Section 27
Heterojunction Bipolar Transistor

27.3 Types of Heterojunctions

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PURDUE UNIVERSITY

School of Electrical and Computer Engineering

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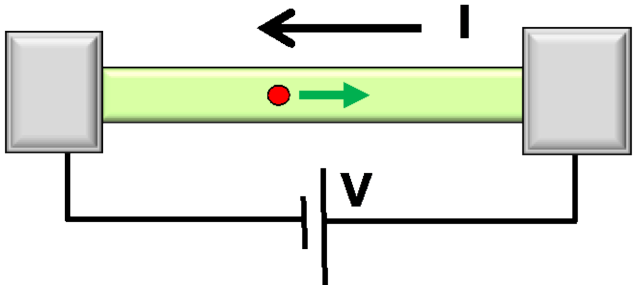


I = G × V

= q × n × v × A

charge density velocity area

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

$$\nabla \bullet D = q\left(p - n + N_D^+ - N_A^-\right)$$

$$\beta_{DC} = \frac{I_C}{I_B}$$

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

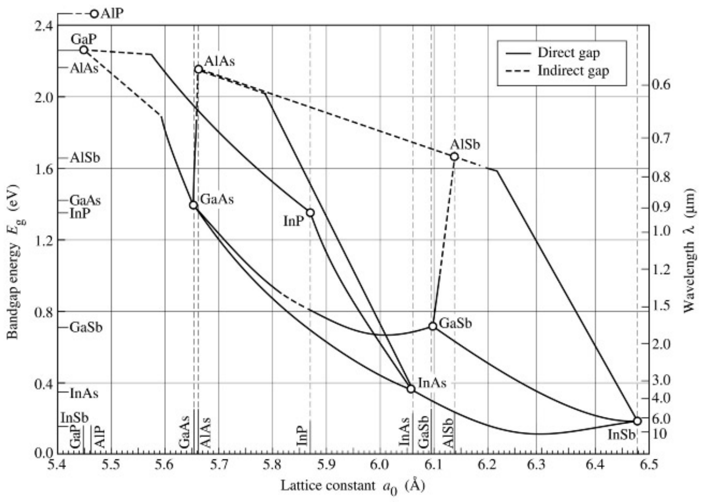
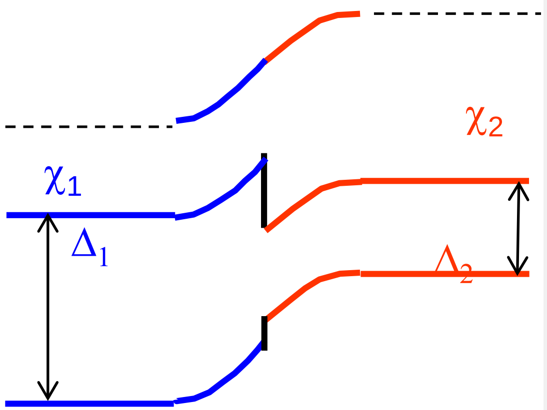


Fig. 7.6. Bandgap energy and lattice constant of various III-V semiconductors at room temperature (adopted from Tien, 1988).



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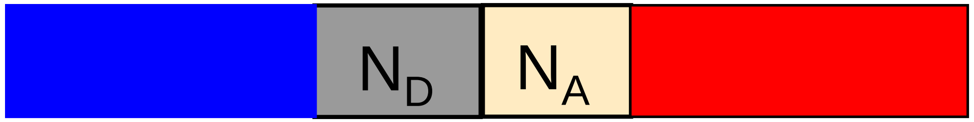
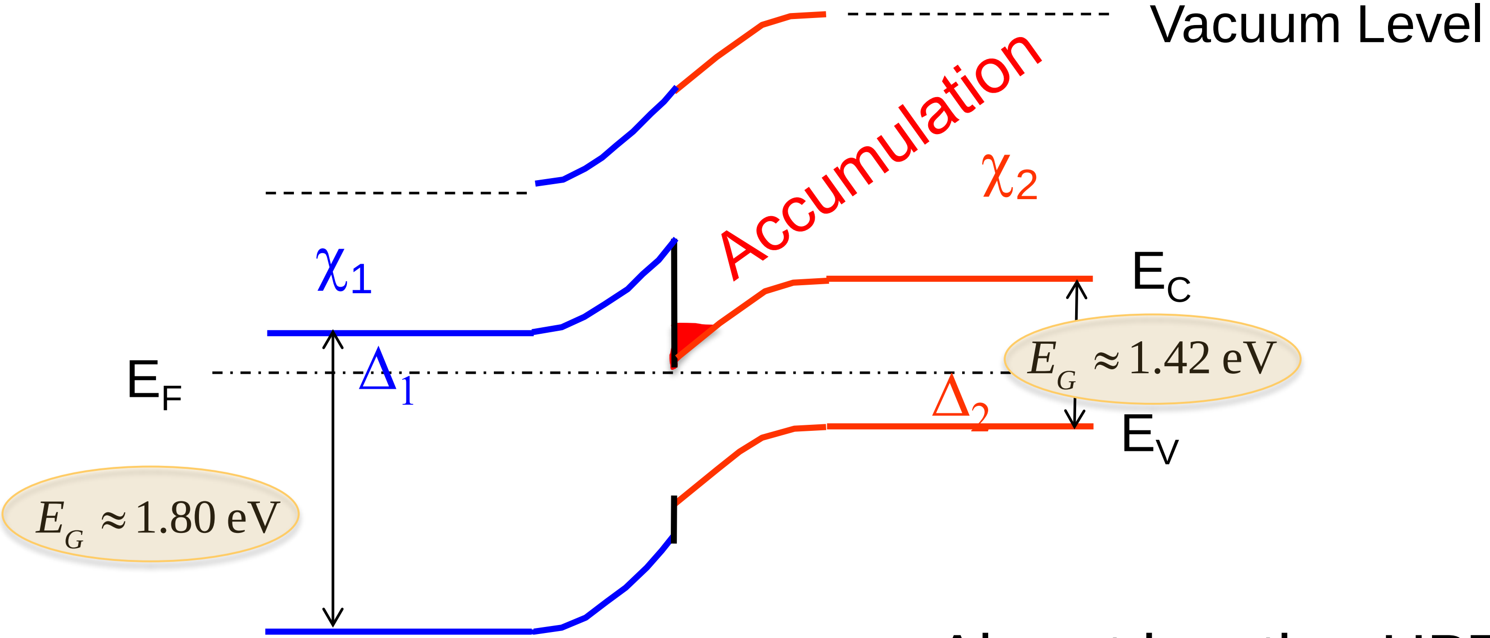
N-$Al_{0.3}Ga_{0.7}As$: p-GaAs
(Type-I Heterojunction)

