Advances in Light and Electron Optics

IM.2.P049
A new design for solid state backscattered electron detectors providing improved image contrast and detection speed

A. Liebel[1], R. Eckhardt[1], A. Niculae[1], H. Soltau[2]

[1]PNDetector, Munich, Germany
[2]PNSensor, Munich, Germany

andreas.liebel@pndetector.de

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, improved collection efficiency and readout concepts can help to expand the operating range of BSE Detectors.

The quality of a BSE image is not only characterized by the spatial resolution but also by the image contrast and signal to noise ratio. The latter is mainly determined by the current of backscattered electrons and the integration time per pixel. Therefore, higher contrast and signal to noise ratio, especially at low primary electron energies, is routinely achieved by using slower scan speeds or higher beam currents. This however may harm sensitive samples or decrease the spatial resolution.

Another solution for increasing image contrast and signal to noise ratio without changing the imaging conditions of the microscope is to enlarge the detector collection efficiency. Advanced entrance windows minimize the detector dead layer and therefore increase the quantum efficiency. Higher collection efficiency can also be achieved by using optimized detector geometries. Figure 1(a) shows the calculated geometric collection efficiency for detectors with different size and geometry. A smaller central hole of the chip through which the primary electron beam is guided increases the detector solid angle. It also helps to more efficiently collect electrons which are preferentially backscattered at high take angles. In figure 1(b) the measured signal to noise ratio with two different detector geometries is plotted versus the pixel dwell time. The profit in signal to noise ratio due to the higher collection efficiency is obvious. Figure 2 shows two sample BSE images taken at 3 keV with identical microscope conditions and readout. The right image is from a detector with optimized geometry and shows a highly improved contrast. We will present further images and measurements which demonstrate the benefit in image quality.

The fact that the signal currents can be enlarged without significantly increasing the active area of the detector can be also advantageous with regard to detection speed. Higher signals can be obtained while keeping the signal capacitance of the chip at a low level of a few pF. With the preamplifier electronics positioned close to the detector, as shown in figure 3, TV-Speed imaging with pixel dwell times smaller 100 nsec can be achieved for moderate to low beam currents. We will present rise time measurements and sample images showing this advantage.

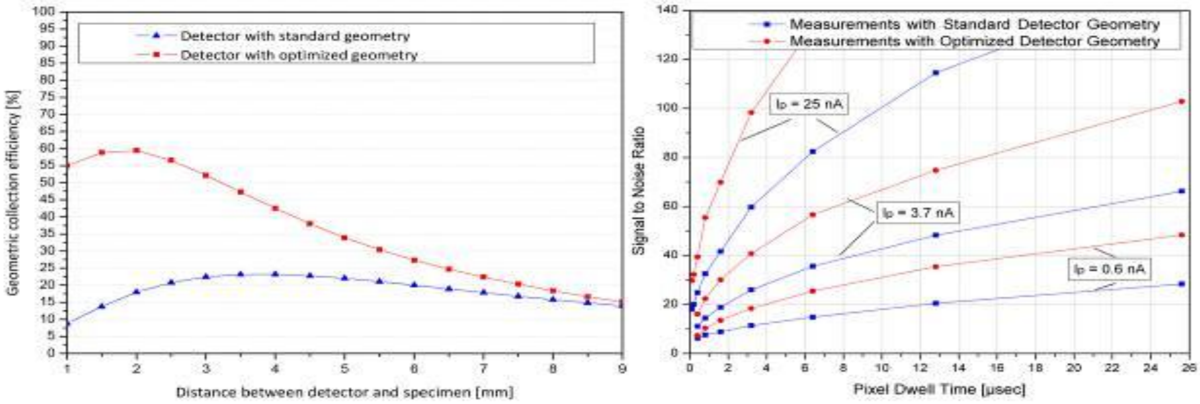

Figure1. a) Calculated geometric collection efficiency for different detector geometries. 100 % correspond to a solid angle of 2π. b) Measured Signal to noise ratio as a function of pixel dwell time for three different primary beam currents. The new detector with optimized geometry shows a large increase of the SNR.

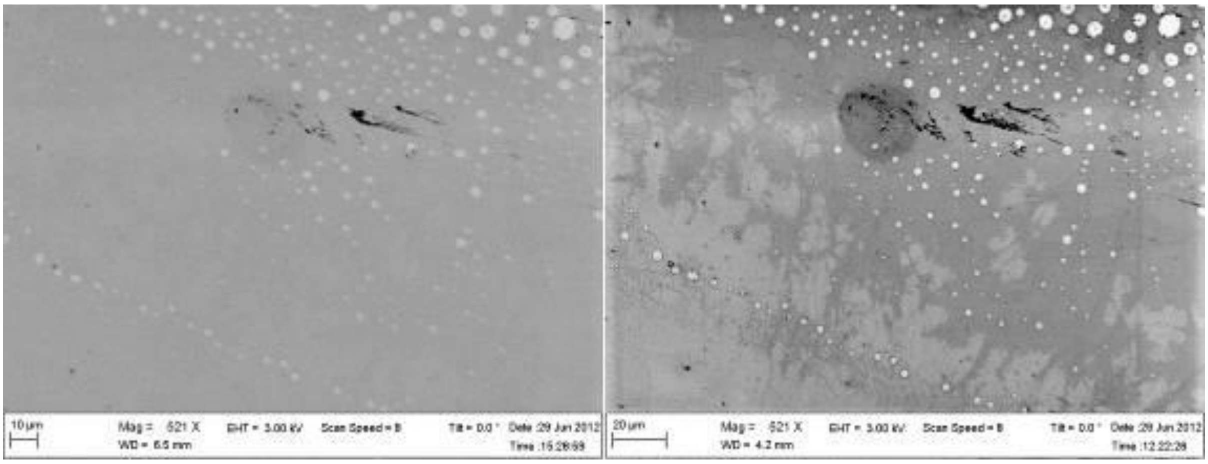

Figure 2. Two BSE images taken at 3 keV primary beam energy and identical microscope and readout conditions. The left image was taken with a standard geometry detector while the right image is from a detector with optimized entrance window and geometry and shows a highly improved contrast.

Figure 3. BSE Detector with optimized geometry (1.0 mm central hole diameter and 40 mm² active area). The Chip is directly connected to the preamplifier electronics which reduces the total signal capacitance and enables TV speed imaging (pixel dwell times < 100 ns) at low primary beam currents and energies.