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Solid State Backscattered Electron Detectors with Improved Image Contrast and Detection Speed

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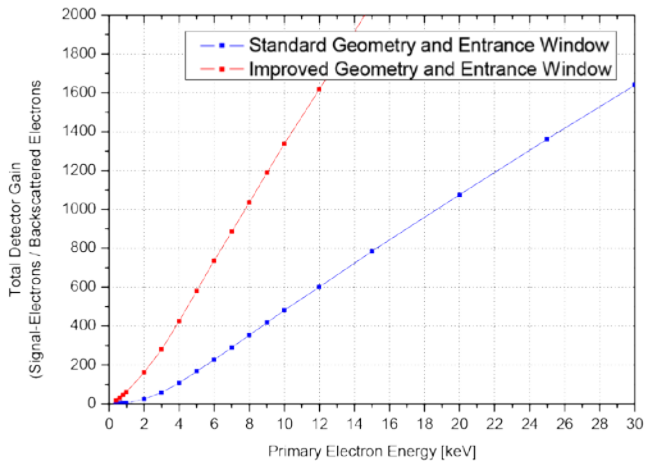
The typical operation conditions in Scanning Electron Microscopy have changed a lot during the last two decades. Imaging of insulating layers or biological samples demand for the use of low electron energies and currents. These conditions are not only challenging for the microscope itself but also for their detection systems. Many currently used Backscattered Electron (BSE) detectors show a highly reduced quantum efficiency for electron energies smaller 5 keV. This decreases the image contrast and signal to noise ratio and the necessary high gain of the readout electronics limits the detection speed. However, there are ways to increase the collection efficiency and the bandwidth of BSE detectors and therefore improve the detector performance.

One way to enlarge the signal of a BSE detector is to increase its solid angle. Optimizations of the geometry of our standard detector design led to an increase in collection efficiency up to a factor of three. The sensitivity for small electron energies can be increased by using advanced detector entrance windows which reduce the detector dead layer and therefore increase the quantum efficiency. Figure 1(a) shows the calculated total detector gain for detectors with different collection efficiency. This value describes the average number of signal electrons produced for every BSE electron hitting the detector. The improvement in collection efficiency results in a large increase of the average number of signal electrons, for example 180 signal electrons instead of 60 at an energy of 3 keV. This leads to an improvement of the image contrast and also to higher signal to noise ratios. Sample images illustrating this benefit in contrast due to the higher collection efficiency will be shown.

Figure 1(b) shows the measured signal to noise ratios plotted over the pixel dwell time for different BSE signal currents. It shows that also the SNR is highly increased due to the improved collection efficiency which helps to provide better image quality with less primary beam current or energy or at faster scan speeds. Sample images which compare the different signal to noise ratios will be presented.

There are different time constants which limit the detector bandwidth. One is determined by the detector signal capacitance. By applying a bias voltage to the diode the detector volume can be partially or fully depleted which decreases the detector capacitance down to a value of 3 pF. Additionally, the parasitic cable and connection capacitances have to be decreased in order to achieve higher gains without further limiting the bandwidth. We shortly introduced a new concept of preamplifier electronics with very small parasitic capacitances which enables signal rise times down to 100 nsec for low to moderate detector gains. Figure 2 shows a measured signal rise time of approximately 80 nsec which was acquired by scanning over a sharp silicon edge. This short rise time leads to sharp images without any smearing effects even for pixel dwell times of 100 nsec as can be seen in figure 3.



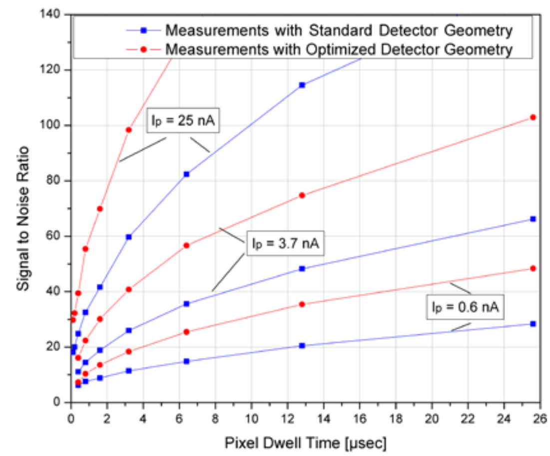


Fig. 1. a) Calculated total detector gain which describes the average number of signal electrons produced for every BSE electron hitting the detector and b) Measured Signal to Noise ratios for different primary beam currents plotted against the pixel dwell time.

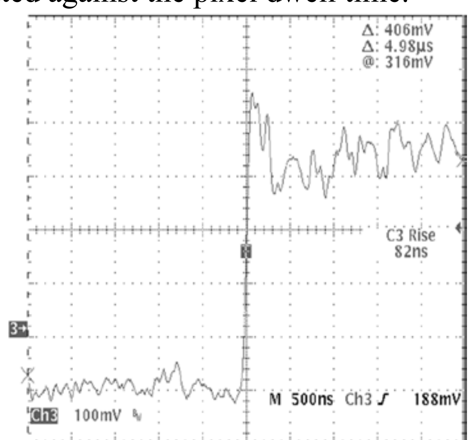


Fig.2. Signal rise time of approx. 80 nsec measured by scanning over a sharp silicon edge

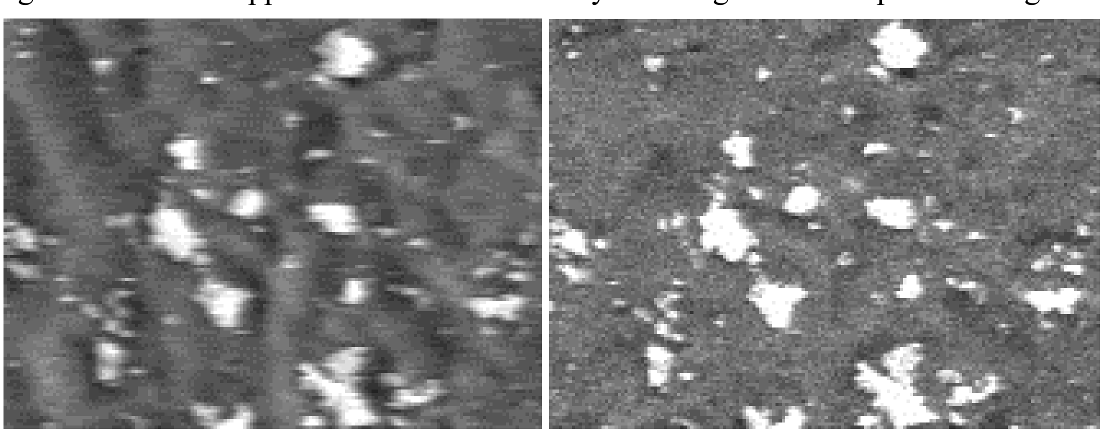


Fig.3. Comparison of two BSE image sections with 168 x 125 pixels taken at 100 nsec pixel dwell time. The left image was acquired with a conventional BSE detector with 250 nsec signal rise time and shows smearing in the scanning direction. The right image was taken with 80 nsec signal rise time and shows sharp details without smearing.