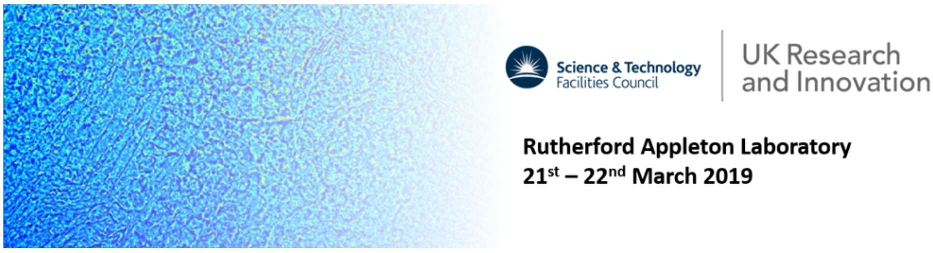
High-Z Pixel Detector Workshop 2019



Report of Contributions

Contribution ID: **8** Type: **not specified**

Welcome to STFC

Thursday, 21 March 2019 09:30 (30 minutes)

Presenter: VEALE, Matthew (STFC)

Contribution ID: **9** Type: **not specified**

Macroscopic and microscopic ingomoginities in HR GaAs: Cr wafers

Thursday, 21 March 2019 10:00 (1 hour)

The report provides an overview of investigations of HR GaAs: Cr wafer characteristics dependencies on the properties of raw material (n-GaAs). Wafers with a diameters of 76, 100 mm produced by LEC and VGF technologies were investigated. It has been established that macroscopic inhomogeneities of resistivity and photosensitivity distributions in HR GaAs: Cr wafers are determined, in particular, by the macroscopic inhomogeneity of the impurity allocation in n-GaAs wafers. It is shown that microscopic inhomogeneity in HR GaAs: Cr is basically determined by the growth technology and the conditions of post-growth annealing of n-GaAs ingots.

Presenter: Prof. TYAZHEV, Anton (Functional Electronics Laboratory of Tomsk State University Tomsk, Russia)

Contribution ID: **10** Type: **not specified**

Discussion 1

Thursday, 21 March 2019 11:00 (30 minutes)

Contribution ID: **11** Type: **not specified**

Contribution 2

Contribution ID: **12** Type: **not specified**

Interconnect Activities @ STFC

Thursday, 21 March 2019 11:30 (30 minutes)

Presenters: Dr SCHNEIDER, Andreas (STFC Interconnect Group); Mr LIPP, John (STFC Interconnect Group)

Contribution ID: **13** Type: **not specified**

High-Z Detector Development @ STFC. Past, Present & Future

Thursday, 21 March 2019 13:00 (1 hour)

The STFC have been working with high density compound semiconductor materials for over a decade. Our HEXITEC spectroscopic X-ray imaging detector [1] was developed to take advantage of the properties of detector materials like cadmium telluride (CdTe). Since it's conception and thanks to exceptional energy resolution, HEXITEC has gone on to be used in wide variety of applications from materials science at synchrotrons [2] to industrial applications in the fields of security [3] and medical [4] imaging. In the first part of this talk I will review our experience with CdTe, GaAs:Cr and CdZnTe detectors when used with the HEXITEC technology. Key parameters such as energy resolution, charge sharing rates and uniformity will be discussed.

As the HEXITEC technology approaches its 10th birthday, we have recently begun work on a new generation of detector technology. Due for delivery in early 2020, MERCURY builds upon our experience with HEXITEC and compound semiconductor materials and will deliver a spectroscopic imaging system operating at a continuous 1 MHz frame rate. This high frame rate is required to deal with the ×100 increase in flux that is expected at Diffraction Limited Storage Ring (DLSR) synchrotrons which will become commonplace in the next 10 years. The second part of this talk will provide an update on this development and discuss the requirements for the technology. For example, these extreme frame rates necessitate a move away from the CR-RC shaping currently implemented in HEXITEC and a move towards the inclusion of ADCs in-pixel. The MERCURY design also capitalises on our recent work on charge induction in small pixel detectors and the inclusion of a dual-polarity front end will allow correction of charge loss due to depth-of-interaction effects at higher energies [5].

The final part of this talk will look towards our plans for a successor to the Large Pixel Detector (LPD) technology [6] which was delivered to the XFEL.EU in 2017. DynamiX is a proposed small pixel integrating detector for use at XFELs and DLSR Synchrotrons. The technology will have small pixels of < 100 µm, operate at a continuous frame rate of 1 MHz and deliver a large dynamic range of the order 105 × 12 keV X-rays. The high frame rate of this camera system has been chosen to match the aspiration to deliver continuous high repetition rate pulses at upgraded FEL light sources like XFEL.EU and LCLS-II. The higher average intensity at these upgraded facilities will mean that sensors will have to endure much higher absorbed radiation doses. This increased radiation hardness requirement and the arrival of high energy instruments (> 12 keV) will drive the need for High-Z systems. The results of recent characterisation of CdZnTe and GaAs:Cr-based LPD sensors at the LCLS FEL that are supporting this development will be discussed [7].

