Section 27
Heterojunction Bipolar Transistor

27.4 Abrupt Junction HBTs

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PURDUE UNIVERSITY

School of Electrical and Computer Engineering

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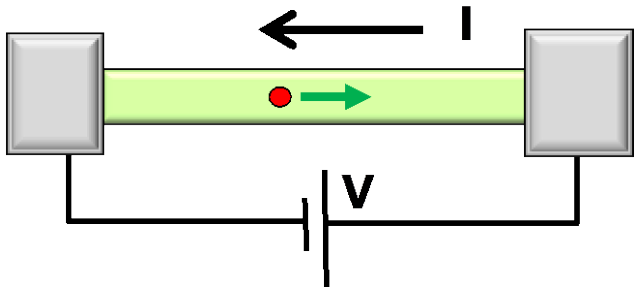

$$I = G \times V$$
$$= q \times n \times v \times A$$

charge density velocity area

$$\beta_{poly,ballistic} \rightarrow \frac{n_{i,B}^2}{n_{i,E}^2} \times \frac{N_E}{N_B} \times \frac{\upsilon_{th}}{\upsilon_s}$$

$$\frac{n_{i,B}^2}{n_{i,E}^2} = \frac{N_{C,B}N_{V,B}e^{-E_{g,B}\beta}}{N_{C,E}N_{V,E}e^{-E_{g,E}\beta}} \approx e^{\left(E_{g,E}-E_{g,B}\right)\beta}$$

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- 27.1 Applications, Concept, Innovation, Nobel Prize
- 27.2 Heterojunction Equilibrium Solution
- 27.3 Types of heterojunctions
- 27.4 Abrupt junction HBTs status
- 27.5 Graded junction HBTs
- 27.6 Graded base HBTs
- 27.7 Double heterojunction HBTs
- 27.8 Modern Designs

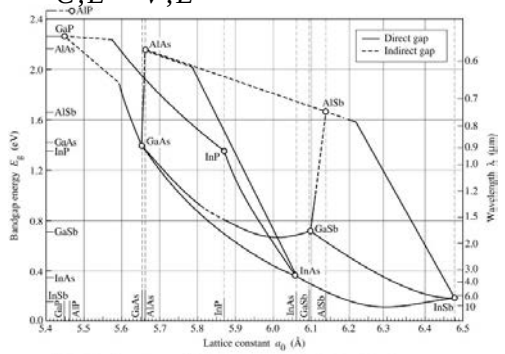
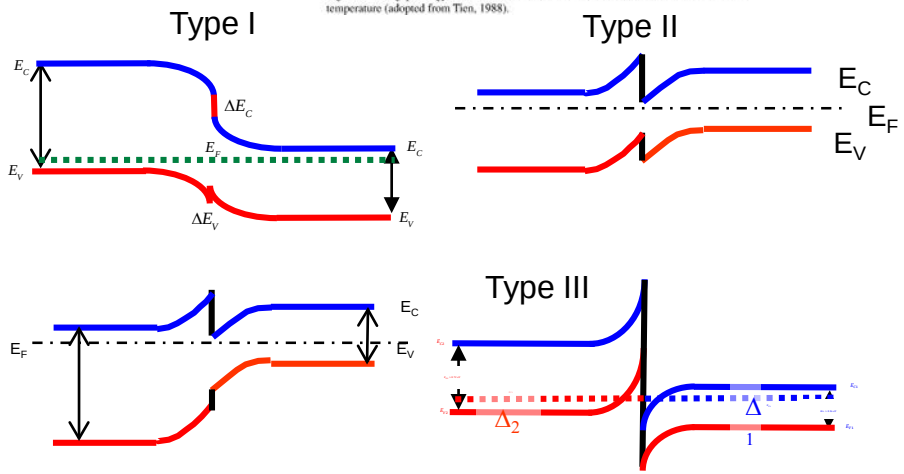


Fig. 7.6. Bandgap energy and lattice constant of various III-V semiconductors at room temperature (adopted from Tien, 1988).

