Characterization of silicon detectors using the Mesh method

The Mesh method is an excellent tool for the determination of the spatial properties of X-ray imaging detectors with high accuracy. The method has been adapted for testing the fully depleted pn-CCDs for the DUO / ROSITA missions and the DEPMOSFET device prototypes for the XEUS wide field imager and is now available at the MPI HLL. It is about to become a standard analysis tool for the purpose of device analysis.

The Mesh method is useful to address the following topics:

- Examination of charge splitting between pixels
- Measurement of diffusion and drift of signal electrons in the sensor material
- Scanning of the pixel structure in depth by repetitive measurements with different X-ray energies
- Analysis of insensitive regions of the sensor surface
- Combined topological examination and chemical analysis of the structured sensor surface by illumination with X-ray energies near the oxygen, aluminum, nitrogen and silicon absorption edges.
- Optimization of device operating conditions

The results of the Mesh measurements are used to determine the properties of the devices under test with high accuracy. Additionally, they can be used to test, verify and improve simulation tools and models, which, in effect, leads to better detectors.

For the measurements, a “mesh” is placed in front of the sensor. The mesh consists of a carrier material intransparent for X-rays of the selected energy equipped with an evenly spaced grid of pinholes with a grid constant equal to or larger than the pixel size. The mesh is slightly tilted and shifted with respect to the pixel array (fig. 1). The mesh devices used consist of a gold foil of 3 μm to 10 μm thickness with a typical hole diameter of 5 μm. For convenience, the mesh grid constant is often chosen equal to the pixel pitch.

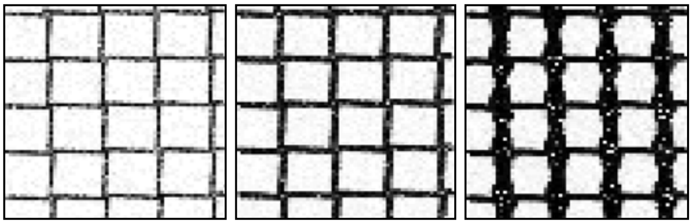

Fig. 3: *Example for Moire-patterns measured with the Mesh-Method on an XMM-type CCD. From left to right: Cu-Kα (0.93 keV), Ti-Kα (4.51 keV) with charge storage under two CCD registers, Ti-Kα with charge storage under one register. From pattern angle and periodicity, the relative alignment of Mesh and detector can be calculated.*

Considering the spatial distribution of the ratio of charge splitting events (fig. 1), Moire-patterns can be observed. From the Moire-patterns, some effect of e.g. photon energy or operation mode of the device can be seen (fig. 3), but more significant information about the device properties can be obtained if the relative alignment of Mesh and pixel grid is used. This information can be calculated from periodicity and shape of the measured Moire-pattern. Then, the relative position with respect to the pixel borders can be determined for every hole, so any kind of data from the respective pixel can be correlated with the position of the incident photon. In effect, the entire pixel area is scanned with high spatial accuracy. Fig. 4, for instance, shows the difference in charge splitting behaviour for different charge storage modes within an XMM type CCD. The increased fraction of charge splitting events is already indicated by fig. 3. Only if the charge is stored under 2 shift registers, an unambiguous minimum for electrons is expressed, leading to sharp and well defined locations for the storage and transfer of electrons

References:
- H. Tsunemi et al., NIM A 421 (1999), 90-98
- H. Tsunemi et al., NIM A 436 (1999), 32-39

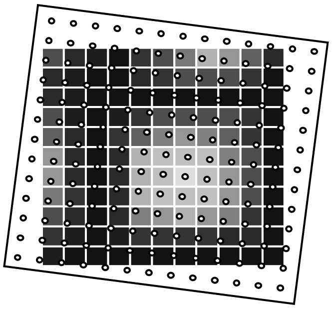

Fig. 1: *Principle of the Mesh method. The relative position of the holes with respect to the pixel borders causes different fractions of events with charge splitting (grey coded). The result is a Moire pattern.*

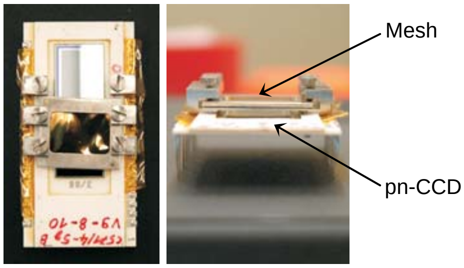

Fig. 2: *Experimental setup. The mesh is mounted in front of the sensor entrance window in a distace of about 1 mm. The sensor area not covered by the mesh is shielded with a copper baffle during measurement.*

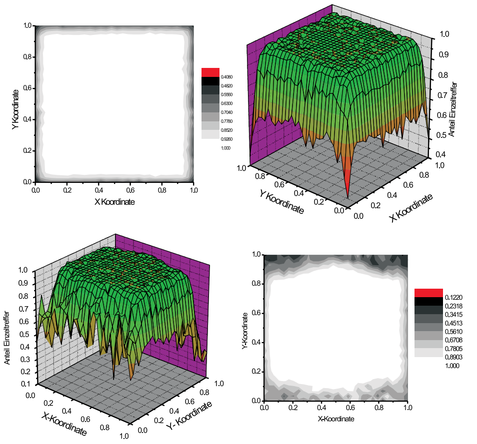

Fig. 4: *Result of mesh measurements on an XMM type CCD. Shown: Charge splitting ratio vs. position in pixel for charge storage under two registers (upper row) and under one register (lower row). The effect of increased charge splitting due to weakly defined potential minima for electrons can be clearly seen at the edges of the pixel.*

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