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A Detector for Fast Electron Current Measurements based on Silicon Drift Detector Technology

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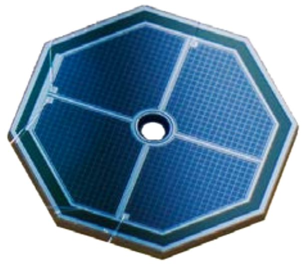
Solid state detectors for electron current measurements are a well-established tool in electron microscopy, especially for the detection of backscattered electrons (BSE) underneath the pole piece inside a SEM or for the measurement of transmitted electrons in STEM or TEM applications. The progress in electron microscopy over the last years has led to many interesting new applications but also to continuously growing requirements on the microscopes. Modern detectors must provide a high sensitivity to low energies, a high gain for the sometimes weak electron signals and short response times to enable high scan speeds.

State of the art solid state electron detectors consist of a detector chip with several annular diodes as shown in Figure 1a. They are connected to external electronics, typically based on a transimpedance amplifier circuit as shown in Figure 1b. The bandwidth of such a detector is mainly limited by the detector capacitance C_D which is typically in the magnitude of several picofarad and the stray capacitance C_F in the amplifier feedback loop which is determined by the cable connections and electronics and has a typical value from several hundred femtofarad up to some picofarad. The feedback capacitance C_F limits the transimpedance gain R_F which can be used without significantly decreasing the detector bandwidth. Hence, the range in which the bandwidth of detectors based on this technology can be increased is limited and new detector concepts are necessary to accomplish future tasks.

We will introduce a new concept based on the principle of the Silicon Drift Detector (SDD) - a sensor which is well known from Energy Dispersive X-ray (EDX) spectroscopy (see Figure 2). A new read out scheme of the SDD for fast current measurements will be presented which provides a solution for strongly decreasing both mentioned capacitances and therefore dramatically increasing the bandwidth of the detection system. Similar to known SDD devices with integrated Field Effect Transistor (FET) it has a very small anode with a signal capacitance smaller than 200 fF. The characteristic of the new device is that it uses a second chip-integrated Field Effect Transistor, the Feedback FET. Its channel resistance can be adjusted by varying the gate voltage and therefore this transistor serves as an adjustable feedback resistor R_F with very low parasitic capacitance due to the integration on the chip. Hence, the detector device works as a transimpedance amplifier configuration with very low detector signal capacitance and very low feedback capacitance C_F of only several femtofarad. Figure 3 shows a measurement of the detector rise time and the transimpedance gain, i.e. the value of R_F plotted for different feedback transistor gate voltages. The measured rise time for a transimpedance gain of 10 MΩ is still well below 500 nsec. For a conventional electron detector diode where the feedback capacitance is in the order of typically more than 250 fF the rise time for the same transimpedance gain would be larger than 5 µsec.

We will present further measurements demonstrating the high bandwidth of this detector. First images from a backscattered electron detector prototype based on this technology will be shown.



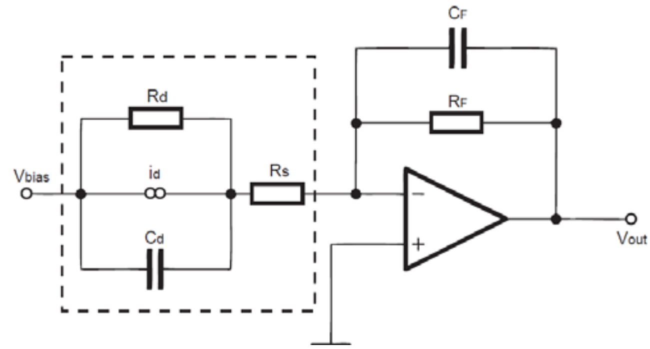


Fig. 1. a) Picture of a state of the art Backscattered Electron Detector Chip with four annual diodes and b) the typical transimpedance amplifier scheme for such a detector. The dashed rectangle indicates the components of the chip.

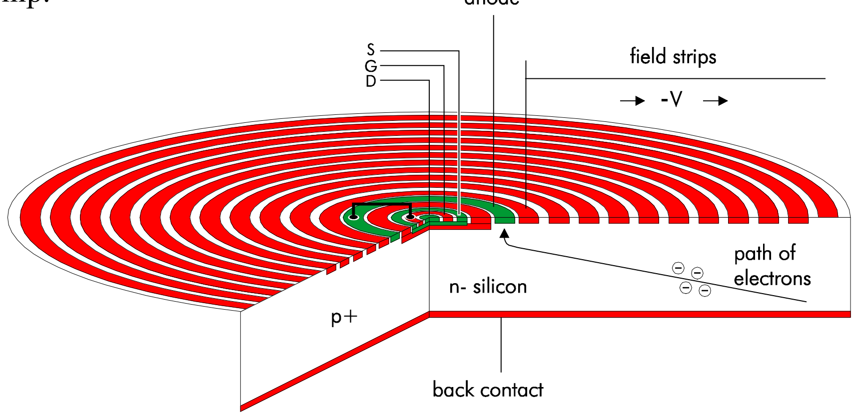


Fig.2. Principle of the Silicon Drift Detector with integrated Field Effect Transistor as it is used for Energy Dispersive X-ray spectroscopy.

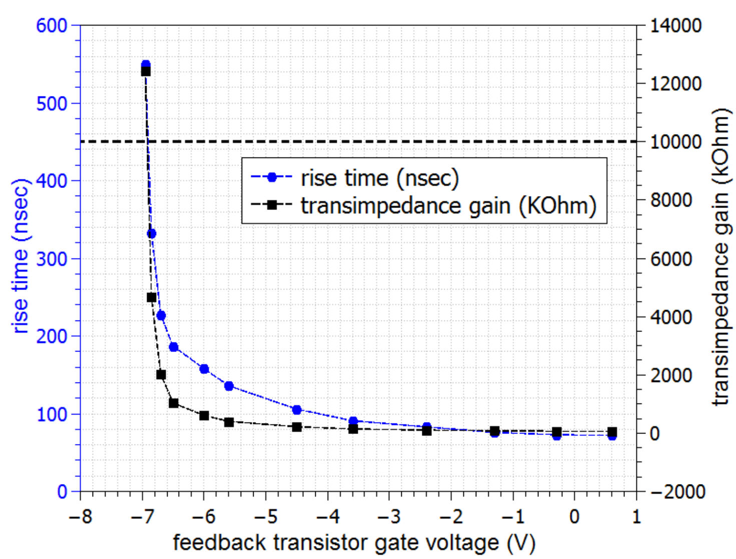


Fig.3. Measurements with the new SDD technology based electron current detector showing the signal rise time and the transimpedance gain for different feedback transistor gate voltages. In this case short LED light pulses were used as input signal. Even for a transimpedance gain of 10 MΩ the signal rise time is well below 500 nsec.

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