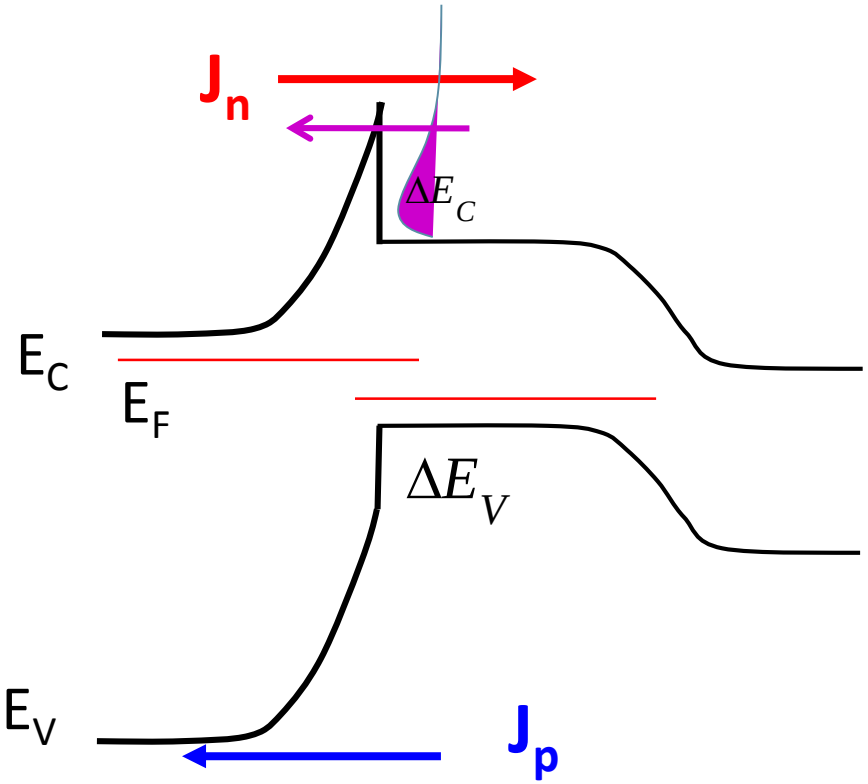


Mark Lundstrom, “Heterostructure Fundamentals,” Purdue University, 1995.

Herbert Kroemer, “Heterostructure bipolar transistors and integrated circuits,” Proc. *IEEE* , **70**, pp. 13-25, 1982.

Abrupt Junction HBTs

$$J_{n,B\to E} = q\left(\frac{n_{iB}^2}{N_B}\right)\upsilon_{Rp}e^{-\Delta E_C/k_BT} = J_n(V_{BE}=0)$$



Gain in abrupt npn BJT defined only by valence band discontinuity!

$$J_n = q\left(\frac{n_{iB}^2}{N_B}\right)\upsilon_{Rp}e^{-\Delta E_C/k_BT}e^{qV_{BE}/k_BT}$$

$$J_p = q\left(\frac{n_{iE}^2}{N_E}\right)\frac{D_p}{W_E}e^{qV_{BE}/k_BT}$$

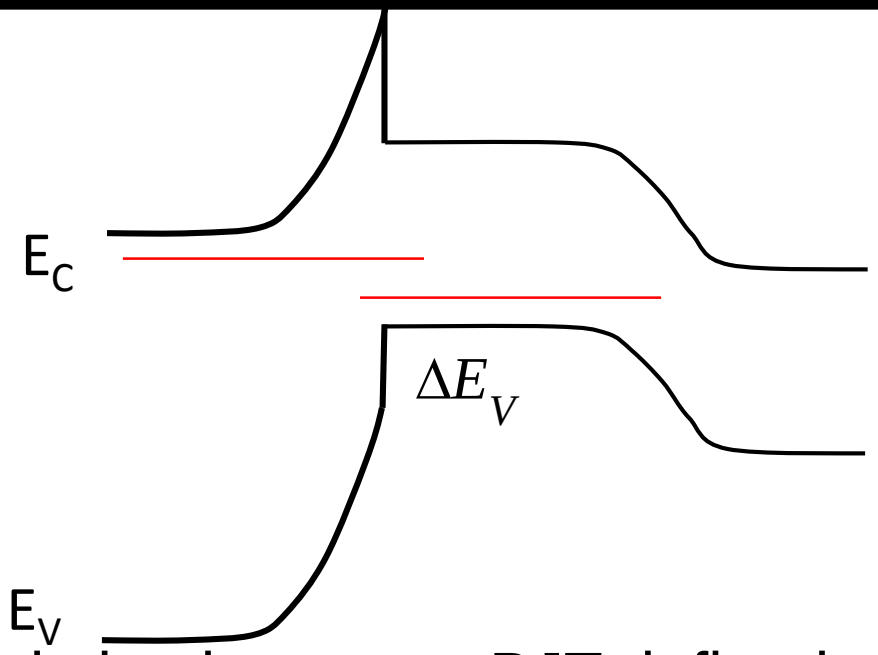
$$\beta = \frac{N_E}{N_B}\frac{\upsilon_{Rp}}{\left(D_p/W_E\right)}\left[\frac{n_{iB}^2}{n_{iE}^2}e^{-\Delta E_C/k_BT}\right]$$

$$\frac{n_{i,B}^2}{n_{i,E}^2} = \frac{N_{C,B}N_{V,B}e^{-E_{g,B}\beta}}{N_{C,E}N_{V,E}e^{-E_{g,E}\beta}} \approx e^{\left(E_{g,E}-E_{g,B}\right)\beta}$$

$$\beta = \frac{N_E}{N_B}\frac{\upsilon_{R,p}}{\left(D_p/W_E\right)}e^{\Delta E_V/k_BT}$$

Thermionic Emission Approach

Abrupt Junction HBTs



Gain in abrupt npn BJT defined only by valence band discontinuity!

$$\beta = \frac{N_E}{N_B}\frac{\upsilon_{R,p}}{\left(D_p/W_E\right)}e^{\Delta E_V / k_B T}$$

