 10nm lines of HSQ with a pitch of 30nm using PMMA and HSQ double patterning.