

10.3.2.5 Semiconductor detectors

In a semiconductor detector photons are absorbed in the semiconductive material to produce electron-hole pairs. It employs the *internal photo-electric effect*. Electrons are raised from the valence band into the conduction band. Semiconductive materials can be either *intrinsic* or, if doped, *extrinsic*.

In a *photoconductive detector* an electric potential is applied across the absorbing region and causes a current to flow in proportion to the irradiance if the photon energy exceeds the energy gap between the valence and the conduction band (See Note 1). Depending on their spectral responsivity function, photoconductive detectors are divided into photoconductive detectors for the visible wavelength range e.g. *cadmium sulfide photoconductive detectors*, photoconductive detectors for the near infrared wavelength range e.g. *lead sulfide photoconductive detectors*, photoconductive detectors for the infrared wavelength range e.g. *silicon doped with arsenide- or Si:As photoconductive detectors*, and the *mercury-cadmium-telluride- or HgCdTe photoconductive detector*.

A *photodiode* is a two-electrode, radiation-sensitive junction formed in a semiconductive material. A *junction* is formed by two successive regions of a semiconductive material having, respectively, an excess of electrons (n-type) or holes (p-type). A bias potential applied to the detector creates a region at the interface that is depleted of majority carriers. Each incident photon produces electron-hole pairs in the depletion region resulting in a measurable signal current. The photodiode can be operated either with *zero bias* in the *photovoltaic mode*, where the photodiode is actually generating the electric potential supplied to the load, or in a biased mode, the *photoconductive mode*, where the reverse current is proportional to the irradiation. A *Schottky barrier photodiode* is constructed by deposition of a metal film on a semiconductor surface in such a way that no interface layer is present. The barrier thickness depends on the impurity dopant concentration in the semiconductor layer. The incident radiation generates electron-hole pairs within the depletion region of the barrier where they are collected efficiently and rapidly by the built-in field. A *PIN (p-intrinsic-n) diode* is a *planar diffused diode* consisting of a single crystal having an *intrinsic* (undoped or *compensated*) region sandwiched between *p-* and *n-type regions*. A bias potential applied across the detector depletes the intrinsic region of charge carriers, constituting the radiation sensitive detector volume. The number of electron-hole pairs produced is dependent on the energy of the incident photons. An *avalanche photodiode* is a photodiode in which the photogenerated electron-hole pairs are accelerated by a bias *potential* so that further electron-hole pairs are formed leading to saturation of the photocurrent. This operational mode for photon counting is the so-called Geiger mode, similar to that of the gas filled Geiger counter. Avalanche photodiodes can also be operated in the proportional mode.

A *phototransistor* is a *bipolar transistor* with its base-collector junction acting as a photodiode, which, if irradiated, controls the response of the device. Due to the inherent

Note 1 Normally there are a number of conduction electrons available at room temperature, without any irradiation, giving rise to dark current.

current gain (of the transistor) the responsivity of the phototransistor is greater than that of the photodiodes. A *Darlington phototransistor* consists of two separate transistors coupled in the high-impedance *Darlington configuration* with a phototransistor as the input transistor. A *field effect phototransistor* or *photo-FET* is a *field effect transistor* (FET) that employs photogeneration of carriers in the channel region. It is characterised by high responsivity due to the high current gain of the FET.