Design of a simple add-on to change a single-beam SEM into a multi-beam SEM

M. Scotuzzi, C.W. Hagen and P. Kruit
Department of Imaging Physics, Delft University of Technology, Delft,
Lorentzweg 1, 2628CJ, Delft, The Netherlands
m.scotuzzi@tudelft.nl

In Delft we developed a multi-beam Scanning Electron Microscope (MBSEM) where the emission from a single Schottky electron source is divided in 196 beams (14x14 array), that are focused at the sample with a theoretical spot size of 1.2 nm, at 15 kV and a probe current (per beam) of 26 nA[1,2]. To enable individual blanking of each beam for lithography or Electron Beam Induced Deposition[3], a deflector array needs to be installed. The most natural way to do that would be to integrate it in the source module. However, this is a very challenging task combining many electrical feedthroughs with the high voltage source environment. Therefore we propose a novel design of a Multi Beam SEM, where we aim for *flexibility* and *versatility,* namely the changes to be made to a standard microscope do not have to be permanent and will have to fit easily in a variety of SEMs. The multi-electron beam unit consists of a beam splitter, a combination of a macro lens M1 and a micro-lens aperture array (MLA), and a deflector array (or blanker plate). The unit can be inserted in the electron column via the variable aperture port, while a blanking aperture should be installed in the objective lens, as is done in an environmental SEM. With the aperture installed, only transmission detection is possible. Figure 1 shows two optical designs of an SEM with a multi beam unit, in which the beams have a different angle in the MLA plane, as achieved by changing the strength of the M1 lens. For both cases, first order optics calculations for such a unit in our FEI Nova-Nano-Lab show that an on-axis probe size of 1.6 nm can be achieved, with 50 pA current at 5 kV. With the present apertures in the system, 49 beams can be obtained for the inclined beam solution (Fig. 1 left), 9 beams for the parallel beam mode (Fig. 1 right). Furthermore, the statistical Coulomb interactions were evaluated, resulting in negligible effects on the probe size at the sample for total currents and electron energies that are typically found in the condenser optics of single beam systems. We will present simulation results on the optical performance of these two solutions, including an off-axis aberration analysis[4].

---

[1] Mohammadi-Gheidari, A., Hagen, C., & Kruit, P. (2010). Multibeam scanning electron microscope: Experimental results. *J. Vac. Sci. Technol. B,* 28(6), C6G5.

[2] Mohammadi-Gheidari, A., & Kruit, P. (2011). Electron optics of multi-beam scanning electron microscope. *Nuclear Instruments And Methods In Physics Research Section A,* 645(1), 60-67.

[3] Post, P., Mohammadi-Gheidari, A., Hagen, C., & Kruit, P. (2011). Parallel electron-beam-induced deposition using a multi-beam scanning electron microscope. *J. Vac. Sci. Technol.* B, 29(6), 06F310.

[4] We acknowledge support from the European Union under Grant Agreement No. 318804 - SNM

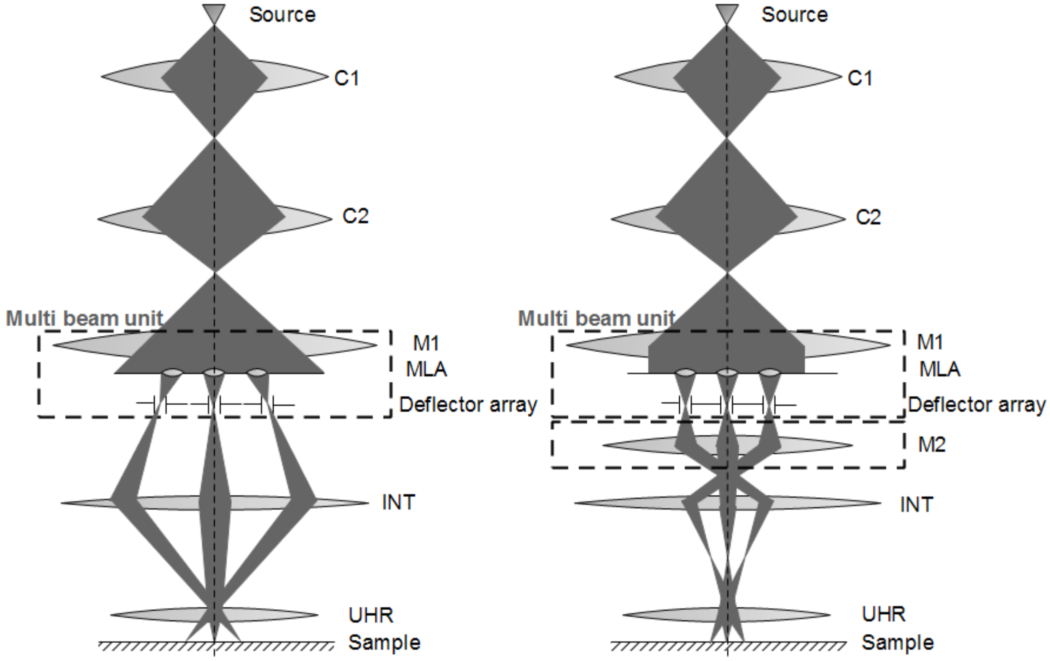

Figure 1: Optical designs of the new concept for a multi-beam SEM. On the left, the beams are inclined, while on the right they are parallel to the optical axis in the multi beam unit. This can be obtained by changing the strength of the M1 lens. In the parallel mode, a second lens M2 below the blanker array is necessary to get a common crossover in the UHR lens.

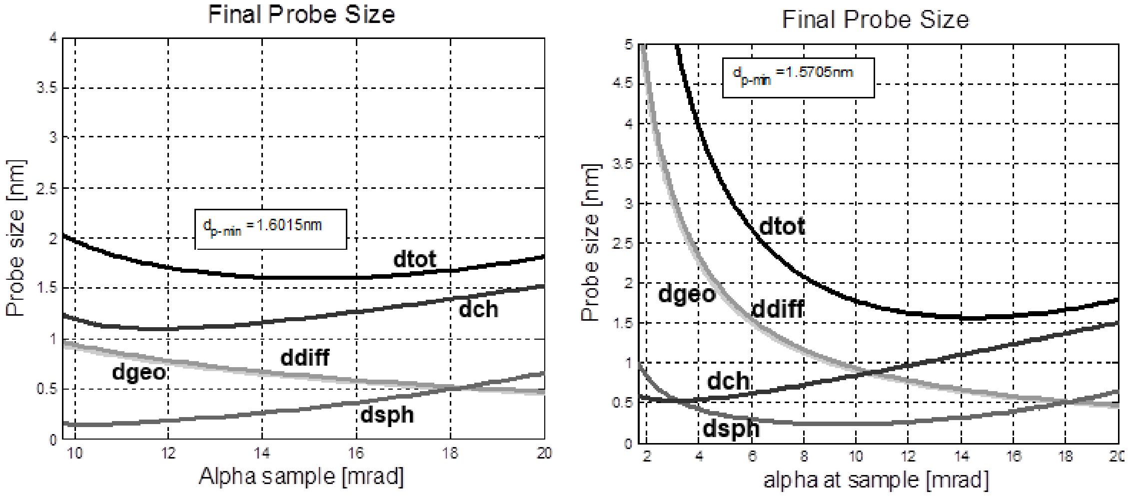

Figure 2: On-axis aberration contributions (geometrical, diffraction, spherical and chromatic) to the total probe size as a function of the half-opening angle alpha at the sample. For the inclined beam mode (left) the minimum probe size is 1.6 nm. For the parallel beam mode (right) the minimum probe size is 1.57 nm.