$$\Delta_1 + \chi_1 + qV_{bi} = E_{g,2} - \Delta_2 + \chi_2$$



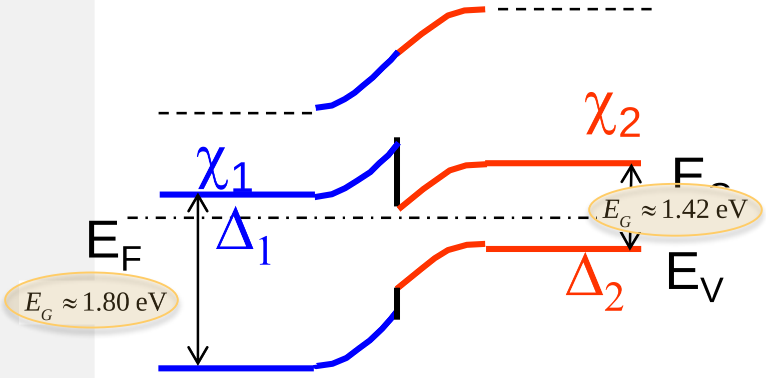
Reminder:
Electrons live above E_{C1}
E_{F1} marks the sea of electrons
T=0K => they fill all states to E_{F1}

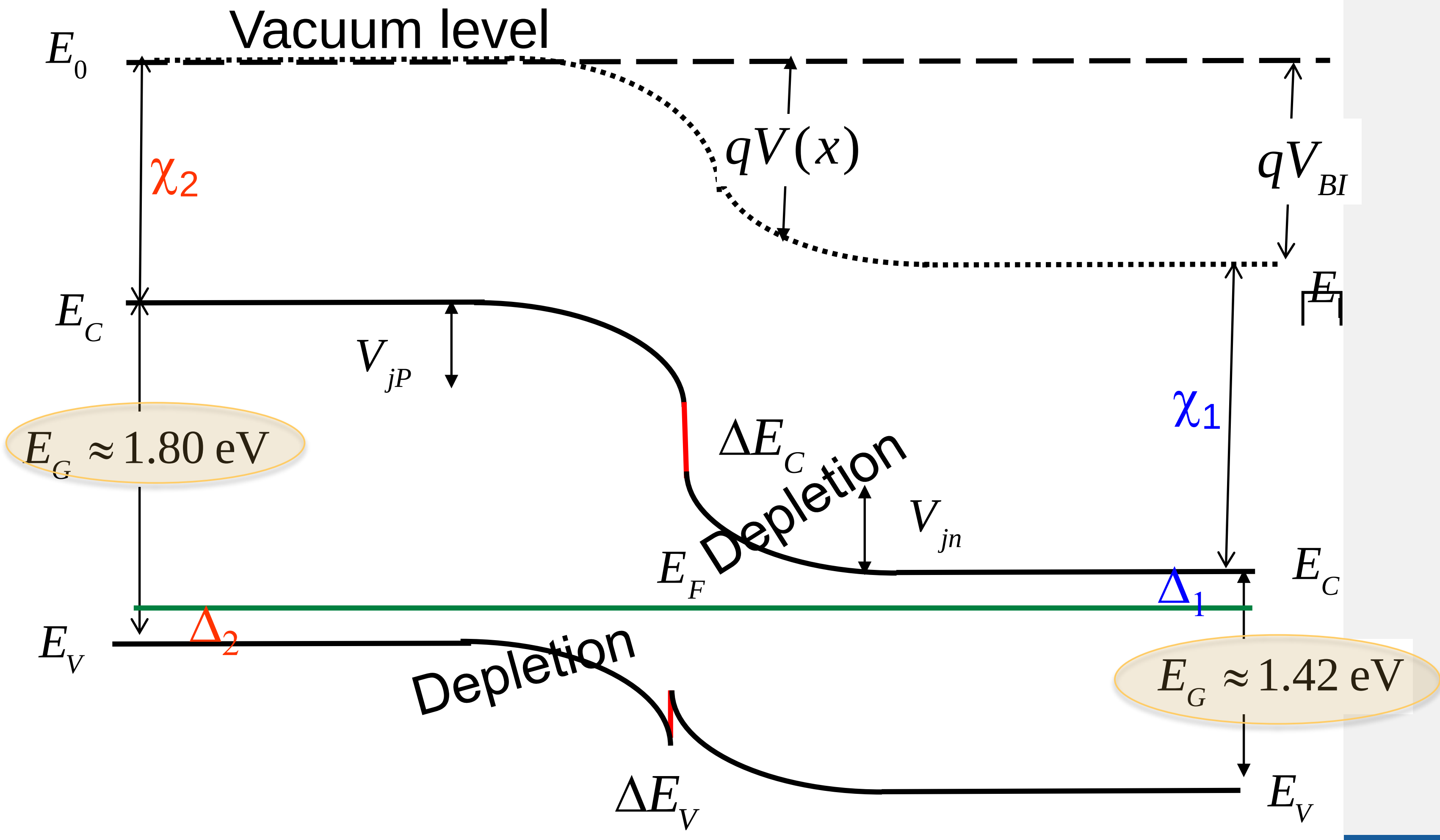


Abrupt junction HBT

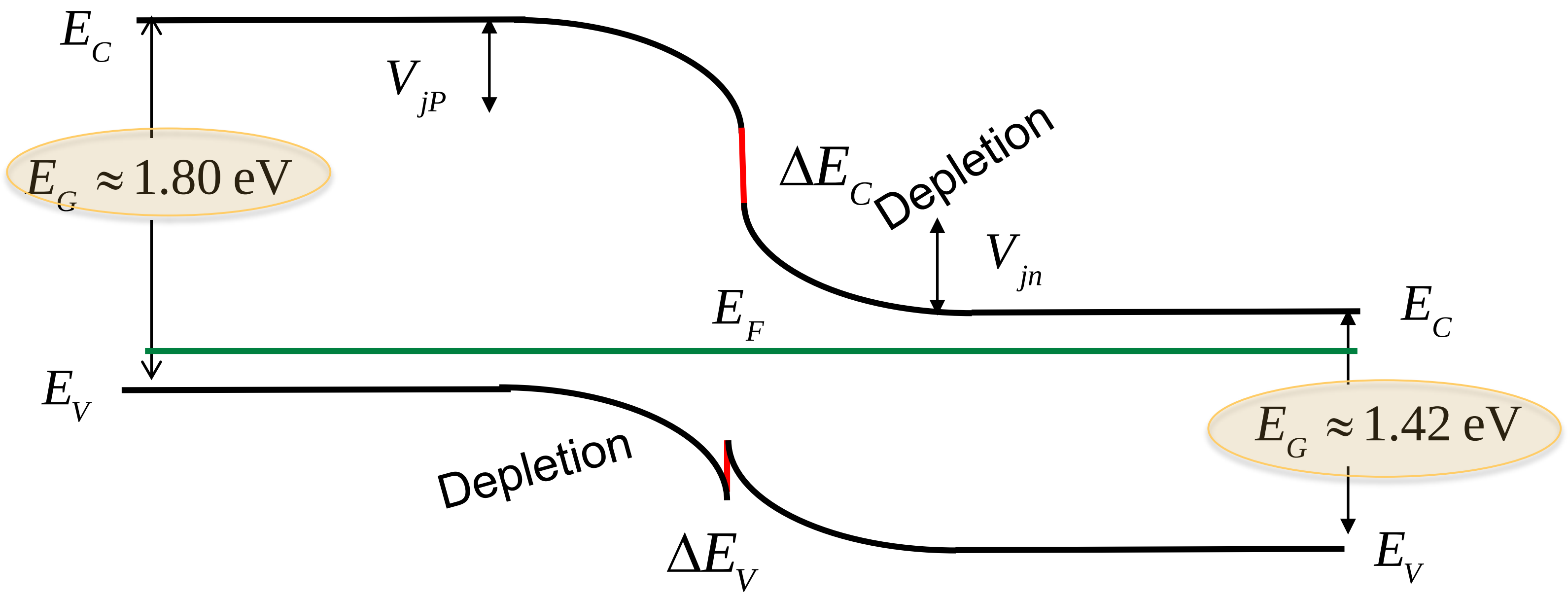
P-$Al_{0.3}Ga_{0.7}As$: n-GaAs (Type I junctions)

