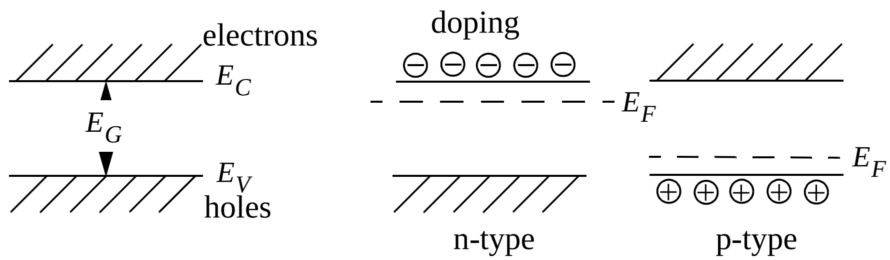
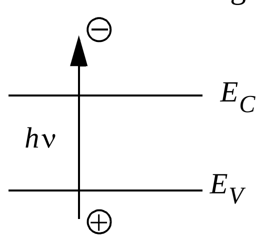
Lecture 13

<u>Semiconductor Photodetectors</u>

- Seimiconductor band structure



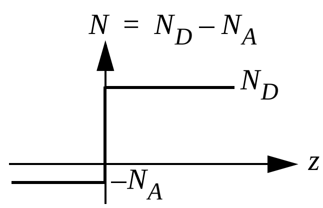
- Optical absorption across the bandgap

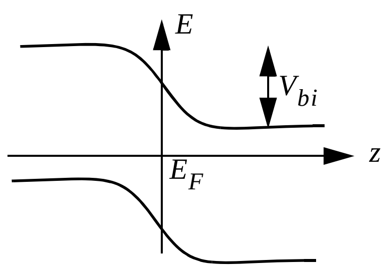


If $h\nu > E_G$, an electron and hole (pair) is created after photon absorption.

In a suitable structure, the electron and the hole can contribute to an electric current through the device.

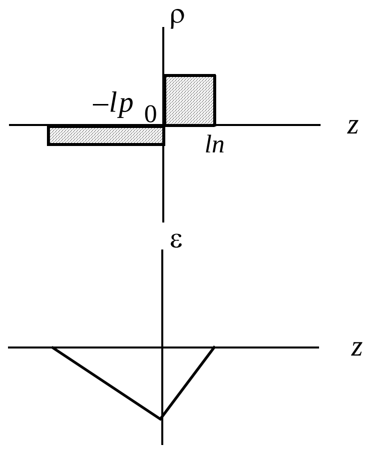
- p-n Junction



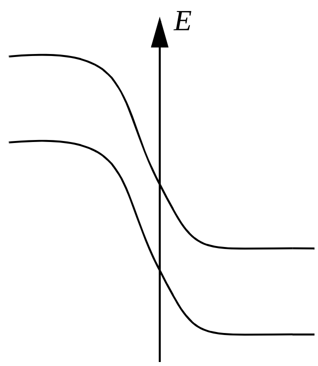


equilibrium

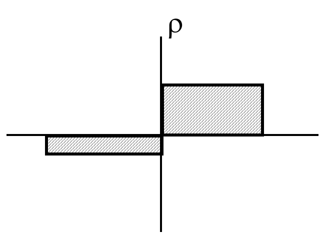
- Depletion approximation: Assumes carriers diffuse across junction and create regions that are totally devoid of free carriers



- Reverse bias



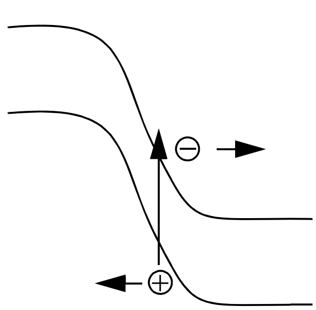
Under reverse bias, no current flows because the barrier to diffusion increases. Under forward bias, barrier to diffusion is *reduced*.

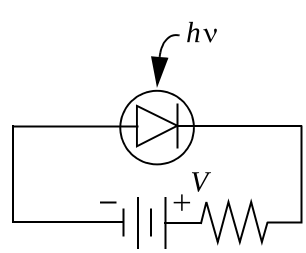


depletion widths wider

<u>Photodiode</u>

Reverse bias condition: electron and hole created in the depletion region follow the electric field and separate.

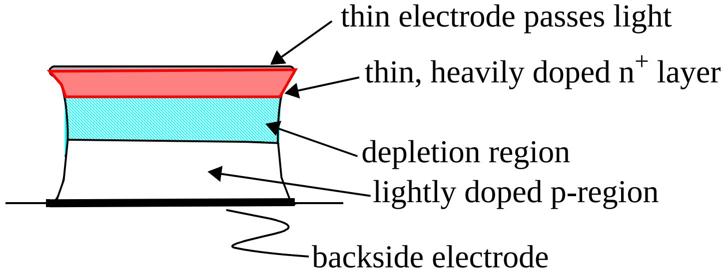




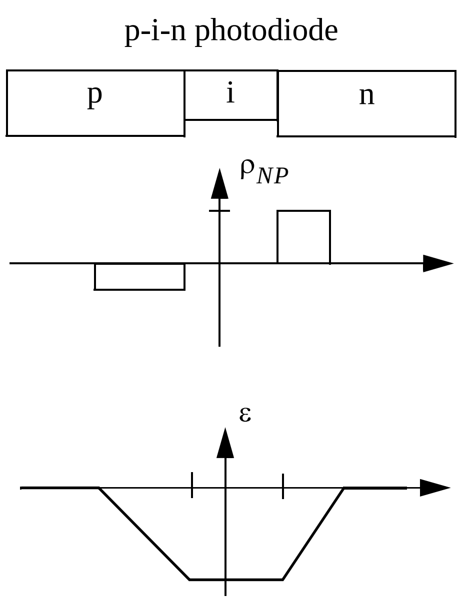
These carriers are pulled apart by the field.

