Parallel Secondary Electron Imaging in a Multi-Beam SEM

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There's an increasing desire in biological research for large scale high resolution image maps and 3-D images of organ structures using scanning electron microscopes (SEM). However, this is extremely time-consuming. For constructing a 3D image of 0.16 mm^3 brain it takes about 317 days[1]. By adopting our Multi-Beam Scanning Electron Microscope (MBSEM), the time can potentially be reduced to 2 days!

Our MBSEM delivers a 14x14 array of focused beams with a resolution and current per beam comparable to a state of the art single beam SEM [2,3]. The challenge in using this array of beams for parallel imaging is to simultaneously detect signals without any overlap between signals of neighboring beams. We designed imaging systems for the parallel detection of Transmitted Electrons (TE), Secondary Electrons (SE) and Backscattered Electrons (BSE). Here we limit ourselves to the first two systems.

For the SE imaging system, a retarding lens is introduced to help focus both the primary- and SE-beams while keeping the SE beams separated in the detection plane near the variable aperture plane of the SEM (figure 1). A YAG screen and optical fibre conduit assembly, and an optical imaging system, are used to detect the SE beams. We have demonstrated that all beams arrive at the specimen in a regular grid, that the SE beams are focused and well separated in the detector plane (figure 2), and that separate beam-lets produce decent SE images (figure 3). We also made progress with the TE imaging system, presented at EIPBN2014, resulting in better resolution TE images. Figure 3 shows TE images of a few beams, and figure 4 shows an image map that comprises the TE images of all beams. We will discuss the flexibility of MBSEM imaging and the detection efficiency of the different imaging systems.

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[1] K,L.Briggman and D.D.Bock; Current opinion in neurobiology 22, pp 154-161 (2012)

[2] A. Mohammadi-Gheidari, P.Kruit, Nuclear Instruments and Methods in Physics Research A 645 (2011) 60

[3] A. Mohammadi-Gheidari, C. W. Hagen and P. Kruit, J. Vac. Sci. Technol. B28, (2010) 1071

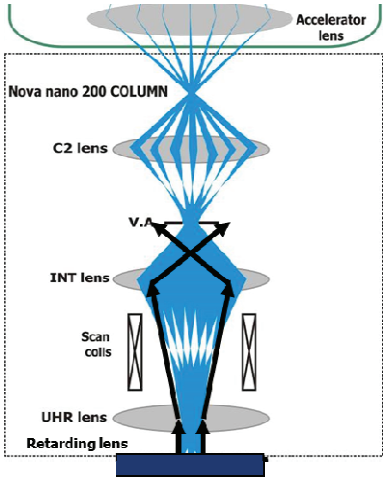

Figure 1

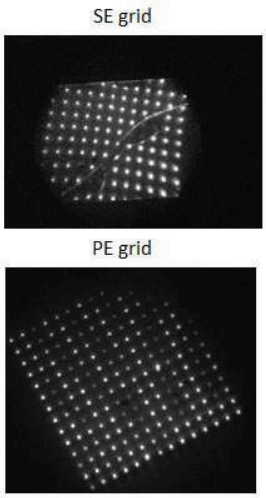

Figure 2

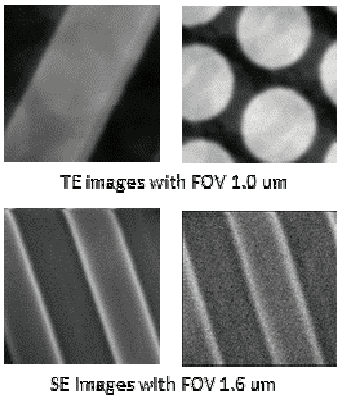

Figure 3

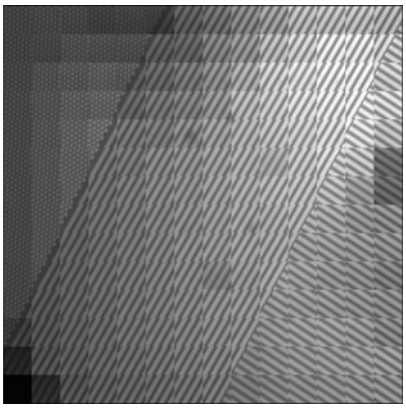

Figure 4

Figure 1: Multi-Beam Scanning Electron Microscope(MBSEM) with secondary electron detection. A retarding lens is used to help focusing the primary beams and secondary beams simultaneously.

Figure 2: Multi-Beam probes on the detection YAG-screen. Upper image shows the grid of SE beams in the variable aperture plane (V.A. in fig. 1) and the lower image shows the grid of primary beams .

Figure 3: Transmission electron (TE)and secondary electron (SE) images. The upper two images are TE- and the lower two are SE-images; they were captured in different experiments. The field of view (FOV) is indicated below the images. the patterns are holes and lines;

Figure 4: TE-image of a test sample (consisting of holes and lines in two perpendicular directions) formed by 14*14 sub-images.