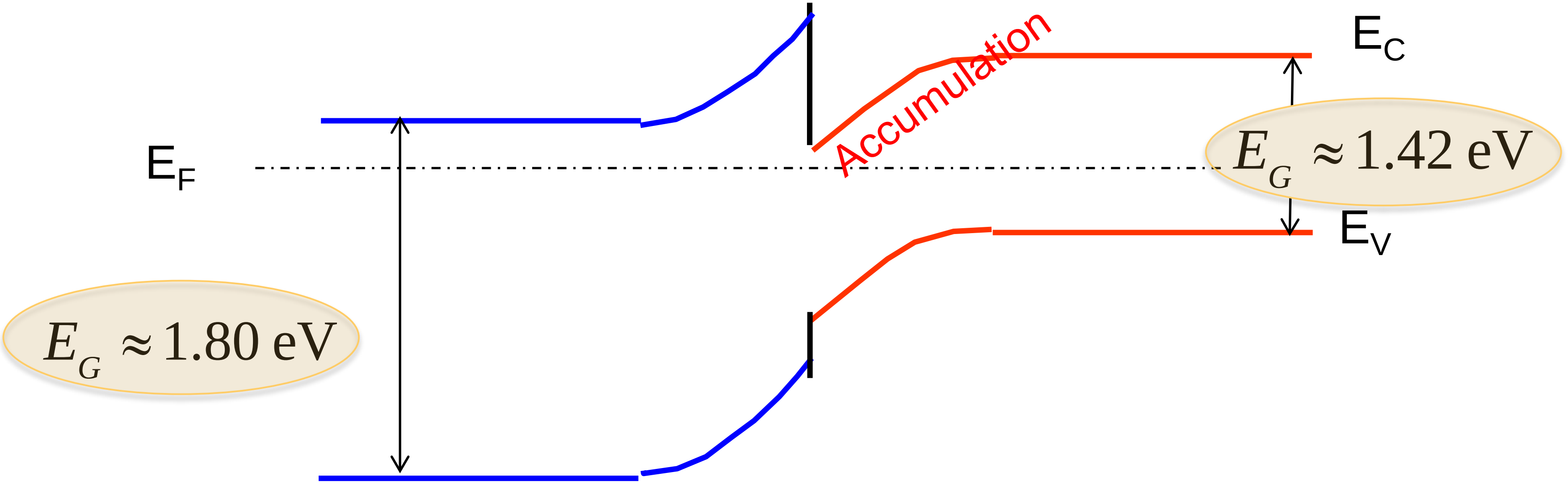
$$\Delta_1 + \chi_1 + qV_{bi} = E_{g,2} - \Delta_2 + \chi_2$$





