Development of a New Silicon Drift Detector Module

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Abstract. A novel 7 cell Silicon Drift Detector (SDD) module for X-Ray Absorption Fine Structure Spectroscopy (XAFS) and similar methods is developed at the Hamburger Synchrotron Strahlungslabor at Deutsches Elektronen Synchrotron. The monolithic 7 cell SDD detector chips were delivered by PN Sensors (Munich, Germany). Each cell has an active area of 7 mm². In this paper we report results from the spatially resolved spectroscopic characterization of the SDD and their consequences for the final design of the complete detector modules. A specialized read out chip is currently developed at DESY and will make it possible to achieve a maximum count rate of 600 Kcps/detector cell.

Keywords: Silicon Drift Diodes, fl-XAFS, detector development
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INTRODUCTION

Energy dispersive detectors used for Fluorescence detected X-ray Absorption Fine Structure (XAFS) spectroscopy should fulfill three basic requirements: The energy resolution should be better than 300 eV (FWHM@ Mn-Kα) even at high count rates, the maximum count rate should be larger than 100 Kcps and they should cover a large solid angle. Silicon Drift Diode (SDD) detectors meet all three requirements [1]. Even if they are operated at room temperature they have an energy resolution better than 300 eV and enable maximum count rates of at least 1 MHz.

For many applications one of the main advantages of an SDD is the fact that it can be operated at room temperature or slightly below. This enables to build detector modules with an extremely small form factor. In contrary to other designs which make use of arrays of single SDD cells [2] our new SDD detector module uses a monolithic 7-cell SDD with an active area of 7 mm²/cell and a substrate thickness of at least 450 µm.

The first steps of signal processing mainly peak detection and shaping are performed by a specialized ASIC which is mounted directly behind the actual sensor. Thus our new module can in contrary to set-ups using discrete electronics make full use of the small form factor. The detector chip is delivered by PN-Sensors, Munich, Germany.

An earlier monolithic 7 cell SDD mounted in a test set-up using conventional peak detection / amplification electronics already proved to be suited for in-situ fl-XAFS measurements [3,4].

Main tasks of the current project are the development of the readout ASIC as well as the development and mounting of the housing. The ASIC design is meanwhile completed and the simulations suggest an achievable spectral resolution of 330 eV at 500 Kcps (FWHM Mn-Kα) at room temperature. At lower count rates the resolution will be of the order of 250 eV.

SETUP OF THE DETECTOR MODULES

The actual SDD detector chip is mounted in an AlN frame, see fig. 1. The readout ASIC will be mounted behind a radiation shield on a flexlead which carries additional electronic components. At the end of this flexlead the cable to the data acquisition system [5] is connected. The AlN housing is mounted at the tip of a hexagonal Cu-tube with 16 mm outer diameter and a length of ~21 cm. The Cu-tube will also serve as heat sink for a thermo-electric-cooler that enables to cool the detector to –5°C.

The radiation shield between the SDD and the readout electronic consists of four layers, 75 µm Polyimide, 250 µm Ti and 500 µm Ta. The ultimate radiation shield which protects the readout electronics is the Ta layer, the purpose of the other layers is mainly to absorb the Ta back-fluorescence [6].

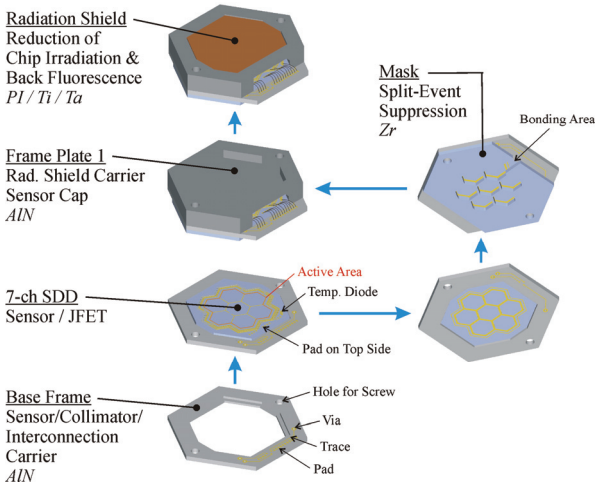

FIGURE 1. Set-up of the module tip.

SPECTRAL CHARACTERIZATION OF THE SDD

Using a test set-up the spectral properties of the SDD were thoroughly tested. Of special interest was the spatial characterization of the spectral performance, especially the behavior at the cell borders and at the central JFET.

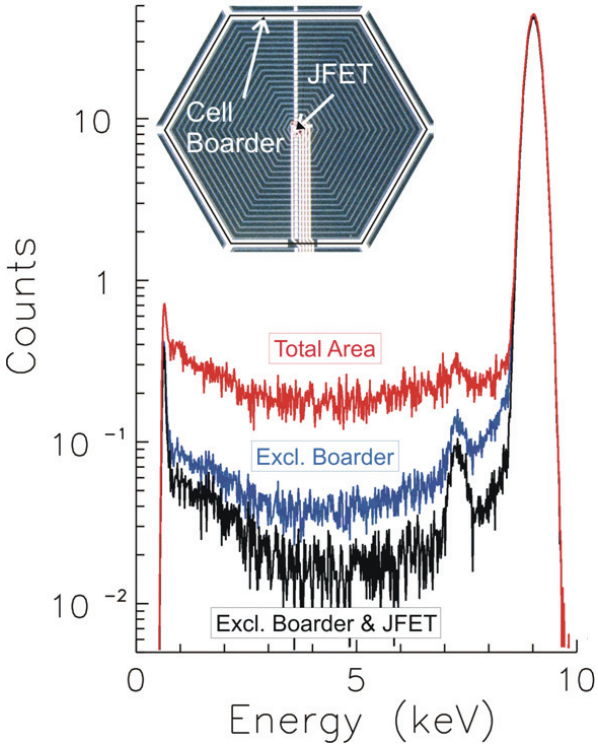

FIGURE 2. Influence of the cell borders and central JFET on the signal to noise ratio.

