Photoconductive Detectors

The conductivity of semiconductors is increased by the absorption of photons. If the minimum energy required to create a free electron or hole, or an electron-hole pair is E_{min} , then photoconduction occurs when $h\nu > E_{min}$.

The photoconductor is a device composed of a single uniform semiconductor material. The incident optical power is measured by monitoring the conductance. The change of conductance is produced by creation of free carriers in the material by the presence of radiation.

There are two types of photoconductors, intrinsic and extrinsic. In case of intrinsic s.c.s E_{min} is the energy gap (Eg) while in extrinsic s.c.s it is either energy Ed needed to excite electrons from the donor level into the conduction band, or the energy E_a to excite a valence electron into an acceptor level.

$h\nu \geq E_g \longrightarrow hc/\lambda \geq E_g \longrightarrow \lambda \leq hc/E_g \longrightarrow$
$\lambda_{max} = hc/E_g$

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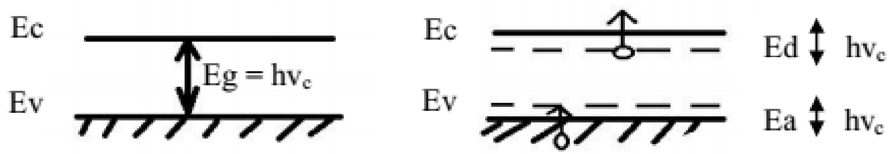

Intrinsic S.C. **Extrinsic S.C.**

The smallest value of Eg at R.T. is ~0.15 eV, enabling intrinsic s.c.s to be used for wavelengths up to 8 µm. E_d and E_a can be arbitrarily small, which would enable extrinsic s.c.s to be used for arbitrary long λs, except for a temperature limitation.

Temperature limitation arises because of the thermal excitation of the charge carriers (electrons or holes). The value of Eg is not

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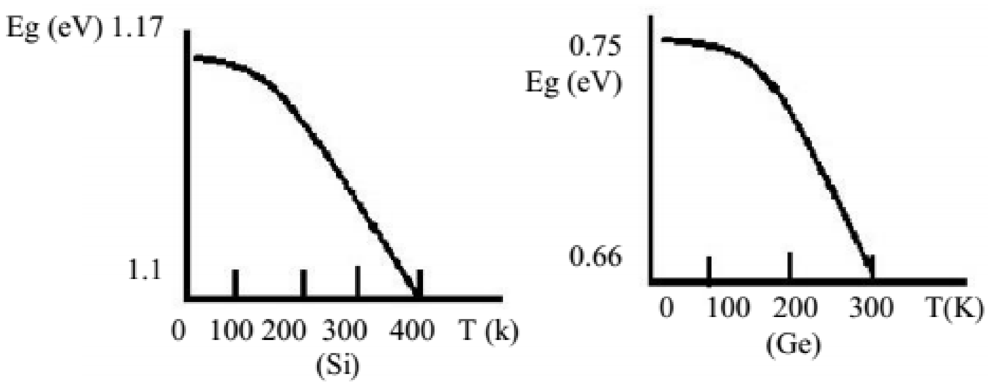
constant, but it changes with temperature as in fig. for Si and Ge, E_g decreases as temperature increases. The probability that an electron will move from the valence to conduction level is ~ exp (-Eg/ 2kT).



Change of E_g with temperature

In Ge, E_g= 0.75 eV at 4.2 k, the wavelength at which Ge starts to absorb light is:

$$\lambda_{(nm)} = \frac{1240}{Eg\ (eV)} = \frac{1240}{0.75} = 1653.3\ nm = 1.653\ \mu m.$$

At R.T. , λ≈ 1.9 µm.

Si starts to absorb light at λ≈ 1.06 µm at 4.2 k, and at λ≈ 1.13 µm at R.T.

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In the extrinsic case, the photoconduction is produced by absorption of a photon at impurity levels and consequent creation of a free electron in the case of an n-type photoconduction or a free hole in the p-type. The cutoff λ in either case is determined by the appropriate ionization energy for the impurity.

It is usually preferable to use the extrinsic type, in which small amounts of impurity atoms (dopants) are added, rather than the intrinsic type. The impurities give extra energy levels within the gap between valence and conduction bands. Photon absorption is then possible at energies lower than Eg, since electrons in the donor levels can be excited into the conduction band, or electrons