The electric field exists *only* inside the depletion region. So the light absorption must also occur there to create current.

Construction



- Photodiodes can be used at longer wavelength than photomultiplier – $E_G < \Phi$
- Typically fast response time < 10 nsec
- Compact, inexpensive



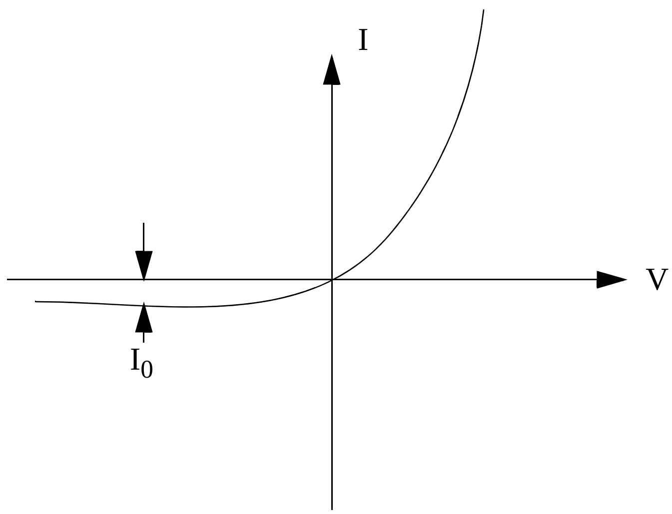
constant ε-field in the i-layer

Solar cells

(Reference: *Solar electricity, 2nd edition, Tomas Markvart, ed., John Wiley, 2000*)

silicon p-n juntion diode:

$$I = I_0\left[\exp\left(\frac{qV}{kT} - 1\right)\right]$$



Solar radiation -

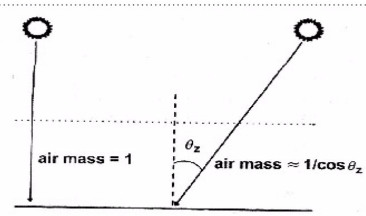


Fig. 2.2

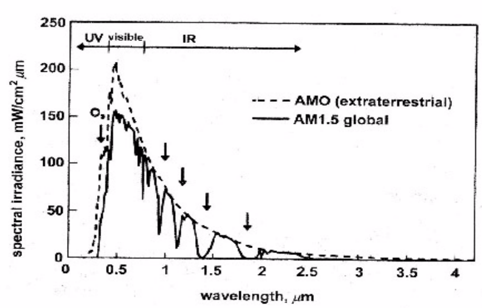


Fig. 2.3 The solar spectrum

AM 1.5 - on a clear day, the typical maximum solar irradiance is ~1kW/m^2 or 100 mW/cm^2, which translates to ~4.4X10^{17} photons/cm^2-sec.

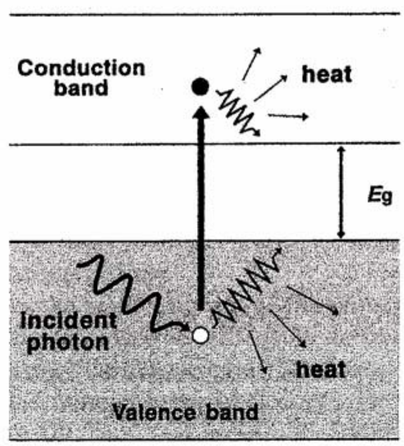


Fig. 3.8 The generation of electron–hole pairs by light

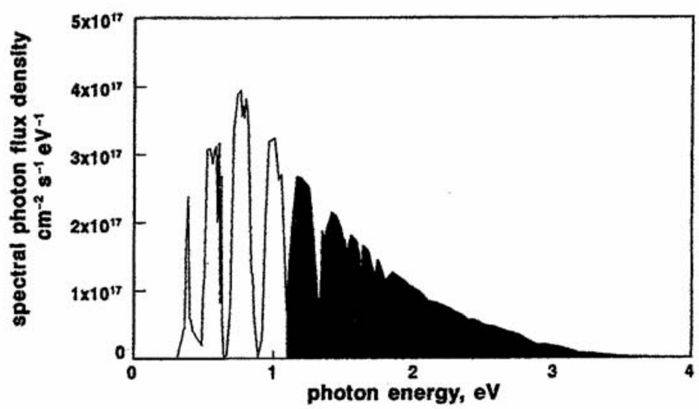


Fig. 3.9 Photon flux utilised by a silicon solar cell

In principle, when absorbed, this photon flux could produce a 'generation current' of

$$I_l = qNA$$

where N is the number of photons absorbed per second, and A is the area that is exposed to light. For the entire solar spectrum, this corresponds to about 70mA/cm^2. The band gap for crystalline silicon is 1.1 eV, so only the part of the spectrum shown above that is shaded in black can be absorbed. Thus, for silicon, the maximum generation current is about 44 mA/cm^2.