References

[1] M. C. Veale et al, "HEXITEC: A High-Energy X-ray Spectroscopic Imaging Detector for Synchrotron Applications,"Syn. Rad. News (2018) 31(6), pg. 28 –32 (https://doi.org/10.1080/08940886.2018.1528431)

[2] E. Liotti et al, "Mapping of multi-elements during melting and solidification using synchrotron X-rays and pixel-based spectroscopy,"Sci. Rep. (2015) 5, 15988. (https://doi.org/10.1038/srep15988)

[3] A. J. Dicken et al, "Depth resolved snapshot energy-dispersive X-ray diffraction using a conical shell beam,"Opt. Exp. (2017) 25(18), pg. 21321-21328. (https://doi.org/10.1364/OE.25.021321)

[4] J. Zhang et al, "Development of 3D HEXITEC CdZnTe detector - A large area high-resolution γ-ray imaging camera for future SPECT imaging,"J. Nucl. Med. (2018) 59:1770a. (http://jnm.snmjournals.org/content/59/suppl

[5] M. C. Veale et al, "Improved spectroscopic performance in compound semiconductor detectors for high rate X-ray and gamma-ray imaging applications: A novel depth of interaction correction technique,"NIMA (2019) 927, pg. 37-45. (https://doi.org/10.1016/j.nima.2019.01.045)

[6] M. C. Veale et al, "Characterisation of the high dynamic range Large Pixel Detector (LPD) and its use at X-ray free electron laser sources,"J. Inst. (2017) 12, P12003. (https://doi.org/10.1088/1748-0221/12/12/P12003)

[7] M. C. Veale et al, "Cadmium zinc telluride pixel detectors for high-intensity x-ray imaging at free electron lasers,"J. Phys. D: Appl. Phys. (2018) 52, 085106. (https://doi.org/10.1088/1361-6463/aaf556)

Presenter: VEALE, Matthew (STFC)

Contribution ID: **14** Type: **not specified**

Discussion 2

Thursday, 21 March 2019 14:00 (30 minutes)

Contribution ID: **15** Type: **not specified**

High-Z Activities at DESY

Friday, 22 March 2019 09:00 (1 hour)

Presenter: Dr BECKER, Julian

Contribution ID: **16** Type: **not specified**

Discussion 4

Friday, 22 March 2019 10:00 (30 minutes)

Contribution ID: **17** Type: **not specified**

Outline of high-Z pixel sensors developments at ESRF

Friday, 22 March 2019 11:00 (30 minutes)

Developments and research around X-ray sensors have always received a significant support at ESRF, as the sensor quality governs the performance of the whole detection chain and thus the quality of the data. This talk briefly introduces the ongoing and planned developments particularly on high-Z semiconductor pixel sensors, in relation with the detection challenges set by the EBS and the future applications on beamlines.

Presenter: Prof. PONCHUT, Cyril (ESRF)

Contribution ID: **18** Type: **not specified**

Discussion 5

Friday, 22 March 2019 12:00 (30 minutes)

Contribution ID: **19** Type: **not specified**

Investigations into material discrimination using multispectral X-ray imaging with Medipix3RX detectors

Friday, 22 March 2019 13:30 (30 minutes)

n classical X-ray imaging, the absorption or penetration of X-ray photons through a material is used for imaging, but the energy of the incoming photons is not recorded. This makes a targeted material recognition impossible, since a higher absorption of the X-ray photons can result both from a higher density of the sample to be examined and from a higher penetration depth of the radiation. Thus, for example, it cannot be determined during safety-relevant X-ray examinations whether a plastic explosive or a package of flour is involved.
The Medipix3RX, in combination with a high-Z semiconductor sensor, such as cadmium telluride, offers the possibility to capture differentiated energy ranges of a wide X-ray energy spectrum in a single X-ray image and to separate them. This energy-selective examination allows the differentiation of several materials and thus, open up a completely new field of application for X-ray examinations in various fields such as non-destructive material examination, medical applications, homeland security and industrial applications. This talk introduces energy threshold based spectroscopic X-ray imaging using the Medipix3RX Assembly with a 1 mm CdTe sensor, which allows high absorption probabilities for high energy photons, and present first results of this spectroscopic investigations.