Type I junctions

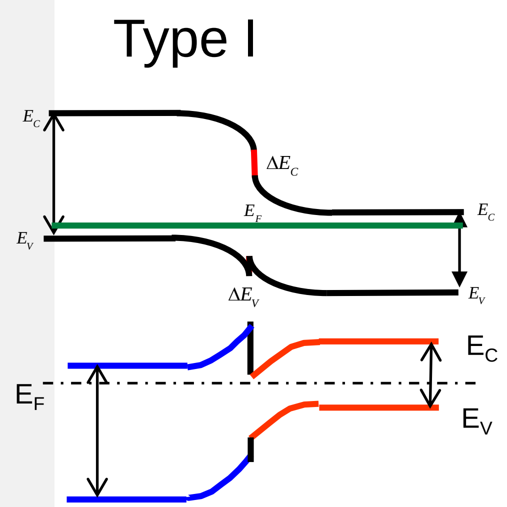


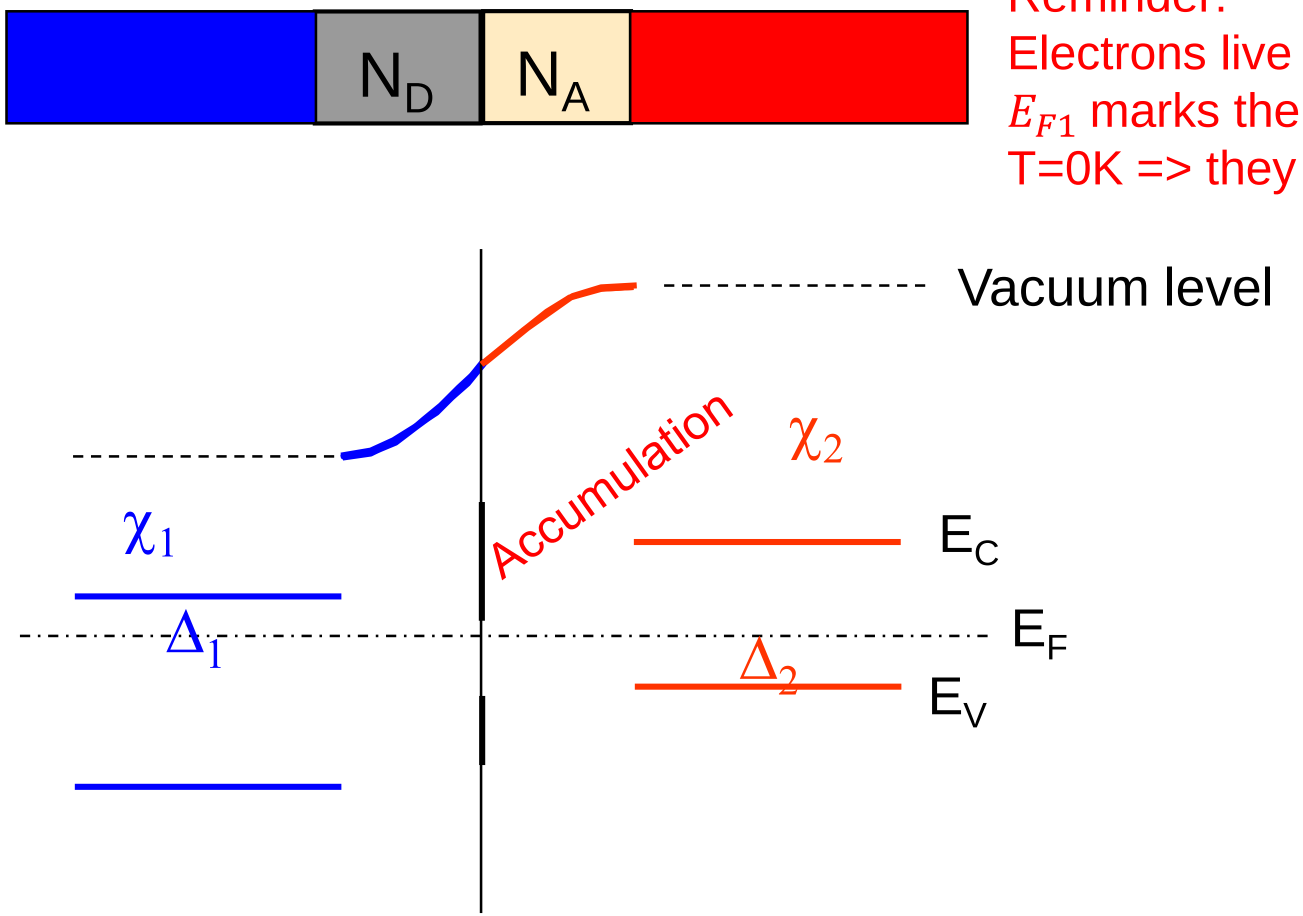


(AlInAs/InP) Type II Junctions

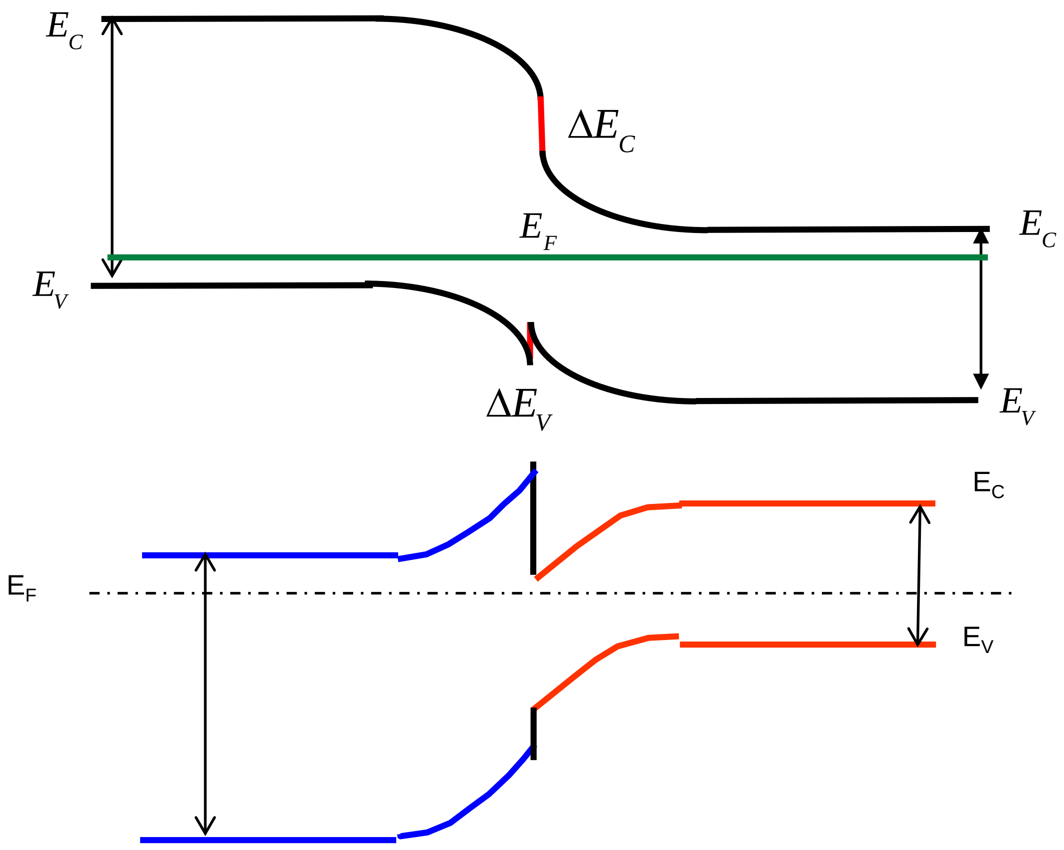
$$\Delta_1 + \chi_1 + qV_{bi} = E_{g,2} - \Delta_2 + \chi_2$$

Reminder:
Electrons live above E_{C1}
E_{F1} marks the sea of electrons
T=0K => they fill all states to E_{F1}

