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Edgeless sensor development for the LPD hyprid pixel detector at XFEL

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Abstract

In this paper we summarise the investigation into a possible design of flat panel geometry for the large pixel detector (LPD) at the X-ray free electron laser (XFEL) at DESY. LPD will be one of the detections systems for applications such as coherent X-ray diffraction imaging, small molecule imaging and pump-probe techniques. A proposed design of the LPD is to incorporate edgeless technology through the use of current terminating ring structures. Additionally dry etching techniques to minimize the edge effects associated with tiled detectors are also examined

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1 Introduction

In 2013, XFEL (X-ray Free Electron Laser) will switch on at DESY, Hamburg. Its peak brilliance will be billions times higher than that of conventional X-ray light sources, emitting light pulses with a duration < 100 femtoseconds, and covering a range from 0.085-6nm. It will open up areas of experimentation in wide-ranging fields such as structural biology, plasma technology and materials science [1. The brilliance of the XFEL will set new standards. Its peak brilliance will be billions of times higher than that of conventional X-ray light sources, and its average brilliance will still be 10,000 times higher. The duration of the light pulses will be less than 100 fs. This time resolution will even make it possible to film chemical reactions that occur much too rapidly to be captured by other methods.

It will be possible to vary the wavelength of the X-ray laser flashes from 0.085 to 6 nm, thus making it possible to recognize details even at the atomic level. The X-ray laser flashes will display the properties of laser light, thereby making it possible to record three-dimensional images of the nanoworld.The light will be generated using the SASE principle [2]. SASE stands for Self-Amplified Spontaneous Emission. With SASE, the electrons interact with the radiation that they (or their neighbours) emit. As a result, the electrons organize themselves into extremely small bunches, so that the spontaneously emitted X-ray flashes are amplified like laser light.

2 LPD

The time and intensity of the X-rays have created demanding requirements for the pixel detector needed for such signals. The Large Pixel Detector (LPD) [3] will be designed and built by Rutherford Appleton Laboratory (RAL) and Glasgow for the experiment as the detection system at stations such as pump-probe, coherent X-ray diffraction imaging and small molecule imaging, and will be optimized to detect 12KeV X-rays. The LPD will be based on a flat panel geometry, consisting of tiled detectors. In such an arrangement, the separation between rows of sensors permits sensor bias to be distributed on metal rails that separate the sensors. These then bond or glue directly to the sensor surface to communicate the sensor bias. In this arrangement, near 100% area coverage is achieved and the readout electronics do not protrude on any edge of the sensor. One possible improvement to this design would be the application of active edge technology. Such technology has been previously applied in 3D detectors [4], and it will be the goal of the group at Glasgow to adapt this technology so to be suitable for the flat panel LPD at XFEL.

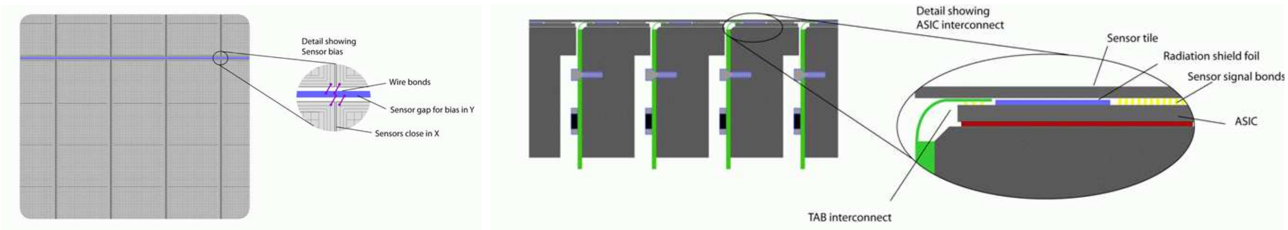

Figure 1: Schematic for the flat panel geometry of LPD

Performance Parameters	Max Value	Units
No of Pixels	20k x 20k	pixels
Radiation Hardness	2x1016	ph/pixel
Dark Current	< 1	Eq. photon
Read Noise	< 1	Eq. photon
Quantum Efficiency	80	%
Linearity	1	%
Timing	5	MHz

Table 1: Proposed performance parameters required for the LPD at XFEL

3 Edgeless Detectors

Standard Si detectors have relatively large insensitive region around active area. The region is due to presence of multiple guard rings and can extend to more than 1mm, depending on detector application. Nevertheless, guard rings are necessary to isolate the active area from detector edge. The main difficulty in fabricating edgeless detectors is to control and minimize edge currents. Reverse currents are mainly due to the presence of a high density of lattice defects in a diced surface, with a significant fraction of these being electrically active. They are responsible for the high conductivity of the cut surface, and help produce an effective screening of electric field in the region adjacent to the chip cut.

3.1 DRIE

One proposal is to use a DRIE - Deep Reactive Ion Etching [5] - process to cut the detectors. Etching offers advantages of low surface damage and the possibility of being integrated as a standard microelectronics fabrication process. To optimize the etch recipe for through-etched side cuts of silicon wafers, a test structure mask was processed with various feature shapes and dimensions.

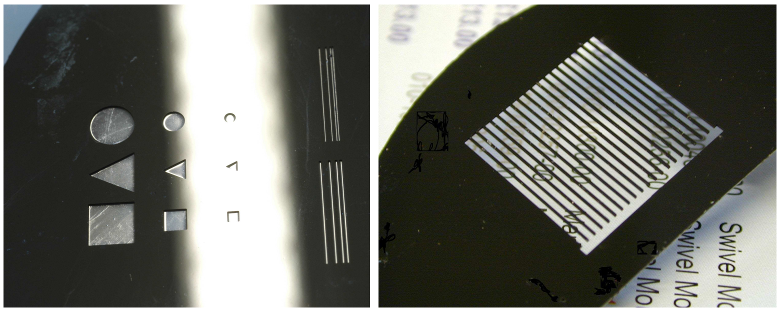

Figure 2: 2 Test structures for DRIE thru etches and trenches

The fabrication was performed in the JWNC fabrication facilities at the Engineering Dept at the University of Glasgow, and the etching done using an STS DRIE ICP machine. An example using the resultant optimised etch is below with the parameters of the recipe detailed in Table 2. The thru-etch time was found to be 120 minutes.

Step	Etch	Passivation
Gas	SF_6/O_2	C_4F_8
Flow Rate (sccm)	130/10	85
Time (s)	13	7.5
Platen Power (W)	15	15
Coil Power (W)	600	600

Table 2: Optimized parameters for a thru etch/trench cut of Si wafers using a STS ICP machine

3.2 CTR

Additionally, to minimize the dead areas between the end of the pixels and the cut edge, a Current Terminating Ring CTR - is used to apply the full detector bias across the detector chip cut, collecting the resulting leakage current on an outer ring which surrounds the active area[6]. It is biased at the same potential as the detecting strips, and is necessary to maintain a stable electrical field. Results from Noschis et al [7] show technology allows successful use of tiled edgeless sensors. Subsequently, CTR structures have been designed for the LPD pixel detector. Implementation of such designs would then reduce the dead areabetween tiled sensors from 2mm to less than 50μm

4 Future Work and Conclusions

This work has detailed the proposed use of Edgeless technology for the LPD for XFEL. Designs utilizing CTR structures and DRIE cuts have now been finalized, and submitted to the foundry for fabrication. Late 2008 we will receive baby detectors (32x16 pixels) which will allow for the characterization of the Active Edge designs. In parallel, simulations using ISE TCAD are underway, so to optimize the deigns for the next fabrication run in mid-2009.

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