

10

Photodetectors and Solar Cells

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Photodetectors are semiconductor devices that electrically detect optical signals. In its operating wavelength, the photodetector should have high sensitivity, high response speed, minimum noise, small size, low voltage, and high reliability under operating conditions. Solar cells are used to generate power from the sunlight and have some similarities with photodetectors. The main differences between them are device area, operating frequency, and optical noise.

Specifically, we cover the following topics:

- Absorption of photons to create electron-hole pairs in photodetectors
- Structures of some important photodetectors
- Absorption of photons to convert them to electrical energy from solar cells
- Structures of some important solar cells

▶ 10.1 PHOTODETECTORS

Photodetectors are semiconductor devices that convert optical signals into electrical signals. The operation of a photodetector involves three steps: carrier generation by incident light, carrier transport and/or multiplication by whatever carrier-gain mechanisms may be available, and interaction of the current with the external circuit to provide the output signal.

Photodetectors have a broad range of applications, including infrared systems, optical fibers, and detectors for optical-fiber communications. For these applications, the photodetectors must have high sensitivity at the operating wavelengths, high response speed, and low noise. In addition, the photodetector should be compact, use low biasing voltages or currents, and be reliable under the required operating conditions.

10.1.1 Photoconductor

A photoconductor consists simply of a slab of semiconductor with ohmic contacts at each end of the slab as shown in Fig. 1a, and a corresponding layout that consists of interdigitated contacts shown in Fig. 1b. When incident light falls on the surface of the photoconductor, electron-hole pairs are generated either by band-to-band transitions (intrinsic) or by transitions involving forbidden-gap energy levels (extrinsic), resulting in an increase in conductivity.

For the intrinsic photoconductor, the conductivity is given by

$$\sigma = q(n_i + \Delta n_i) \quad (1)$$

and the increase in conductivity under illumination is due mainly to the increase in the number of carriers. The long-wavelength cutoff for an intrinsic photoconductor is given by Eq. 9, Chapter 9. For the extrinsic photoconductor, photoionization may occur between the band edge and an energy level in the energy gap. In this case, the long-wavelength cutoff is determined by the depth of the forbidden-gap energy level.

Consider the operation of a photoconductor under illumination. At time zero, the number of carriers n_0 generated in a unit volume by a given photon flux is n_0 . At a later time t , the number of carriers $n(t)$ in the same volume decays by recombination:

$$n = n_0 \exp\left(-\frac{t}{\tau}\right) \quad (2)$$

where τ is the carrier lifetime. From Eq. 2 the recombination rate is

$$\left|\frac{dn}{dt}\right| = \frac{1}{\tau} n_0 \exp\left(-\frac{t}{\tau}\right) = \frac{n}{\tau} \quad (3)$$

If we assume a steady flow of photons flux impinging uniformly on the surface of a photoconductor (Fig. 1a) with an area $A = WL$, the total number of photons striking at the surface is \mathcal{P}_{ph} flux per unit time, where \mathcal{P}_{ph} is the incident optical power and $h\nu$ is the photon energy. At steady state, the carrier generation rate G must be equal to the recombination rate n/τ . If the detector thickness D is much larger than the light penetration depth, the total steady-state carrier generation rate per unit volume is

$$G = \frac{\eta}{\tau} \frac{\mathcal{P}_{ph}(A/h\nu)}{WLD} \quad (4)$$

where η is the quantum efficiency, the number of carriers generated per photon, and n is the carrier density, the number of carriers per unit volume. The photoconcurrent flowing between the electrodes is

$$I_p = qnAD = q\eta \frac{\mathcal{P}_{ph}}{h\nu} WLD = q\eta \frac{\mathcal{P}_{ph}}{h\nu} WLD \quad (5)$$

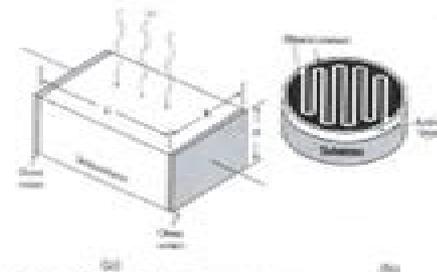


Fig. 1 (a) Schematic diagram of a photoconductor that consists of a slab of semiconductor and a contact at each end. (b) Typical layout consisting of interdigitated contacts with a small gap.

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