... but we are hoping for even better gain

$$\beta \rightarrow \frac{n_{i,B}^2}{n_{i,E}^2}\times\frac{N_E}{N_B}\times\frac{\upsilon_{th}}{D_p/W_E} \sim \frac{N_E}{N_B}\times\frac{\upsilon_{th}}{D_p/W_E}e^{\left(\Delta E_g\right)\beta}$$

For full gain, we need graded junction HBT

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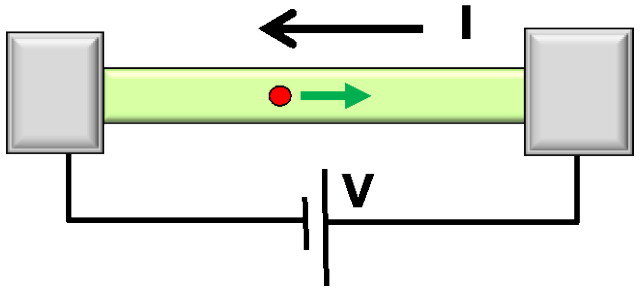

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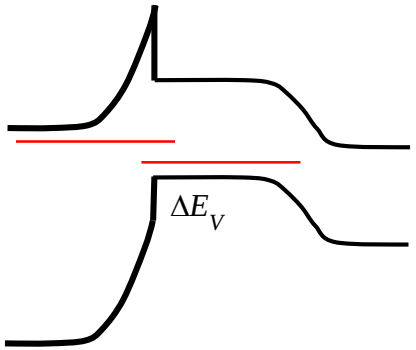

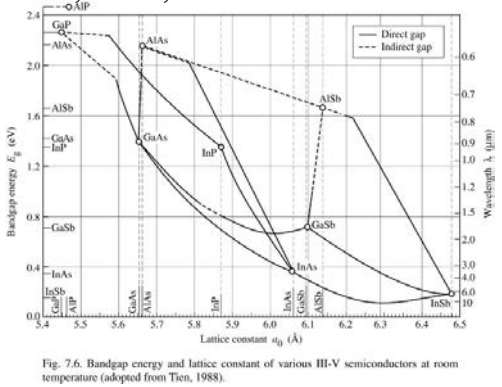

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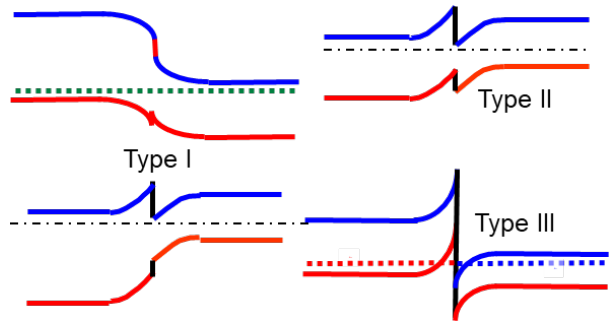

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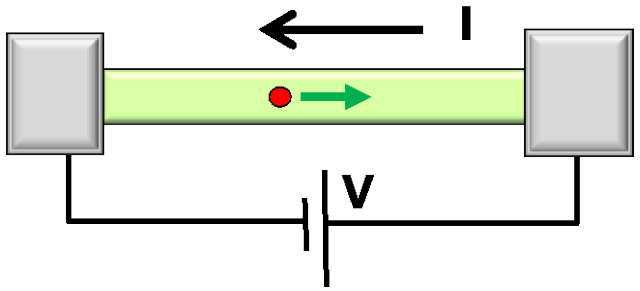

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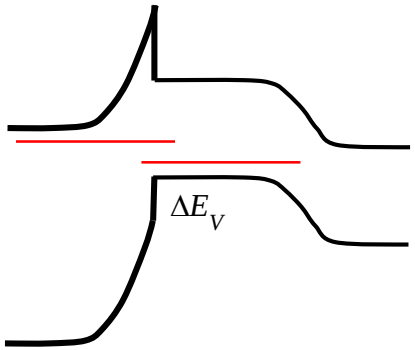

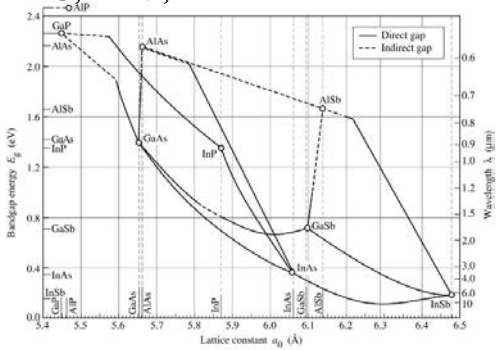

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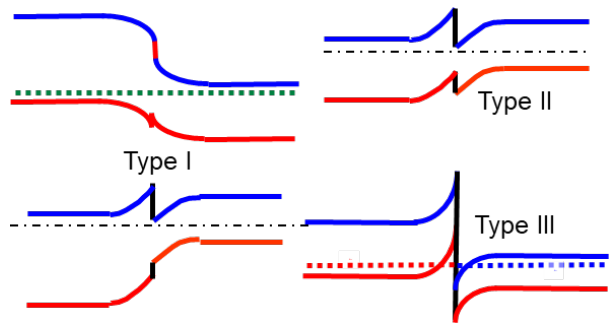

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