

7.1. DETECTORS FOR X-RAYS

comprehensive survey of the present status and the future potentialities of gas-filled position-sensitive detectors.

7.1.6.3. Semiconductor detectors

Semiconductor detectors are essentially solid-state ionization chambers in which the incoming photon generates electron-hole pairs instead of electron-ion pairs. Semiconductor detectors are sensitive to the entire electromagnetic spectrum from visible to X-rays, and they can also detect electrons directly. There are, therefore, three possible methods of constructing semiconductor X-ray detectors, each of which has its advantages and disadvantages.

- (1) They can be exposed directly to the incoming X-rays.
- (2) The X-ray photons can be made to produce visible light photons that are then detected in a light sensor.
- (3) The X-rays can be made to produce electrons that are detected by the semiconductor detector.

In semiconductor one- or two-dimensional PSD's, the detector and the read-out circuitry are usually integrated on the same chip. In these devices, the pixel size and position are fixed once and for all so that they are geometrically completely stable. Integrated read-out circuitry has a low input capacity and thus an extremely low read-out noise.

All semiconductor X-ray PSD's are derived from imagers for visible light, which are of two basic types: photodiode arrays (PDA's) and charge-coupled devices (CCD's) (Lowrance, 1979; Allinson, 1982; Borso, 1982; Third European Symposium on Semiconductor Detectors, 1984).

In PDA's, the detection of a photon-generated charge takes place in a depletion layer that is formed either in a suitably biased *p-n* diode or in a metal-oxide-semiconductor (MOS) capacitor. The electron-hole pairs are separated by the field associated with the depletion layer. The individual diodes store charge during the integration period; this is read out into a

common video output line *via* MOS multiplexing switches. This architecture is usually adopted for linear arrays where the switches can be arranged around the periphery of the diodes with a minimum amount of dead space between them and where they can be shielded from the incident X-rays. PDA's tend to suffer from a high fixed-pattern noise due to differences in the performance of individual MOS switches.

In CCD's (Howes & Morgan, 1979), the sensing elements are always MOS capacitors suitably biased to establish charge-storage volumes. During read out, the charge is transferred in a 'bucket-brigade' fashion from one MOS capacitor to the next until it reaches the output. In linear CCD's, this output is at one end of what is essentially an analogue shift register. Most two-dimensional CCD's are frame-transfer devices: at the end of the exposure, the charge is transferred line by line to an identical array of MOS elements; while the next 'frame' is exposed in the image array, the contents of the buffer array are transferred, one line at a time, to a single-line buffer from which they are shifted out element by element. Since the transfer circuitry in CCD's is interlaced with the detector elements, they are more difficult to shield and are more subject to radiation damage.

7.1.6.3.1. X-ray-sensitive semiconductor PSD's

For X-ray diffraction applications, the main disadvantage of semiconductor devices is that the universal trend in their manufacture is in the direction of miniaturization, leading to a very small pixel size. Thus, imaging devices with up to  $2000 \times 2000$  pixels have been produced but the pixel size is typically  $\sim 10 \mu\text{m}$  for CCD's and  $\sim 20 \mu\text{m}$  for PDA's; in most X-ray diffraction applications, it would be difficult to scale down sample and source sizes to a point where the pattern size is

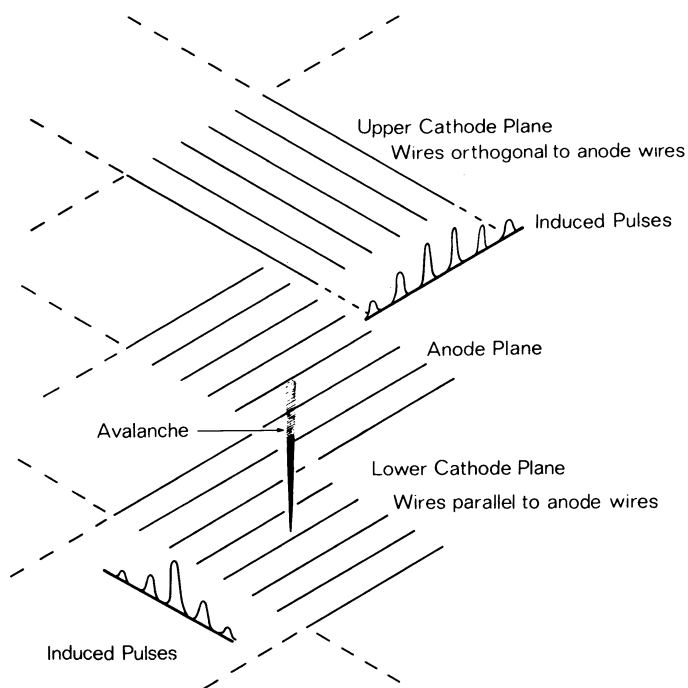


Fig. 7.1.6.5. Three-plane MWPC. Note the pseudo-quantization due to charge collection on one anode wire. The cathode wires may either be connected to a tapped delay line as in Fig. 7.1.6.4(c) or to individual amplifiers as in Fig. 7.1.6.4(d) (courtesy of A. R. Faruqi).

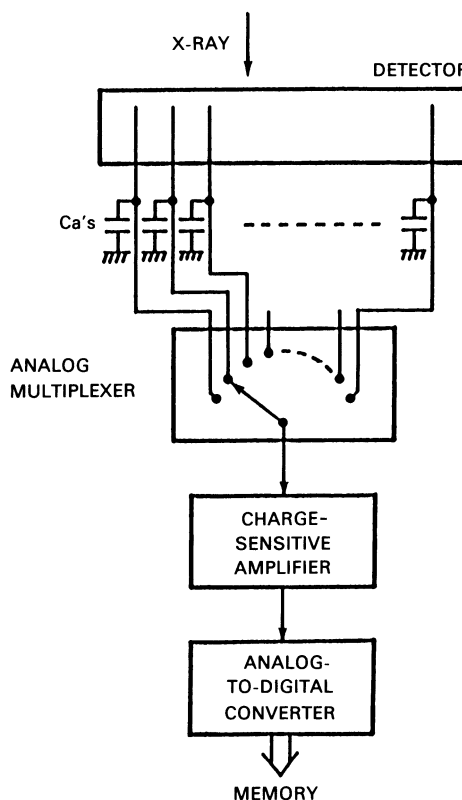


Fig. 7.1.6.6. Integrating LPSD. From Mochiki (1984); courtesy of K. Mochiki.