XPAD detectors: from the laboratory to industrialization

Hybrid pixel detectors will mark the end of the era of CCD cameras in numerous experiments using X-rays. The "XPAD" technology, born of a collaboration involving the Néel Institute, is one example of such a detector. This development has produced three generations of XPAD detectors and has led to the birth in 2010 of imXPAD, a startup company dedicated to production and commercialization of these detectors. Initially, hybrid pixel detectors were designed for particle physics. In the 1990's, experiments done on the new synchrotrons, such as the European Synchrotron Radiation Facility (ESRF) in Grenoble, suffered from the lack of X-Ray detectors with fast enough dynamics to exploit the new potentialities offered by synchrotron X-Ray beams. Since then, Néel Institute staff in charge of the French Collaborative Research Group beamline "D2AM" at the ESRF have worked with people at the Centre de Physique des Particules in Marseille (CPPM) and the SOLEIL synchrotron (Paris) to develop three generations of the "XPAD" hybrid pixel detector technology.

XPADs (X-ray Pixel chips with Adaptive Dynamics) have many advantages over earlier detectors. They are hybrid pixel detectors : silicon sensors are "bump-bonded" directly, pixel by pixel, to an underlying, dedicated electronics chip. They measure the position and the number of incident photons with specific new characteristics compared to the CCD (Charge Coupled Device) detectors used previously. In CCD cameras, X-ray photons are converted to visible light which is accumulated over a given period. In these new detectors, the X-Ray photon counts are processed individually and only the events above a certain energy threshold are counted, reducing spurious noise sources. In addition, with XPADs one can accumulate many more photons without reaching saturation, therefore gaining in dynamic range, and one can record more than 1000 frames per second. Further, the 3rd generation detector "XPAD3" has an electronic shutter which can be triggered by an external signal, allowing nanosecond resolution in time-resolved experiments. The performances achieved by XPADs allow us to envisage new synchrotron experiments that would have been impossible with conventional detectors. Moreover, these detectors will also find their place in laboratory experiments and in medical X-Ray applications.

The initial role of Néel Institute staff in the XPAD project was to start up the collaboration and define the key features of the electronics chips: dynamics, counting rate, energy resolution, pixel size, etc. Subsequently, our main role has been the testing and calibration of XPAD detectors using synchrotron radiation. To illustrate the performance of XPADs, we present (Fig. 2) some X-Ray diffraction results obtained on the D2AM beamline. These concern the structural and compositional properties of Indium Gallium Nitride (InGaN) alloy "core-shell" nanowires, properties important for optimizing the nanowires' emission wavelength. The extended DAFS (Diffraction Anomalous Fine Structure) spectra give information on the In content and the local atomic environment of the resonant atoms (Ga), i.e. they show how the strains resulting from the unequal sizes of Ga and In atoms are accommodated locally.

Figure 1 : Inside a prototype Silicon XPAD3 detector : 8 modules are tiled as close as possible to each other to offer a 7x12 cm² detection surface with almost 540000 pixels of size 0.13x0.13 mm².

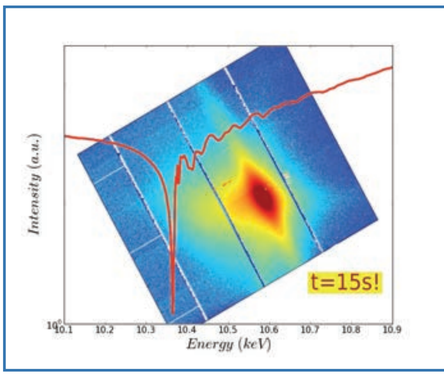

Figure 2: From an X-Ray diffraction study of InGaN core-shell nanowires grown on GaN : The red trace is a Diffraction Anomalous Fine Structure (DAFS) spectrum extracted from reciprocal space maps at several energies from 10.1 keV to 10.9 keV. One such map is put, color-coded, as the background 2D image. Around the intense GaN (101) reflection (red, brown) coming from the substrate, the map shows a surrounding signal (yellow, green) due to the scattering of the InGaN core-shell nanowires. The measurement was performed at the Gallium K-edge without attenuators using a XPAD3 pixel detector on beamline D2AM at the ESRF. The quality of the DAFS spectrum acquired in only 15 seconds is remarkable.

Here, the main interest of the 2D pixel detector XPAD is the high counting dynamics per pixel, which allows us to benefit from the high counting rate for diffracted X-Ray photons when measuring DAFS oscillations. Moreover the detector allows measurement of several DAFS spectra and the fluorescence background simultaneously.

At present, XPAD detectors use well-tested silicon sensors, but detection efficiency is quickly lost for X-Rays from 15-20 keV onwards. In parallel, we have also worked on using more efficient sensors. We have obtained very good results with prototype Cadmium Telluride (CdTe) sensors. These are available only in limited sizes so far and it is intended to continue our collaboration with CPPM-Marseille and SOLEIL to create CdTe detectors with larger surfaces.

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FURTHER READING

XPAD3-S : A FAST HYBRID PIXEL READOUT CHIP FOR X-RAY SYNCHROTRON FACILITIES
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