Influence of resist temperature during exposure on ultra-high resolution electron beam lithography using HSQ resist

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When making electron beam pattering of structures with sub-10 nm resolution additional effects making considerable contribution to the resist exposure process have to be considered. Typically, diffusion range of secondary electrons (SE) into the resist material, adhesion of the resist to the substrate surface and nanomorphology in resist material may crucially affect ultra high resolution patterning capabilities. Taking into account that some of these effects may depend on temperature of the resist, variation of the resist temperature during exposure could influence the size and shape of formed structures. Resist temperature during exposure has been reported to have a substantial influence on sensitivity for the variety of electron beam resist materials[1]. Here we report on investigation of temperature effect during exposure on ultra high resolution e-beam lithography using HSQ (FOx-12, Dow Corning) negative tone resist. The information on beam spot size is a prerequisite for achievement of quantitative e-beam patterning in sub-10 nm scale regime. Therefore, quantification of the electron beam spot size was performed by deconvolution of the FWHM from SEM images of Au nano-particles (Fig. 1) giving minimum achievable spot of ~4.6 nm. Droplet of Au nano-particles was placed directly on the resist allowing *in situ* e-beam focusing prior the resist exposure. Contrast curves (Fig. 2) were obtained for HSQ resist exposed at different temperatures during exposure (-20 ^{0}C; 25 ^{0}C and 60 ^{0}C) on the sample stage equipped with Peltier element. The results show rise of sensitivity and contrast improvement with temperature rise within investigated temperature range. Finally ultra high resolution lines&spaces structures were written in HSQ resist at different temperatures. SEM images show improved contrast and smoothness of the developed structures for the sample exposed at 60 ^{0}C compared to the samples exposed at lower temperatures (Fig. 3). While whole complexity of the temperature effect on the resist exposure process requires more understanding, observed effects could probably be attributed to the amplification of thermally activated processes based on bond breaking and scission together with slight decrease of mean free path of SE at higher temperature of the resist. Ample experiments are underway to quantify possible impact of temperature during exposure on final resolution and resist performance in sub-10nm regime.

1 S. Babin, J.Vac. Sci. Technol. B 21, 135 (2003).

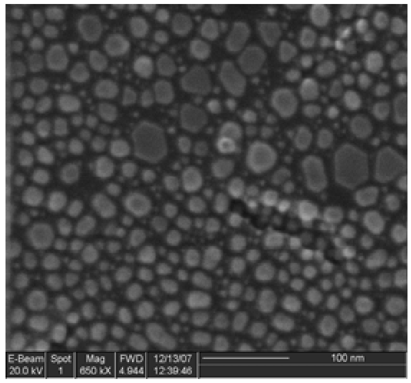

Fig 1: SEM image of Au nanoparticles on carbon used for deconvolution of e-beam spot size. (25%-75% width= 2.72 nm; FWHM=4.67 nm).

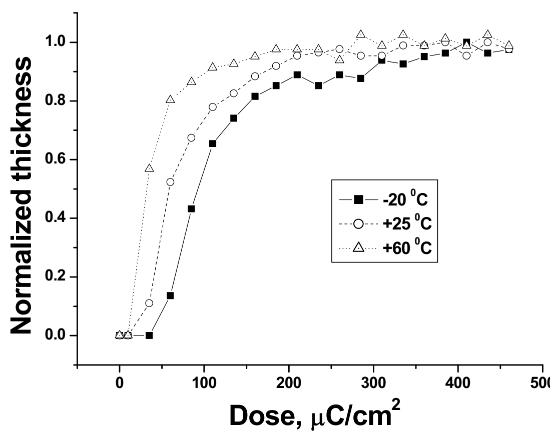

Fig 2: Contrast curves for the HSQ resist exposed at different temperatures.

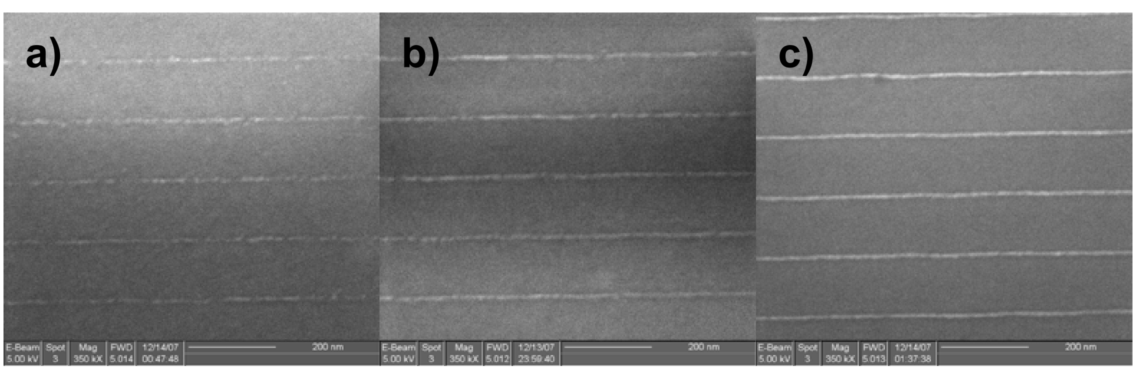

Fig 3: SEM images of lines&spaces written in 5nm HSQ layer (dose 4 mC/cm^2) at different temperatures: a) -20 ^{0}C; b) 25 ^{0}C; c) 60 ^{0}C. Average measured linewidth: a) ~6.6 nm; b) ~6.5 nm; c) ~7.5 nm.