"Acceptor" ~ \[ e^- \text{ in \text{\textit{Si}}} \rightarrow \text{1 extraneous hole} \] (and uncharged majority)

+ \[ \text{acceptor mass, \text{\textit{Si}}} \]

+ \[ \text{donor + acceptor} \]

+ \[ \text{electrons drop down to } n \text{ level!} \]

- \[ n \text{ if } N_A \gg N_D \rightarrow n \text{-type} \]

- \[ P \text{-type if } N_A < N_D \]

"complicated" and roughly equal, or at least, lots of both types

- \[ \text{Amphoterism} - \text{as Si in GaAs, could be a mess} \]

- \[ \text{Nonhydrogenic} \]

- \[ \text{states deep in band} \]

- \[ \text{this is hoping when by little distance because accept not very like host} \]

- \[ \text{Background: } \text{unintentional } \leq 10^{14} \text{ cm}^{-3} \text{ (as I put in S8)} \]

- \[ \text{for best samples} \]

- \[ \text{intentional: } \text{often } \approx 10^{17} - 10^{19} \text{ cm}^{-3} \]

- \[ \text{my own work: } \approx 3 \times 10^{18} - 3 \times 10^{19} \text{ cm}^{-3} \]
What happens at some temp? \((kT < 25 \text{ meV})\)

\[ G \approx 6 \text{ meV (with doping\% \text{ or } \%)} \]

\[ E_F = \frac{2m^*}{3}\sqrt{kT} \text{ (meV) (approx)} \]

- For n-type: probably still donor electron \(E_F \rightarrow E_{\text{CB}}\)
- For p-type: some (most) acceptors \(E_F \rightarrow E_{\text{VB}}\)

At \(0K\)

\[ E_E = E_{\text{CB}} + \frac{E_{\text{D}}}{n} \]

- Extended population of CB

\[ E_F \approx \text{ Fermi energy} \]

\[ E_F = \frac{E_{\text{CB}}^0 + E_{\text{D}}}{} \]

\[ n = \frac{N_o}{2} \left( \frac{m^*}{2\pi} \right)^{3/2} \exp \left( -\frac{E_F}{kT} \right) \]
\[ n = \frac{2}{k_B} \frac{\mu}{E_g} \frac{1}{kT} \]

**Derivation:**

\[ n = \frac{2}{k_B} \frac{\mu}{E_g} \frac{1}{kT} \]

\[ n_0 = \frac{E_G}{kT} = n_0 \frac{E_G}{kT} \]

\[ p = p_0 \frac{(E_G - \mu)}{kT} = p_0 \frac{E_G}{kT} \]

\[ \mu + E_V = 0 \quad \text{then} \quad E_C = E_G \]

**Before:** \( n = p \)

**Now:** \( n = p + \text{ionized donors} \)

\[ n = p_0 \frac{E_G}{kT} + n_0 \frac{E_G}{kT} \]

\[ n^2 = n_0 p_0 \frac{E_G}{kT} + n_0 N_D \frac{E_G}{kT} \]

\[ n^2 = n_0 p_0 \frac{E_G}{kT} + n_0 N_D \frac{E_G}{kT} \]

\[ \uparrow \quad \text{Doping small} \]

\[ n = \sqrt{n_0 N_D} \frac{E_G}{2kT} \]

**Handout from 3.2.6**
Alloys

certainly 1% + or - not depends on our

"average" alloy

bad gap engineering hard work

→ discussion of quantum wells

Type 1 vs Type 2

End of Ch 3

→ skipping more topics at end

- Thermoelectric
- Superlattices
  - Bloch oscillators
  - Zener tunneling (actually, maybe explain)

\[ V = \frac{E}{d} \]

for constant E

\[ U \sim V \]

then U \sim existing U