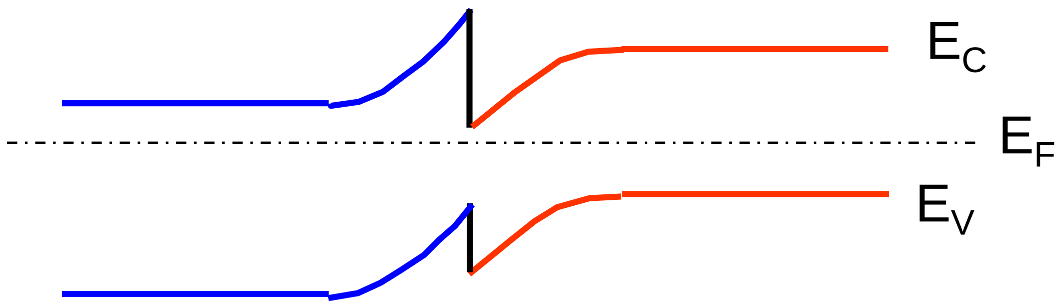




Type I

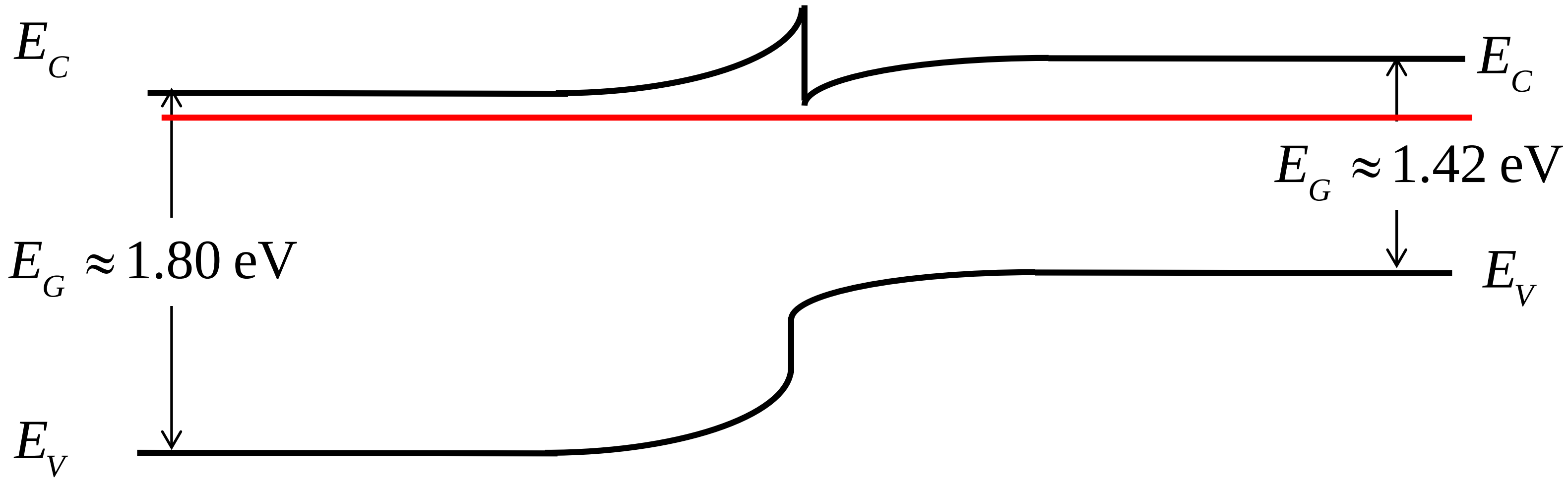


Type II



N-$Al_{0.3}Ga_{0.7}As$: n-GaAs Junctions

'Isotype Heterojunction'

