In Ge, which is another indirect gap material, the conduction band edges occur at the L-point \((2\pi/a)(1/2, 1/2, 1/2)\) on the B. Zone. Each bond has a spheroidal energy surface oriented along the \([111]\) crystal axis, with longitudinal mass \(m_l^* = 1.59 m_e\) and transverse mass \(m_t^* = 0.082 m_e\). There are eight such spheroidal surfaces, but because only half of each is inside the BZ, the value of \(\eta\) is 4 rather than 8 (Fig 1.7).

In GaAs, one finds (in \(\hbar^2/2m_e\) unit), \(A = -6.98, B = -4.5, |C| = 6.2\) and \(\Delta = 0.0341 eV\) with its band structure as shown (Fig 1.8). This direct gap semiconductor with \(E_g = 1.43 eV\) (at 300 K) at \(\Gamma\)-point (i.e. \(\vec{k} = 0\)), which ensures excellent optical properties making it attractive for opto-electronic devices. The conduction band is well represented by spherical constant energy surface, with

\[
\varepsilon(\vec{k}) = E_c + \frac{\hbar^2 k^2}{2m_e^*} \quad m_e^* = 0.067 m_e
\]

The values of the hole masses are \(m_{lh}^* = 0.45 m_e, m_{lh}^* = 0.1 m_e\) (however there is some uncertainties in the hole masses because of difficulties in their measurements).

AlAs is an important III-V semiconductor because of its excellent lattice constant matching GaAs. This material has indirect band gap, and is usually used as an AlGaAs alloy for barrier materials in GaAs/AlGaAs heterostructures.

It is important to note that the band gap in semiconductors, in general decrease with increase in
It is possible to mix semiconductors to produce an alloy. If A and B are two semiconductors with lattice constant $a_A$ and $a_B$, then the lattice constant of the alloy $A_xB_{1-x}$ is given by

$$a_{\text{alloy}} = x \cdot a_A + (1-x) \cdot a_B \quad \text{(Vegard's Law)}$$

The band structure of the alloy may be obtained by the weighted average,

$$E_{\text{alloy}}(\vec{k}) = xE_A(\vec{k}) + (1-x)E_B(\vec{k}) \quad \text{(Rigid Band Model)}$$

which is approximate, but useful for estimating the change in band gap due to alloying, if $x$ is sufficiently small.

---

**Fig 1.9: Band gap for semiconductor alloys**

For $A_xGa_{1-x}As$, as the figure shows (Fig 1.9), the band gap is direct for $0 < x < 0.45$ and for $x > 0.45$, the material becomes indirect band gap material. The band gap depends linearly on $x$, only for $0 < x < 0.35$, and can be written as

$$E_g(x) = 1.424 + 1.247 \times x \, (eV) \quad \text{at} \ 297 \, K$$

For $GaAs_{1-x}P_x$, a material similar to $A_xGa_{1-x}As$, the band gap is direct for $0 < x < 0.45$ and indirect for $x > 0.45$ and for $x < 0.45$ the linear behavior is well described by

$$E_g(x) = 1.424 + 1.233 \times x \, (eV) \quad \text{at} \ 300 \, K$$

Like all direct gap semiconductors, both $A_xGaAs$ and $GaAs_P$ have wide applications for opto-electronic devices. They are attractive because by changing $x$, one can change the wavelength $\lambda_g$ associated with the band gap:

$$\lambda_g = \frac{1.24}{E_g(\text{in } eV)} \mu m,$$

so that one tailor makes a semiconductor alloy to suit the wavelength requirement of a device.