Influence of temperature on HSQ e-beam lithography

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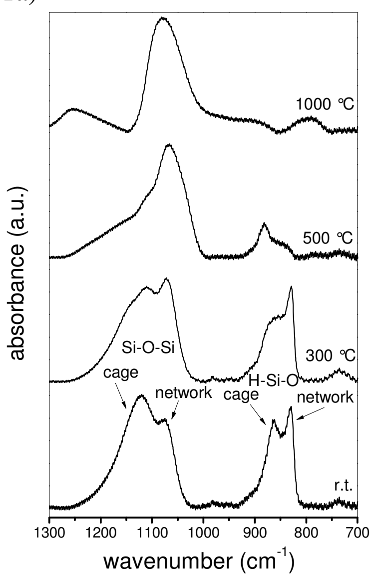
In high resolution electron beam lithography using hydrogen silsesquioxane (HSQ) as a negative tone resist [1] there are several processing steps where temperature may significantly influence lithographic performance. Lithography using HSQ resist includes the following steps: spin-coating with HSQ, drying of the resist in order to remove the solvent, in our case methyl isobutyl ketone (MIBK), e-beam exposure, development in tetramethylammonium hydroxide (TMAH). Baking the resist structures at temperatures above 300°C will further crosslink and solidify the material as suggested by the IR spectra in fig. 1a, where the "network" peaks associated with cross-linking still increase when tempering at higher temperatures [2].

In our study of the influence of temperature during drying, developing and post-development baking of the HSQ, resist contrast and sensitivity, obtained pattern quality and IR spectra are analyzed in context. In accordance with the observation that tempering at relatively low temperatures can already lead to noticeable crosslinking, comparable to the effect of e-beam exposure (c.f. fig. 1b) we find that decreasing the drying temperature below 90°C and drying the HSQ resist at room temperature in vacuum yields better resolution compared with resist that was dried in a furnace or a hotplate at 90°C or above. The difference in pattern quality between samples after a thermal drying step at 90°C (left micrograph) and after vacuum drying at room temperature (right micrograph) can be clearly seen in figure 2.

Another critical process step of e-beam lithography with HSQ is the development of the resist after exposure. The processing method of [1] was extended by developing the exposed resist not at room temperature but at 40°C, which results in significant contrast enhancement (see also [3]), as shown in the contrast curves of fig. 3. Correlations between these findings and IR data will be presented.

[1] W. Henschel et al., J. Vac. Sci. Technol. B 21 (2003) 2018
[2] M.J. Loboda et al., J. Electrochem. Soc. 145 (1998) 2861
[3] Y. Chen et al., Microelectronic Eng. 83 (2006) 1119

1a)



1b)

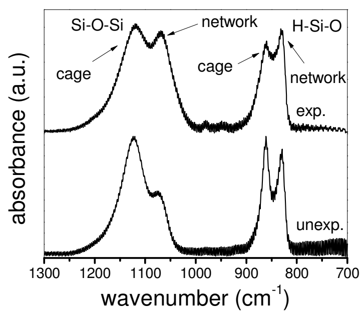


Figure 1a: IR spectra of furnace-dried HSQ resist tempered at r.t., 300 °C, 500 °C, and 1000 °C. All spectra were recorded at room temperature (r.t.)

Figure 1b: IR spectra of HSQ resist. Bottom: spectrum of unexposed resist; top: spectrum of exposed resist. All spectra were recorded at r.t.

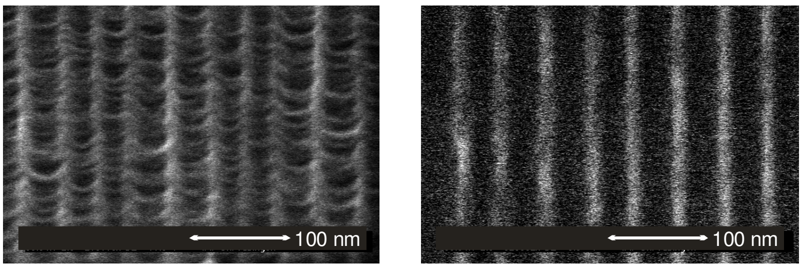


Figure 2: Comparison of two samples that were pre-baked at 90°C (left) and vacuum dried (right) respectively

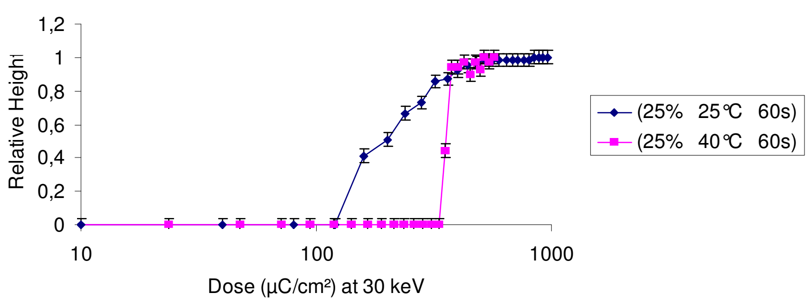


Figure 3: Contrast curves after development in TMAH (25%) at 25°C and 40°C respectively