Parallel Electron-Beam-Induced Deposition using a Multi-Beam Scanning Electron Microscope

A. Mohammadi-Gheidari, P.C. Post, C.W. Hagen, and P. Kruit
Delft University of Technology, Fac. Applied Sciences, Charged Particle Optics Group, Lorentzweg 1, 2628 CJ Delft, The Netherlands, c.w.hagen@tudelft.nl

Using resist-based Electron Beam Lithography (EBL) one can routinely fabricate patterns down to 10 nm, and down to about 5 nm[1] when using ultra-thin resists and dedicated development processes. Using Electron-Beam-Induced Deposition (EBID) even smaller patterns of 1 nm size can be written[2]. In EBID a focused electron beam dissociates precursor molecules adsorbed on a substrate surface, leaving a solid deposit on the surface and gaseous fragments which can be pumped away. The advantage over EBL is that it is a direct deposition technique and it provides a smaller minimum feature size. However both EBL and EBID are inherently slow lithography techniques, i.e. when compared to light lithography techniques, because it is a serial writing process instead of parallel. To enhance the throughput one could write with many electron beams in parallel. To that purpose we developed a multi-electron beam source mounted on a regular Scanning Electron Microscope (SEM). This Multi-Beam SEM (MBSEM) projects an array or 14×14 focused beams onto a sample (see Figure 1) with a probe size and current per beam comparable to that of a standard single-beam SEM[3,4].

We address here the first parallel deposition of dots using multi-beam EBID. These experiments serve as a first test of the MBSEM as a multi-beam EBID system. Furthermore, from the size of the deposits and the distances between them, conclusions can be drawn on the probe size of the individual beamlets, and on the presence of distortion. Square arrays of dots were grown on a $W/Si_3N_4/W$ sandwich membrane (layer thicknesses 200nm/50nm/200nm resp.) in a single exposure with 196 beamlets. As a precursor gas we used the platinum precursor $MeCpPtMe_3$. The specimen chamber was filled with precursor gas at a pressure of 2.5×10^{-5} mbar. After the deposition the gas was pumped out and the dot arrays were imaged directly in the MBSEM using the standard secondary electron detector. Figure 2 shows a multi-beam image of a dot array. Because the imaging is also done with 196 beams simultaneously the result is a convolution of the deposited dot array and the 14x14 array of beamlets that is scanned over the dot array. This explains why there are more than 14x14 bright spots in the image and it explains the variation in intensity across the array. In the presentation we will analyze the results in much more detail.

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[1] Joel K. W. Yang et al., J. Vac. Sci. Technol. B 27, 2622 (2009)

[2] W.F. van Dorp, B. van Someren, C.W. Hagen, P. Kruit, and P.A. Crozier, Nanoletters 5, 1303 (2005).

[3] A. Mohammadi-Gheidari, C. W. Hagen, and P. Kruit; J. Vac. Sci. Technol. B 28, C6G5 (2010).

[4] A. Mohammadi-Gheidari, and P. Kruit; Nucl. Instr. and Meth. A, Article in press (2010).

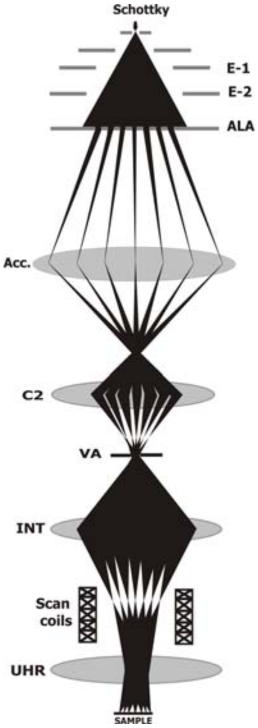

Figure 1(left): Schematic overview of the electron optical system of the Multi-Beam Scanning Electron Microscope[4]. E-1 and E-2 are electrostatic lens electrodes, ALA is the beamlet-defining aperture lens array, Acc. is the accelerator lens, C2 is the condensor lens, VA is a variable aperture, INT is the intermediate lens, UHR is the ultra-high resolution objective lens.

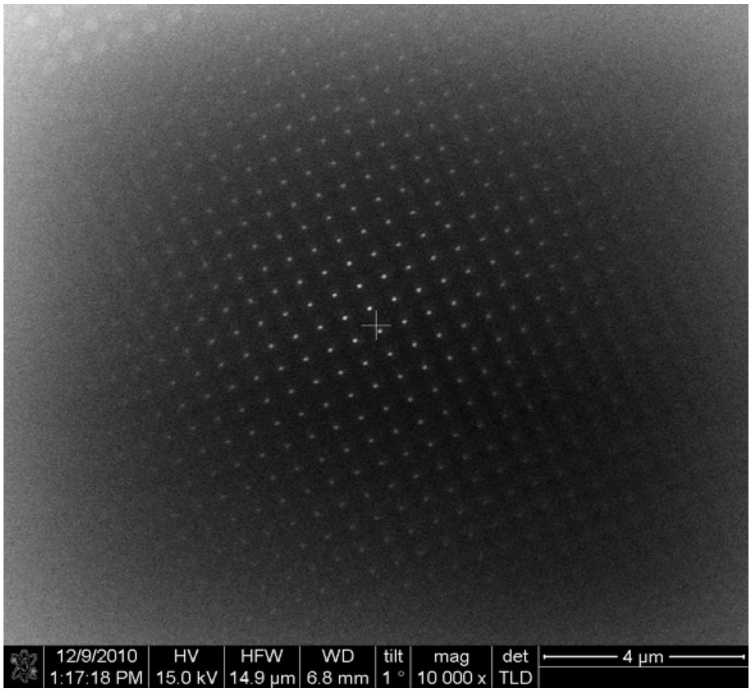

Figure 2(right): A multi-beam image of dots deposited using multi-beam EBID, from MeCpPtMe$_3$ as a precursor gas, obtained with a single secondary electron detector. The dots in the centre are the brightest because these are 'visited' by more beamlets than the outermost dots.