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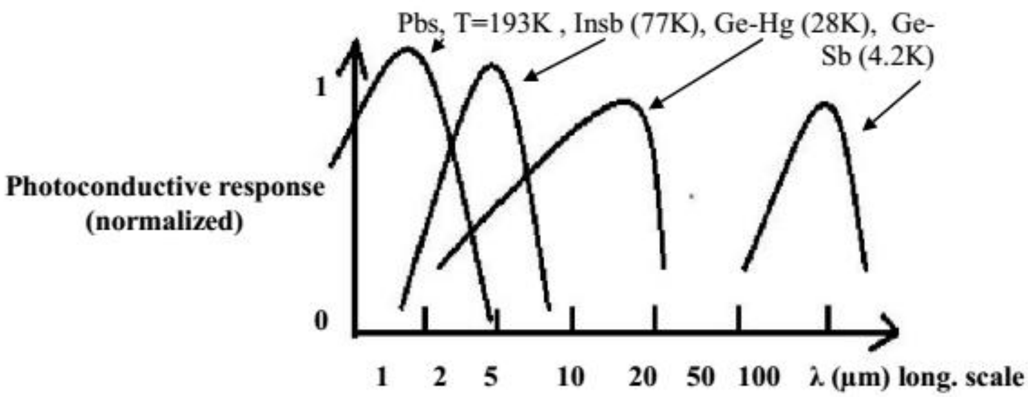
from the valence band can be excited into the acceptor levels, leading in both cases to an increase of conductivity.

The wavelength dependence of 4 types of photoconductors is illustrated in the figure taken at their typical operating temperatures.



Pb, InSb → **intrinsic S.C.S.**
Ge-Hg, Ge-Sb → **extrinsic S.C.S.**

<u>Construction:</u>

The photoconductive detector consists of a wafer of a s.c whose resistance decreases when it is illuminated by visible or IR light Mounted in an evacuated glass bulb.

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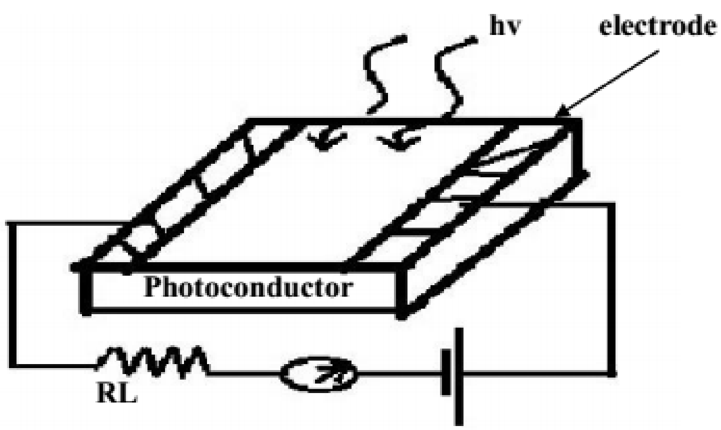

Flow which increases with the radiation intensity due to the release of more electrons in the photoconductor. The photoconductor is chosen such that its "dark" resistance is much larger than the load R_L, and thus most of the bias voltage appears across the detector cell.

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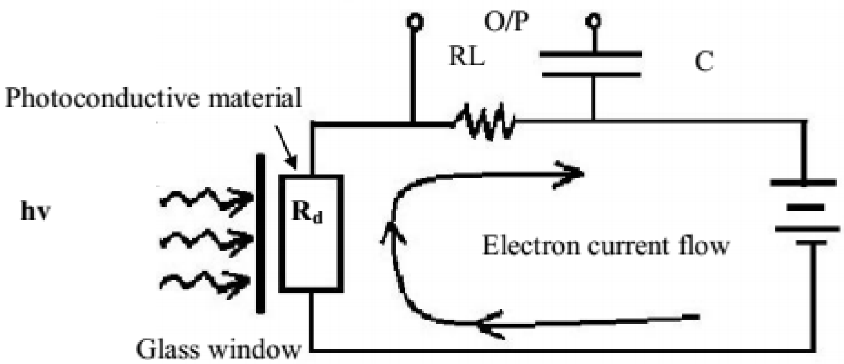
Excess electron (or hole) is created by the photon absorption. It will drift under the influence of the field toward the appropriate contact and current flows in circuit. The glass window is used to protect the photoconductive materials from exposure.



Photoconductive material decreases resistance as radiation applied.

The detector is tied to a load resistance R_L and a power source. The resistance of the photoconductive material may change from several MΩ in the dark to less than 1 KΩ under illumination. Therefore the potential across R_L increases with increasing light intensity.

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Best R_L values can be obtained by making a partial change in R_d under high illumination. Highest output signal can be obtained when $R_L=R_d$.

If a. c. voltage is required (i.e. the rate change of incident radiation), a capacitor (C) is used.

Lead sulfide (Pbs), lead selenide (PbSe), cadmium sulphide (CdS), selenium (Se), and thallium sulphide (Tl2S) are examples of photoconductive materials, they have high "dark" resistance and low irradiated resistance (high dark / light ratio). The minimum detectable power depends mainly on the material and the operation temperature, but tends to lie in the range 10^{-10}-10^{-12} W for detectors of area 1 mm^2.

LIMITATIONS: the donors are easily ionized by virtue of the thermal environment .longest λ that can be detected is ~14µm.

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At R.T, most of the acceptors would be ionized creating large quantities of holes and lowering the resistance of the detector. Most conductive detectors are cooled to liquid N2 (77k) or liquid He (4.2 K).

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