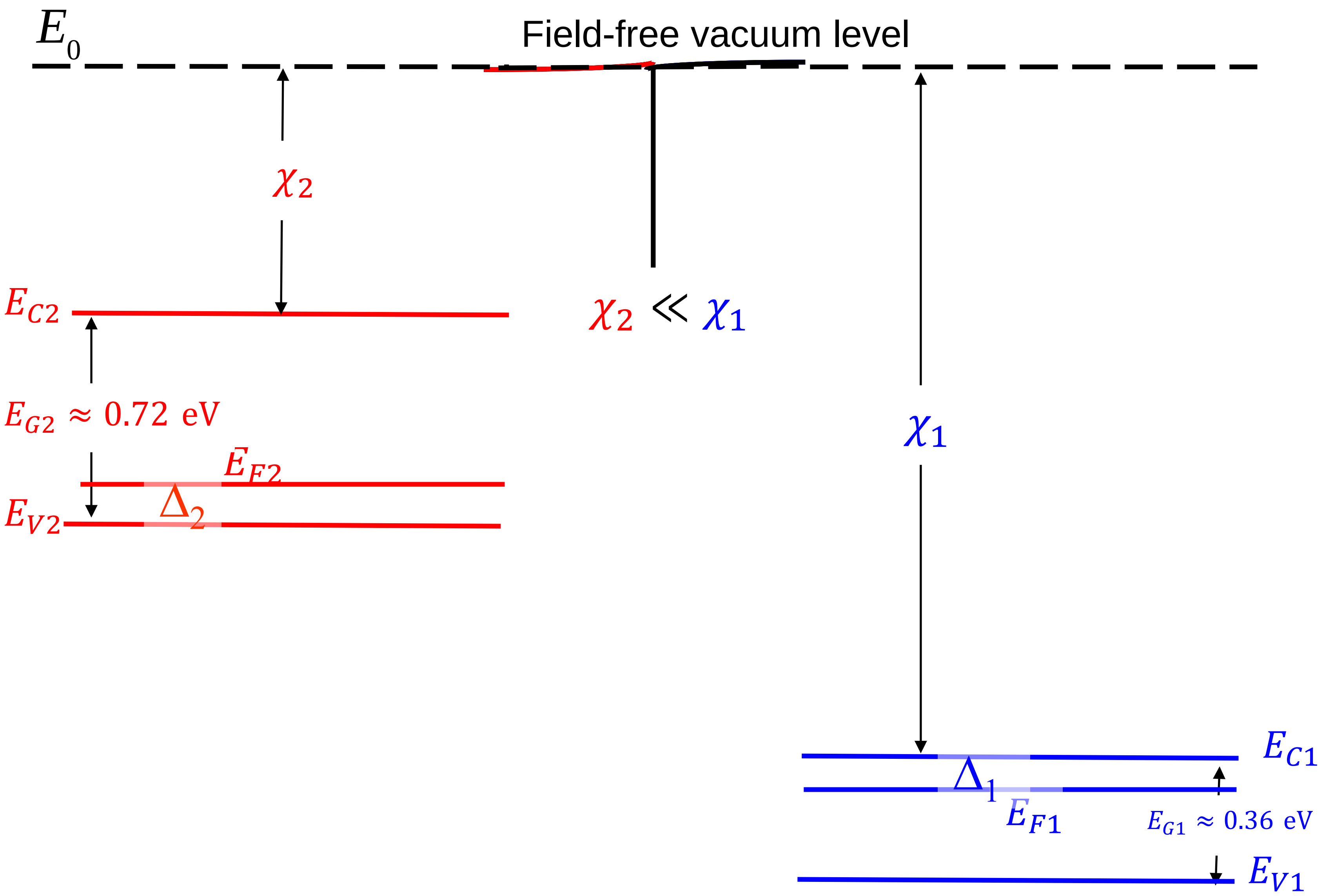


Depletion Layer Accumulation Layer

Metal-Metal junctions have similar features …
different workfunctions => different band lineups
thermoelectric coolers ,
electrons traveling from one side to the other
can gain and lose energy

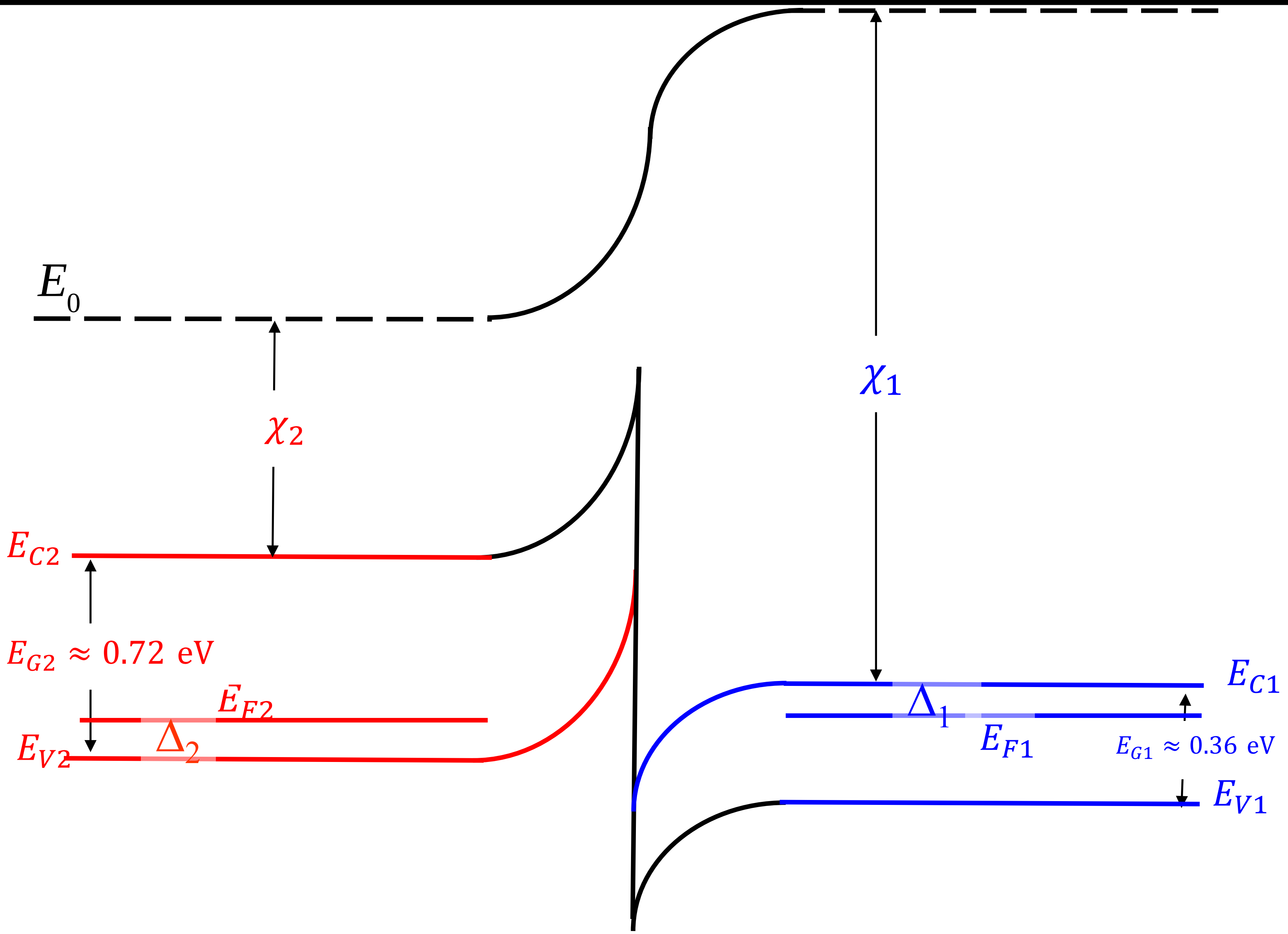
P-GaSb : n-InAs (Type III)