The signal to noise ratio of a monolithic multi cell SDD is usually worse than the S/N ratio which is achieved with a detector made up from discrete detector cells like most Si(Li) and HPGe detectors. However, earlier investigations [4] showed that an improvement of about one order of magnitude is achievable by covering the cell borders and if possible also the central JFET. Figure 2 shows a simulation of the influence of a mask that covers the cell borders and JFET. The simulation is based on line scans across one of the SDD cells with a pencil (4 µm diameter) beam. The measurements were performed at the X1 beamline at HASYLAB at an energy of 9000 eV.

As a consequence of this result the completed modules will be equipped with a mask that covers the cell borders and some also the JFET. Different mask materials will be used. Materials were chosen to have as little interference as possible in the energy range foreseen for the detector. Therefore Zr metal and ZrO_2 and Al_2O_3 ceramics were chosen. Zr is ideally suited because it is usable between 2.5 KeV (highest L emission line) and 18 KeV (k-edge). Considering the decreasing efficiency of a 450 µm thick Si detector at higher energies this will be the main operation range. Different types of masks are displayed in figure 3.

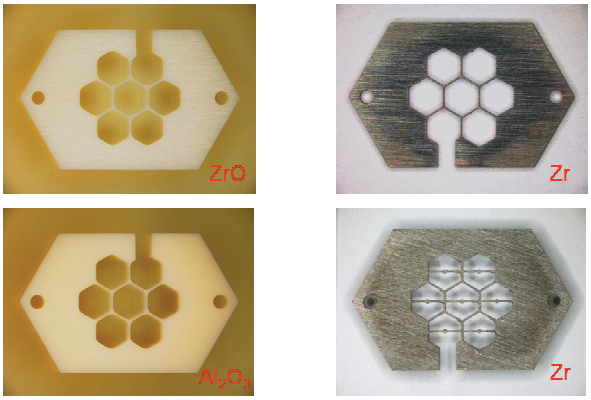

FIGURE 3. Masks to cover the cell boundaries resp. cell boundaries and central JFET (lower right). On the left masks manufactured from ceramics (ZrO top and Al_2O_3 bot.), on the right laser cut masks made of metallic Zr.

Figure 4 shows that the width of the distorted regions at the cell borders is about 80 µm. The nominal width of the straps which cover the cell boundaries is therefore 150 µm. The Zr metal masks were produced using laser cutting techniques (Fa. Nutech, Neumünster, Germany) from 500 µm thick Zr sheets, while the ceramic materials were machined by millcutting.

All mask types were analyzed qualitatively by µ-X-ray fluorescence analysis at beamline HASYLAB beamline L. It was found that the ZrO ceramics contain too high amounts of Hf which makes them unusable. The metallic Zr and the Al_2O_3 turned out to contain no significant amounts of other elements.

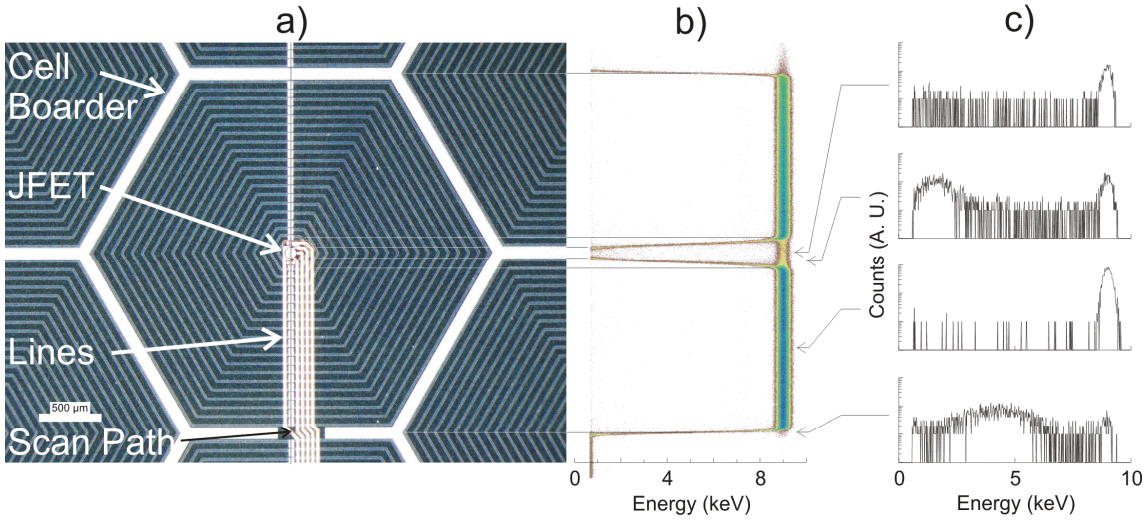

FIGURE 2. Linescan over the central cell of a 7 cell SDD, a) Micrograph of the inner SDD cell, showing the main structures on the chip, b) color encoded spectra along a vertical line scan that crosses the borders and the JFET, c) spectra at selected points of the line scan.

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