E-beam lithography using dry powder HSQ resist having long shelf life

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Hydrogen silsesquioxane (HSQ) is arguably the most popular negative electron beam resist for academic research [1]. One of the most significant advantage of HSQ is its ultra-high resolution. It is reported that isolated 7 nm wide lines can be achieved when using 100 keV e-beam and very thin (20 nm) resist [2]. However, there is one notable drawback of traditional HSQ resist. The shelf life of this liquid resist is too short which greatly limited its wide usage (The specifications of Dow Corning® XR-1541 e-beam resist stated that HSQ should be stored at 5 ºC with a shelf life of only 6 months from the date of manufacture). On the other hand, the positive PMMA resist has unlimited shelf life and is very cheap and easy to work with, which is one major reason that it is still the most popular resist for academic research.

Apparently, the shelf life issue can be resolved if using dry powder HSQ that can be stored for very long time without degradation. An as-needed small amount of the powder resist can be simply dissolved in a solvent before usage, with the remaining resist solution stored in a refrigerator for near future use. However, such a powder resist still doesn't solve the second issue with HSQ [3]. That is, the coated HSQ film must be exposed and developed quickly in order to attain reproducible results (in contrast, PMMA film is very stable in air).

Here we study the exposure property of dry powder HSQ resist (Applied Quantum Materials, Canada; we will refer it as AQM HSQ, and the conventional HSQ as Dow HSQ). We dissolved the powder in MIBK, which is also the solvent for Dow HSQ. For the same concentration, the film thickness is very close for the two HSQ resists. We exposed the resist at 20 keV beam energy, and Figure 1 shows the contrast curves for AQM HSQ and Dow HSQ measured using AFM for 200 nm film thickness. As expected, the contrast curves for the two resists followed very closely to each other, with the AQM resist having very slightly lower sensitivity (i.e. dose corresponding to 50% remaining resist) They have almost the same "gel-point" of ~300 $\mu C/cm^2$ (i.e. the dose at the turning point in the contrast curve). Figure 2 shows the SEM images of the developed HSQ line structures. Note that the line array covers an area of 5 μm by 5 μm square, which is much larger than the electron backscattering range, thus the proximity effect would be quite significant. Much narrower lines could be attained by minimizing proximity effect (e.g. expose isolated line) and forward scattering (e.g. use high electron energy), as well as using very thin resist (<20 nm). Currently we are pushing the resolution limit by using 100 keV exposure and thin resist, and the results will be presented.

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[2] Grigorescu et. al, "10 nm lines and spaces written in HSQ, using electron beam lithography", Microelectron. Eng., 84, 822 (2007).

[3] Clark et. al., "Time-dependent exposure dose of hydrogen silsesquioxane when used as a negative electron beam resist", J Vac Sci Technol B, 24, 3073 (2006).

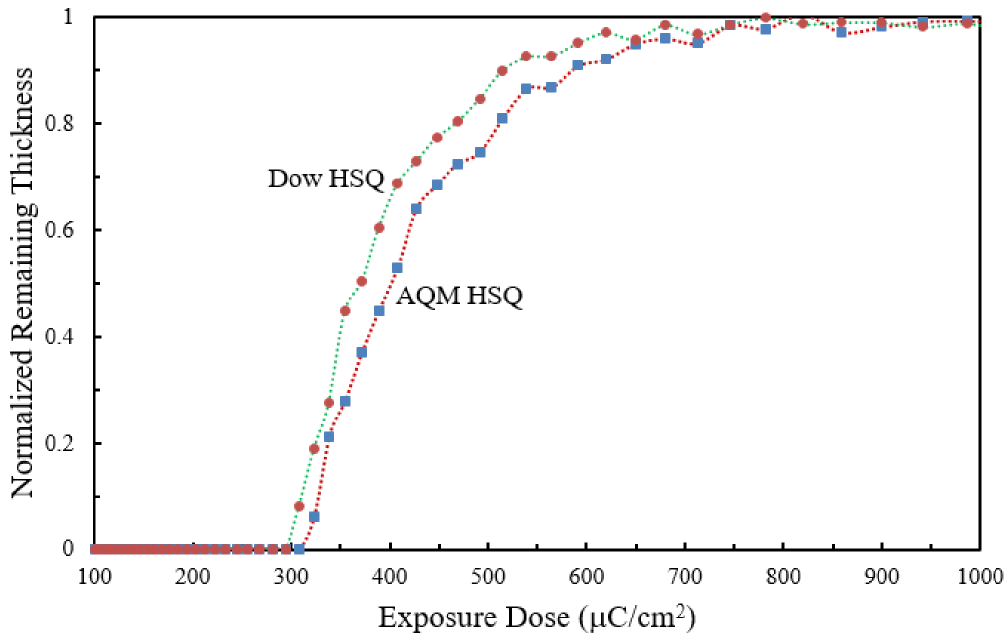
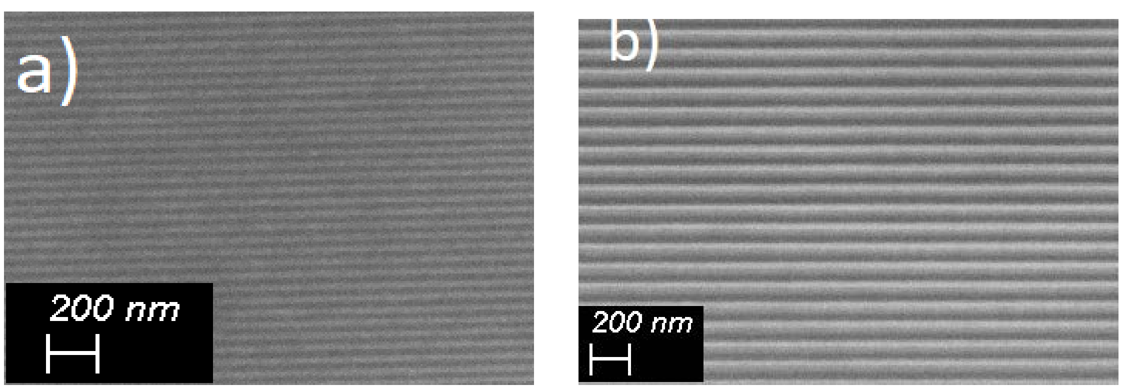


Figure 1. Contrast curves for AQM HSQ and Dow HSQ resist, exposed at 20 keV and developed in 25% TMAH for 60 sec, using 200 nm-thick resist.



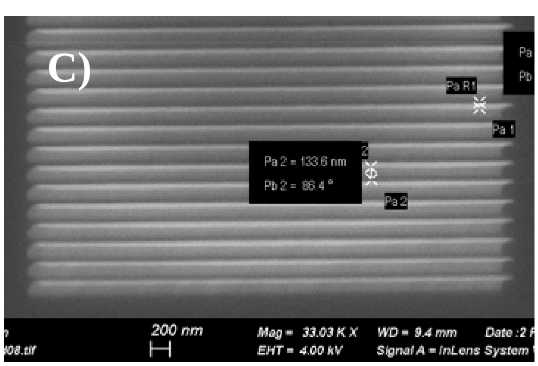


Figure 2. Exposed AQM HSQ and Dow HSQ line array structures. Array periodicity 50 nm, 100 nm and 200 nm for a, b and c, respectively.