# High Acceleration Voltage Characterization of SML Electron Beam Resist for Ultra High Aspect Ratio Nano-Lithographic Applications

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Poly(methylmethacrylate) (PMMA) is a positive tone organic electron beam resist well known to the scientific and industrial communities; it can produce features tens of nanometers in size[1]. To achieve such geometries, the resist film thickness must be around 40nm and hence, it has an aspect ratio limit of approximately 4:1 using an acceleration voltage of 25KeV[1]. Therefore, a higher aspect ratio resist is desirable for both metal deposition and etching applications.However, by increasing the acceleration voltage of 100KeV the aspect ratio can be increased, and the latest results demonstrate an aspect ratio of 12.5:1 has been achieved[2].
A new positive tone electron beam resist called SML2000 has been developed at the University of Manchester to obtain large aspect ratios[3]. This is demonstrated in Figure 1 where the SML2000 resist has been exposed to acceleration voltage of 100KeV.It shows a grating consisting of sub 30nm trenches in 2131nm thick resist. This equates to an aspect ratio of ~75:1 and is *the largest aspect ratio obtained to date*. This was achieved using a standard PMMA development process. Comparing this to PMMA Figure 2 shows a PMMA grating consisting of ~60nm trenches that has collapsed upon development.Reducing the dose resulted in under exposure.
A Monte Carlo model was developed at the University of Manchester to gain a physical understanding of the internal electron scattering effects inside the SML resist system[3]. It was observed from Figure 3 (left) that the PMMA experiences an increased electron scattering by an order of magnitude with respect to the SML2000 resist shown in Figure 3(right) with 361 and 29 scattering events, respectively. This is due to the nature of the molecular properties of the SML2000 resist by confining the primary electrons (PE) to the incident beam inside the resist and the number of secondary electrons (SE) generated is approximately zero. Hence, their contribution to the proximity effect will be zero, making it possible to fabricate sub 30nm structures in such a thick resist.
This is a significant result as the resist thickness is approximately 2 times larger than standard PMMA, the even smaller (sub 30nm) structures can be etched 2 times deeper into the substrate. In addition to this, the SML2000 resist enables the fabrication of nano-structures with a greater cross sectional area of metal that can be lifted off than was previously possible. This is significant because it increases the power handling capability of the nano-structures and reduces their resistance.

[1] S. Lewis, Chapter title: 'Fabrication and characterization of a poly(methylmethacrylate) based nanocomposite electron beam resist for next generation nano lithography' , Book Title: Nanocomposite Materials, Theory and Applications. Published by INTECH, ISBN: 978-953-7619-*X*-*X*, (Feb 2011).
[2] S. Gorelick, J. Vila-Comamala, V. Guzenko, R. Mokso, M. Stampanoni, C. David, 'Direct e-beam writing of high aspect ratio nanostructure in PMMA: A tool for diffractive X-ray optics fabrication', Microelectronic engineering, 87 pp 1052 – 1056, (2010).
[3] S. Lewis, D. Jeanmaire, V. Haynes, P. McGovern, L. Piccirillo, 'Characterization of an ultra high aspect ratio electron beam resist for nano-lithography', Nanotech 2010, Vol. 2, (2010), Pages195 – 198.

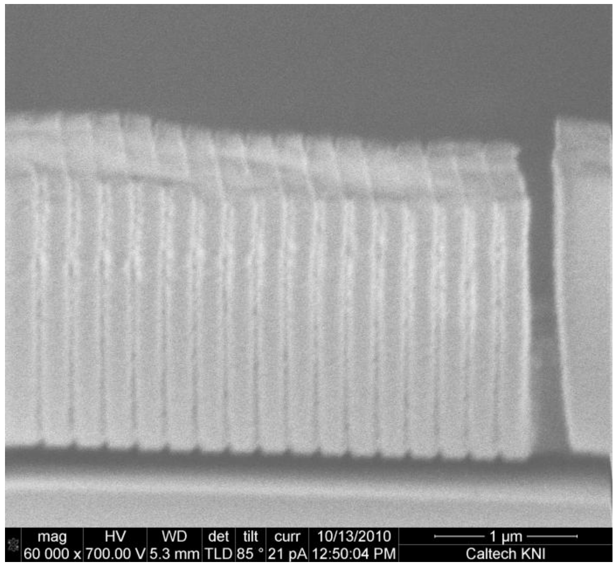


Figure 1: SEM image of high aspect ratio SML grating in 2131nm – thick layer of resist with sub 30nm trenches separated by 171nm wall, the aspect ratio is ~75:1.The exposure pattern consisted of a matrix of 30nm wide by 100µm long lines, they were exposed using a dose of 1050µC/cm$^2$ at 100KeV and a probe current of 239pA was used. The image was acquired at a tilt angle of 85˚.

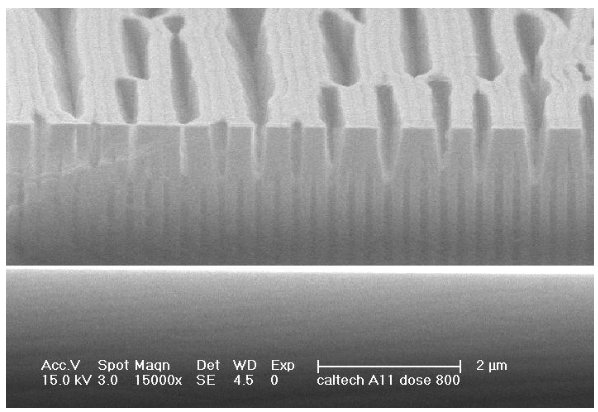


Figure 2: SEM image of 2320 nm thick PMMA that has collapsed. The exposure pattern consisted of a matrix of ~60nm wide by 100µm long lines, they were exposed using a dose of 800µC/cm$^2$ at 100KeV and a probe current of 239pA was used. The image was acquired at a tilt angle of 85˚.

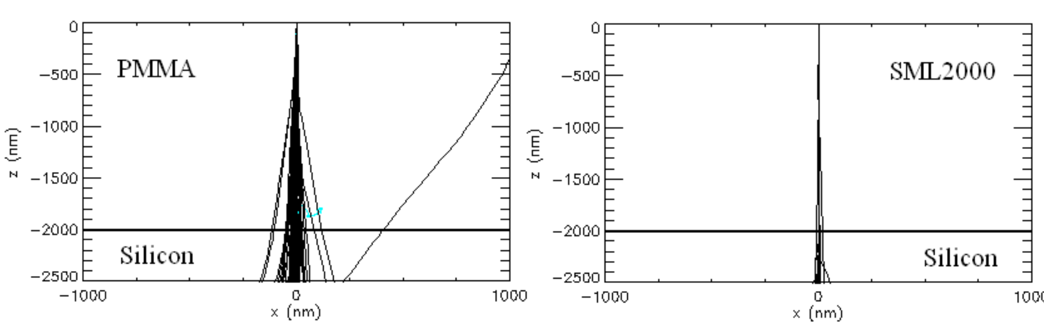


Figure 3: Internal scattering interactions of PMMA (left) and SML (right) exposed at 100KeV and a dose of 800 and 1050µC/cm$^2$ respectively. Secondary electrons are indicated in blue.