High aspect ratio (~25:1) sub-10 nm HSQ lines using electron beam lithography

M.M. Mirza, H.P. Zhou, K.E. Docherty, S. Thoms, D.S. MacIntyre and D.J. Paul
School of Engineering, University of Glasgow, Glasgow G12 8LT, U.K.
m.mirza.3@research.gla.ac.uk

Hydrogen silsesquioxane (HSQ) is a high-resolution negative-tone inorganic resist for electron-beam lithography (EBL). HSQ resist has been widely used to fabricate nanometer scale devices due to its capability for sub-10 nm resolution, small line edge roughness, high etch resistance, and good mechanical strength[1]. Such high resolution patterns, however, have to date only been achieved in thin HSQ resist. This limits high-quality pattern transfer because fabricating high aspect ratio nanostructures require much thicker resist, but thicker resist may limit the resolution of the HSQ patterns.

This work addresses the challenges in achieving highly vertical HSQ patterns with sub-10 nm resolution and aspect ratio higher than 20:1 in order to meet the special requirements as an etch mask, which is a key step in fabricating nanostructures with high aspect ratios. In this paper, we have studied the effect of resist thickness on the resolution of isolated lines and also the effect of e-beam expose dose on the actual size and shape of the HSQ lines for different line widths and resist thicknesses on Si substrates. The HSQ lines with widths of 5, 10, 20 and 30 nm were patterned by a Vistec VB6 UHR e-beam lithography tool, at 100 keV and the optimized dose was determined to be ~2700 $\mu C/cm^2$ for resist thickness of 40, 150 and 250 nm. Tetramethylammonium Hydroxide (TMAH) was used to develop the HSQ patterns. Based on the mechanical strength of HSQ resist, we used 250 nm thick resist, and achieved the reproducible high resolution sub-10 nm HSQ lines with highly vertical profile and high aspect ratio ~25:1 as shown in figures 1 and 2. These HSQ patterns have been successfully used as the etch mask to produce highly vertical sub-10 nm Si nanowires with smooth sidewalls and high aspect ratio up to ~ 50:1, which provides the flexibility for high resolution pattern transfer. Therefore, we expect that the developed HSQ processes combined with the optimized etch process will provide more reliable technologies for device fabrications of less than 10 nm.

[1] K. A. Lister, B. G. Casey, P. S. Dobson, S. Thoms, D. S. Macintyre, C. D.W. Wilkinson, and J. M. R. Weaver, Microelectron. Eng. **73–74**, 319 (2004).

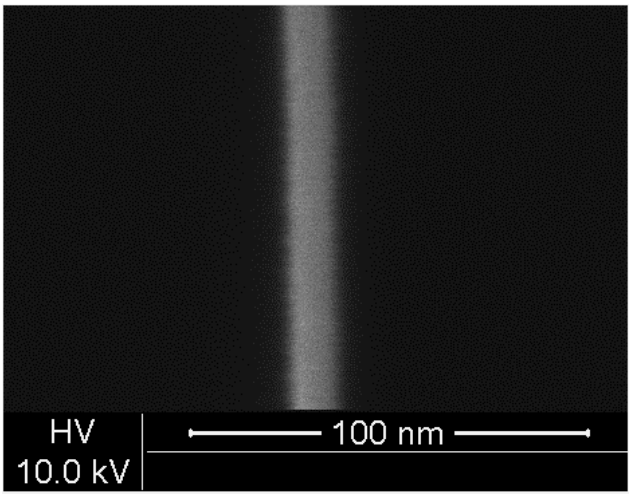

Figure 1: The SEM image taken by a FEI Nova Nano SEM without any metal coating shows the top-view of a high resolution HSQ resist line with sub-10 nm width and 250 nm thick (aspect ratio ~ 25:1).

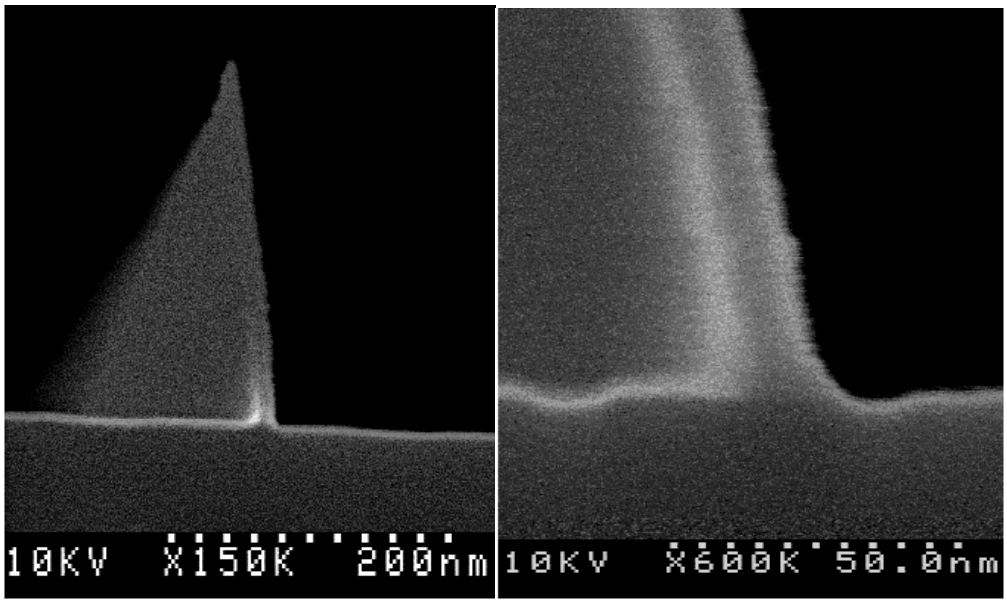

Figure 2: The SEM images taken by a Hitachi S-900 SEM without any metal coating shows the cross section of a highly vertical HSQ resist line with sub-10 nm width, 250 nm high and high aspect ratio ~ 25:1.