Simple add-on to change a single-beam SEM into a multi-beam SEM

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In Delft we are developing a simple add on to turn a single-beam SEM into a multi-beam scanning electron microscope (MBSEM). The multi beam unit (MBU) can be easily inserted in the variable aperture port of a scanning electron microscope, providing *flexibility* and *versatility*, namely the changes to be made to a standard microscope do not have to be permanent and will fit easily in a variety of SEMs. The multi-electron beam unit consists of a beam splitter, a combination of a deceleration lens, a macro lens and a micro-lens aperture array. To enable individual blanking of each beam for lithography or Electron Beam Induced Deposition, a deflector array is also installed, below the beam splitter. The schematics on the left in Figure 1 shows the optical design of an SEM with a multi beam unit. First order optics calculations for such a unit in our FEI Nova-Nano-Lab 650 show that an on-axis probe size of 1.6 nm can be achieved, with 50 pA current per beam at 5 kV. Off-axis aberrations increase the outermost beam size to approximately 1.7 nm. The statistical Coulomb interactions, calculated considering the over-estimated case in which all the beams overlap with the central beam all the way from the blanker to the sample, show a very small increase to the probe size (less than 1 nm). Figure 1 (right) shows a micrograph of the stack of electrodes that form the MBU. The stack is fixed on a support that can be easily inserted in the variable aperture port and is connected to the outside world via flex printed circuits and high voltage connectors. We equipped our FEI Nova with a SECOM platform[1], with an optical microscope inside the vacuum chamber, which enables transmission imaging[2] using a YAG screen covered with Al. Figure 2 (left) shows the optical image of the 5x5 array of focused beams at 5 µm pitch. To demonstrate the throughput enhancement in lithography, Figure 2 (right) shows a SEM micrograph of 25 pillars of 90 nm diameter, deposited by Electron Beam Induced Deposition using the $MeCpPtMe_3$ precursor. Compared to dedicated multi-beam SEMs[2,3], both the number of beams and the current in the beams in our present embodiment is limited, so we expect a different application field than truly high throughput imaging. [4]

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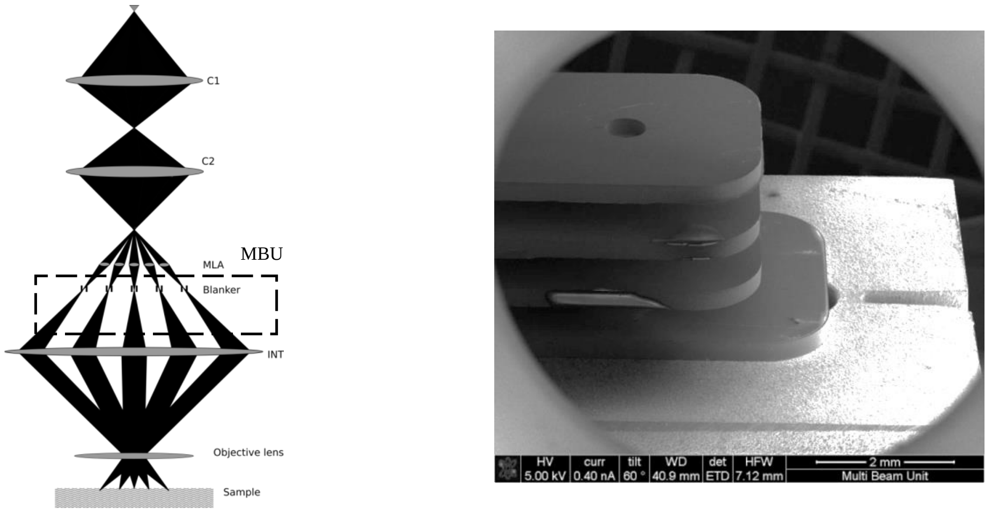

Figure 1: On the left, the design of a multi-beam SEM is shown. The Multi Beam Unit (MBU) is inserted in the variable aperture port and splits the beam into 25 beamlets that are focused on the sample surface by means of the intermediate and objective lenses. On the right, an SEM micrograph is shown of the stack of electrodes forming the MBU.

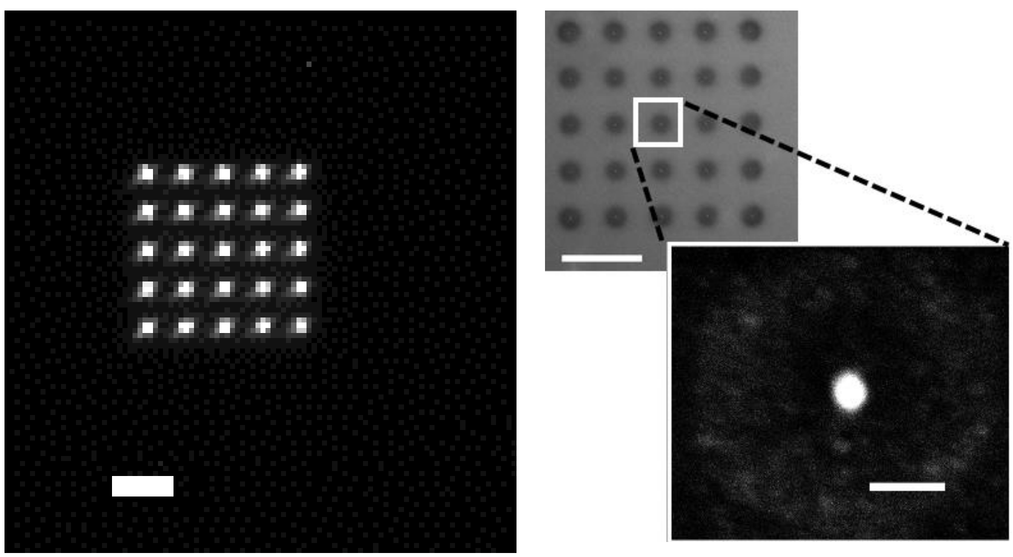

Figure 2: Left, optical image of 25 beams at a pitch of 5 µm, focused on a scintillator located above an objective lens that focuses the light onto a camera; the scale bar is 10µm. Right, first attempt of patterning pillars using EBID: the diameter of the pillars is approximately 90 nm (the bright dots in the centre of the black surrounding halos); the scale bar is 5µm on the pillars overview and 250 nm in the zoomed in image.