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Quantum efficiency measurements of FBK silicon planar sensors with optimized entrance window for soft X-Rays.

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Single photon detection of X-rays in the energy range of 250 eV to 1 keV for hybrid detectors is difficult due to the low quantum efficiency (QE) and to the low signal-to-noise ratio (SNR). The low QE is caused by the absorption of soft X-rays in the insensitive layers of the silicon sensor (entrance window). The entrance window is typically from a few hundred nanometers to a couple of micrometers thick and is comparable to the absorption depth of soft X-rays photons (e.g., the attenuation length of 250 eV X-ray photons is ˜ 100 nm in silicon). The low SNR is mainly caused by the small signal amplitude (e.g, ca. 70 electrons for 250 eV X-ray photons in silicon) with respect to the electronic noise.
In order to cope with these challenges, the QE should be improved by optimizing the entrance window to minimize the absorption of soft X-rays in the passivation layer, and to reduce charge recombination in the silicon/oxide interface and in the highly doped implants. To increase the SNR, and thus achieve single photon resolution, the noise of the readout electronics needs to be reduced. However, even with JUNGFRAU 1.1 (32 electrons r.m.s equivalent noise charge for the very high gain stage) we obtain single photon resolution only down to ca. 600 eV. Low Gain Avalanche Diodes (LGADs) with a multiplication factor between 5-10 increase the signal amplitude and therefore improve the SNR for soft X-rays. Combining LGADs technology with an optimized QE technology can thus allow hybrid detectors to become a useful tool also for soft X-ray detection.
In the present work, the QE of backside illuminated single pad silicon p-i-n diodes with 9 different entrance window variations is studied. The sensors are characterized at the Surface Interfaces Microscopy (SIM) beamline of the Swiss Light Source (SLS) using soft X-rays ranging from 200 eV to 1250 eV. From the investigation, a QE of 62.5% at 250 eV is obtained with one of the variations and further optimization is planned based on this study.
In addition, the QE of the inverse LGADs (iLGAD) with a thin entrance window has also been investigated. The first measurements show similar QE values as the optimized QE technology for p-on-n sensors without multiplication, thus proven the feasibility of implementing optimized QE technology into LGAD technology. Further studies on the iLGADs optimized for soft X-rays, in particular their gain variation as a function of the photon absorption depth, will follow the next months.

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