Presenter: Mr SCHÜTZ, Michael (University Freiburg)

Contribution ID: **20** Type: **not specified**

High-Z sensors in combination with the low noise, charge-integrating pixel detector JUNGFRAU at PSI

Thursday, 21 March 2019 15:00 (1 hour)

The most common sensor material for detectors at synchrotron sources and free electron lasers is silicon due to its outstanding material quality in terms of homogeneity and charge carrier transport properties. However, the low atomic number of silicon (Z=14) is the reason for a relatively low absorption efficiency at energies above 20 keV. Sensors with high atomic number material, so-called high-Z sensors, provide absorption efficiencies that are significantly higher. The usability of different high-Z sensor materials (GaAs, CdTe, CZT) at synchrotron sources has been evaluated in combination with the JUNGFRAU readout chip as a possibility to widen the usable energy range of the detector systems.
High-Z sensors show their best performance in electron collection mode. The current version of JUNGFRAU having a pixel pitch of 75 x 75 µm2 was designed for hole collection and, therefore, has to be operated in fixed gain mode (high, medium or low). When operated in fixed high gain the noise performance is 79 e- ENC (or 0.34 keV) and the available dynamic range is around 120 keV (CdTe (e- Schottky) sensor at room temperature, sensor bias voltage: -500 V, integration time: 5 µs).
Charge-integrating detectors offer interesting insights into the sensor properties as each pixel provides a direct measure of the collected charge of a well-defined area as output. On the other hand, each pixel is very sensitive to temporal as well as spatial sensor effects, which affect the charge collection (e.g. fluorescence, dislocation lines, detrapping of charge carriers etc.).
The Detector Group of the Swiss Light Source (SLS) at the Paul-Scherrer-Institut (PSI) will report on their current results of the dynamic behavior (like signal stability, polarization, afterglow) in high-Z sensors when being irradiated with photon fluxes up to 1010 ph/(mm2·s). Furthermore, recent improvements in understanding of the implications stemming from the short lifetime of holes in the GaAs:Cr sensors will be presented and discussed ("Crater effect") as this severely affects the usability of GaAs:Cr together with charge-integrating readout chips. In a second part, preliminary basic system characterization of CZT will be presented as well as Jungfrau chip related consideration in data treatment and processing for efficient and effective data handling.

Presenters: Dr GREIFFENBERG, Dominic (PSI Detector Group); Dr MEYER, Markus (PSI Detector Group)

Contribution ID: **21** Type: **not specified**

Discussion 3

Thursday, 21 March 2019 16:00 (30 minutes)

Contribution ID: **22** Type: **not specified**

Characterization and investigation of spectroscopic capabilities of a 3mm CdTe Timepix detector

Friday, 22 March 2019 14:00 (30 minutes)

Cadmium telluride (CdTe) offers excellent absorption efficiency in the energy region above 30 keV and therefore for the detection of high energy levels of radiation originating from common radioactive sources. The absorption efficiency can be further improved by increasing the sensor thickness. However, an expansion of the sensor layer thickness simultaneously increases the effect of charge sharing which results in a spreading of charge information over multiple pixels.
This work introduces a new way to diminish the loss of resolution with the aid of a cluster analysis. The core principle of the code provides an independent identification and separation of clusters collected by pixel matrix of the Timepix. The code is capable to identify and analyze unwanted effects like fluorescence and cluster overlapping, minimizing the loss of information in the process while reaming the full spatial resolution of the detector system. The per-pixel calibration of a thick sensor provides further challenges.
To demonstrate the capabilities of the framework, spectroscopic investigations regarding the common radioactive sources Cobalt60, Cesium137, Europium152 and Americium241 in combination with a 3 mm CdTe Timepix detector are presented. A detailed analysis and well defined parameters for the chosen sources will be shown.

Presenter: Mr FEY, Julian (University of Freiburg)

Contribution ID: **23** Type: **not specified**

Discussion 6

Friday, 22 March 2019 14:30 (30 minutes)

Contribution ID: **24** Type: **not specified**

Comparative evaluation of CZT pixel sensors

Friday, 22 March 2019 11:30 (30 minutes)

The European Synchrotron Radiation Facility (ESRF) is being subjected to the second phase of its upgrade, the so-called EBS (Extremely Brilliant Source) upgrade. The new storage ring will be able to deliver X-ray beams with brilliance and coherence increased by a factor 100, ushering in a new generation of synchrotrons. In order to exploit this domain ESRF has launched an ambitious instrumentation programme, focusing on high performance detector systems.

Within this effort, we develop hybrid pixel detectors using semiconductor sensors for photon-counting. To counter-balance limitations set to the detection efficiency by existing silicon sensors in the energy range 30-100 keV, we investigate the use of high-Z semiconductor sensors. In the past, pixelated sensors made of Cadmium Telluride (CdTe) and chromium-compensated Gallium Arsenide (GaAs:Cr) have been used successfully, as sensitive medium. Despite the improvement on the crystal quality over the years, limitations such as time-dependent polarisation effects in CdTe and spatial distortions of the effective pixel shape in GaAs:Cr impelling the search for alternatives such as Cadmium Zinc Telluride (CZT).

Several prototype modules based on pixelated CZT sensors have been developed and tested in terms of imaging performance at the ESRF using X-rays sources and monochromatic synchrotron beams. Each module, consisting of a sensor bonded to a single Timepix chip, is coupled to the MAXIPIX readout system. I will report on results obtained focusing on the comparison of the performance achieved with respect to CdTe and GaAs:Cr sensors.

Presenter: Dr TSIGARIDAS, Stergios (ESRF)