ICHEP 2022 BOLOGNA
ICHEP 2022 XLI International Conference on High Energy Physics Bologna (Italy)
6 13 07 2022

Contribution ID: **1306** Type: **Parallel Talk**

MAPS for x-ray detection: trading high efficiency for low cost

Thursday, 7 July 2022 17:30 (15 minutes)

Within the High Energy Physics community, when dealing with sensors of almost any sort, detection efficiency is certainly one of the key parameter at play. By further narrowing the field to pixel detectors, efficiencies of the order of 99% are the baseline, with far better figures actually characterising present state-of-the-art devices. Physics events are costly and time-consuming to produce, and therefore collection efficiency must be maximised. The same situation exists, for different reasons, in medical radiation applications: there aiming for maximum detection efficiency allows minimising the collateral hazard the probing radiation poses to the patient. However, the industrial and commercial field sets remarkably different boundary conditions. First, radiation sources types are very limited, mostly due to costs, state regulations, and radiation protection issues; in fact, commercial radiation facilities mostly comprises x-ray or g-ray sources of different energy and power. Second, contrary to the medical applications, most of the times the radiation dose delivered to the target is not a showstopper as it would be for a living organism.

Industrial x-ray tubes typically provide energies in the 1 keV - 300 keV range; higher energies are obtained from radioactive sources, like Ir 192 (300 keV - 600 keV), and Co-60 (1.17 and 1.33 MeV). However radioactive sources, which require careful handling and special safety protocols, are relegated to very specific radiography applications, leaving x-rays as the vastly predominant radiation type used in the industry. Modern, solid state x-rays sensors exploit the combination of a suitable sensing material coupled to a readout pixel array. There are two main embodiment of such paradigm:
1) the sensing material acts as a scintillator, converting incoming x-ray into light in the visible or near-visible spectrum; compounds of choice are usually Cesium Iodide (CsI), and Gadolinium Oxysulfide (GOS). The scintillator layer is coupled to a glass substrate with a patterned pixels array, realized in Thin Film Transistor (TFT) technology.
2) the sensing material converts the incoming x-ray into electrical charge (within a depleted semiconductor); materials of choice for the photo-conversion are Germanium (Ge), Selenium (Se), and Cadmium Telluride (CdTe). The pixel array may again be realized with the TFT glass panel technology or, otherwise, may exploit a silicon-based pixel array.
In both aforementioned embodiment, large area detectors (>200 cm2) almost universally employ the TFT panel as pixel collecting layer, as it is the cheapest and most widespread available technology for the task. TFT readout panels offer pixel sizes down to ~0.2×0.2 mm2, and areas up to ~40×40 cm2. Their biggest drawback is the intrinsic slowness of the readout process (basically equal to the refresh rate of TFT displays), resulting in very low frame rates, of the order of about 20 to 60 Hz for a state-of-the-art 20×20 cm2 panel.
To target higher speed and superior overall data-throughput performance, direct coupling of the semiconductor photoc-onversion layer to a silicon-based pixel array, instead of a TFT one, is the choice, exactly has done in HEP, scientific and medical applications. Most x-ray imaging systems installed at light sources and other research facilities in fact adopt this technology. The main drawback, from a commercial point of view, comes when large areas need to be instrumented, as silicon pixel arrays, differently from TFT glass panels, are costly to develop and manufacture in size larger than few cm2, forcing the use of many of them to readout large conversion layers. Furthermore, the sensor and readout array coupling process in itself (bonding) is also expensive and time consuming. Last but not least, with both the TFT and the more expensive silicon readout, the sensing layer itself employs very expensive materials, especially for the photo-conversion layers, where Ge and CdTe are the compounds of choice. Cost is in fact the limiting factor for using large area, fast sensors in applications outside the medical and scientific fields.

We investigated a selected set of industrial x-ray imaging applications, including Computed Tomography and x-ray radiography for the food, manufacturing and logging industry, considering both the radiation flux achievable with commercial, off-the-shelf x-ray sources and the overall imaging quality dependance on the statistics (i.e. the photon count per voxel per integration time) of the collected photons and the sensor in-

trinsic noise and readout scheme (analogue, integrating, counting). We found that in many cases the overall detection efficiency of present industrial systems is far below what seen in science or medicine, and figures as low as few percent are present. Indeed, the (large area sensors) cost factor did push the industry to develop low-efficiency apparatuses, especially when large imaging areas and high readout speed are the application targets.
Within these specific conditions, the use of Depleted Monolithic Active Pixel Sensors (D-MAPS) sensors may provide an effective solution to the industry large area, high speed but low cost dilemma. We verified that a 500 um depleted D-MAPS has a x-rays detection efficiency in the 10 ÷ 100 keV range of the order of few percent which, while definitely lower than that of a CdTe or Ge sensor of equivalent thickness, it is achieved at a fraction of the cost, embeds all the readout electronic within the sensor, and ensures lower power consumption. Low power consumption is another strong industry requirement, as many time the apparatuses are mounted on rotating gigs, and cannot employ any sort of liquid cooling.

In this contribution we will report our findings about how to employ D-MAPS in industrial x-ray imaging and tomography applications, with focus on both the technical and cost aspects of the problem, and the specific requirements the sensors must fulfil for a successful deployment. We will also illustrate potential applications within the industrial world which would be enabled by future D-MAPS based x-ray sensors. Together with this brief technical and economical reviews, we will present actual x-ray characterisation of "thick"MAPS sensors realised in commercial 110 nm technology, as well as design considerations and simulations for future sensors aimed at those applications.

In-person participation

Yes

Primary authors: GIUBILATO, Piero (Istituto Nazionale di Fisica Nucleare); Prof. MATTIAZZO, Serena (Padova University); Ms BONINI, Chiara (Padova Unoversity); Dr CHIAPPARA, Davide (Padova University); Dr SILVESTRIN, Luca (Padova University); Mr PANTANO, Devis (Padova University)

Presenter: GIUBILATO, Piero (Istituto Nazionale di Fisica Nucleare)

Session Classification: Technology and Industrial Applications

Track Classification: Technology Applications and Industrial Applications