$E_{g,2} - \Delta_2 + \chi_2 = \Delta_1 + \chi_1 + qV_{bi}$



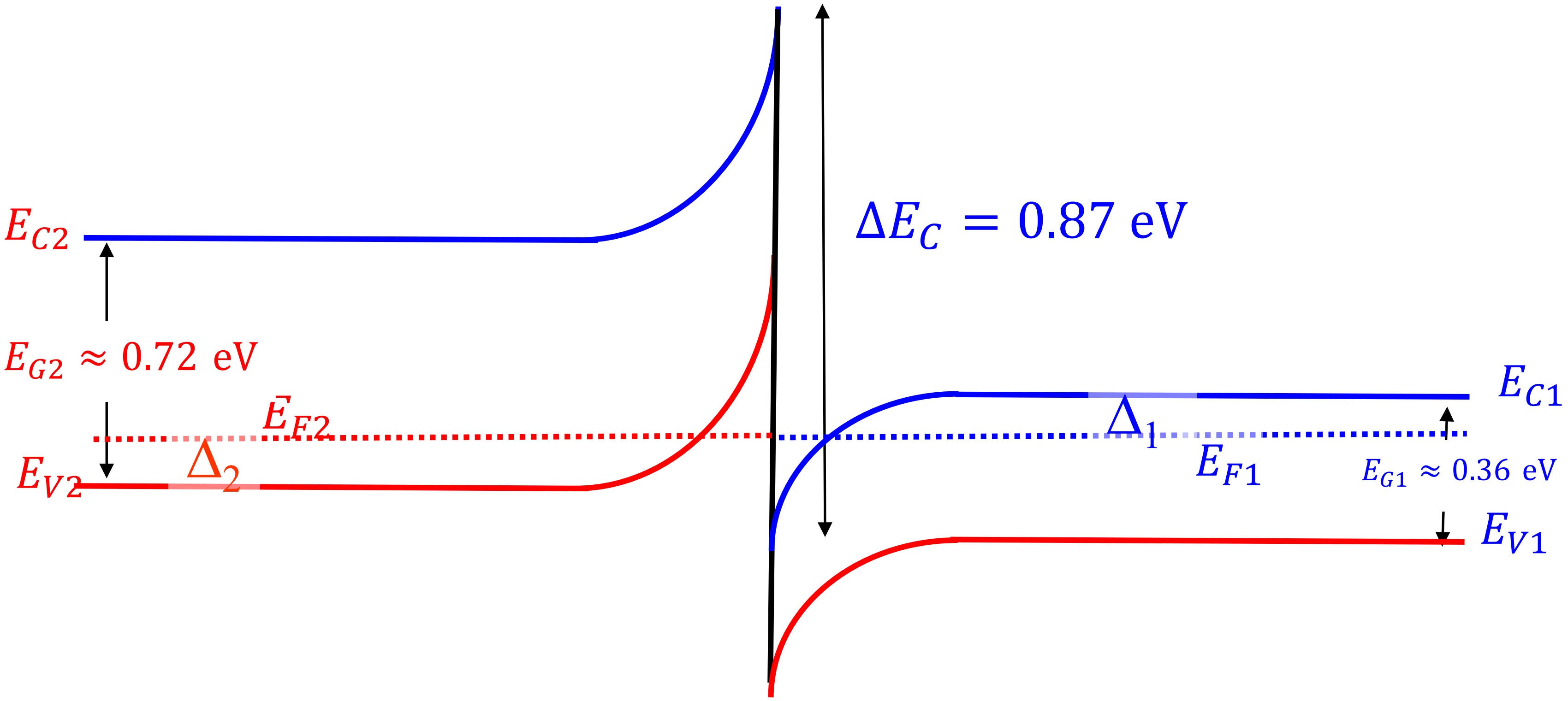
P-GaSb : n-InAs (Type III)

$$E_{g,2} - \Delta_2 + \chi_2 = \Delta_1 + \chi_1 + qV_{bi}$$



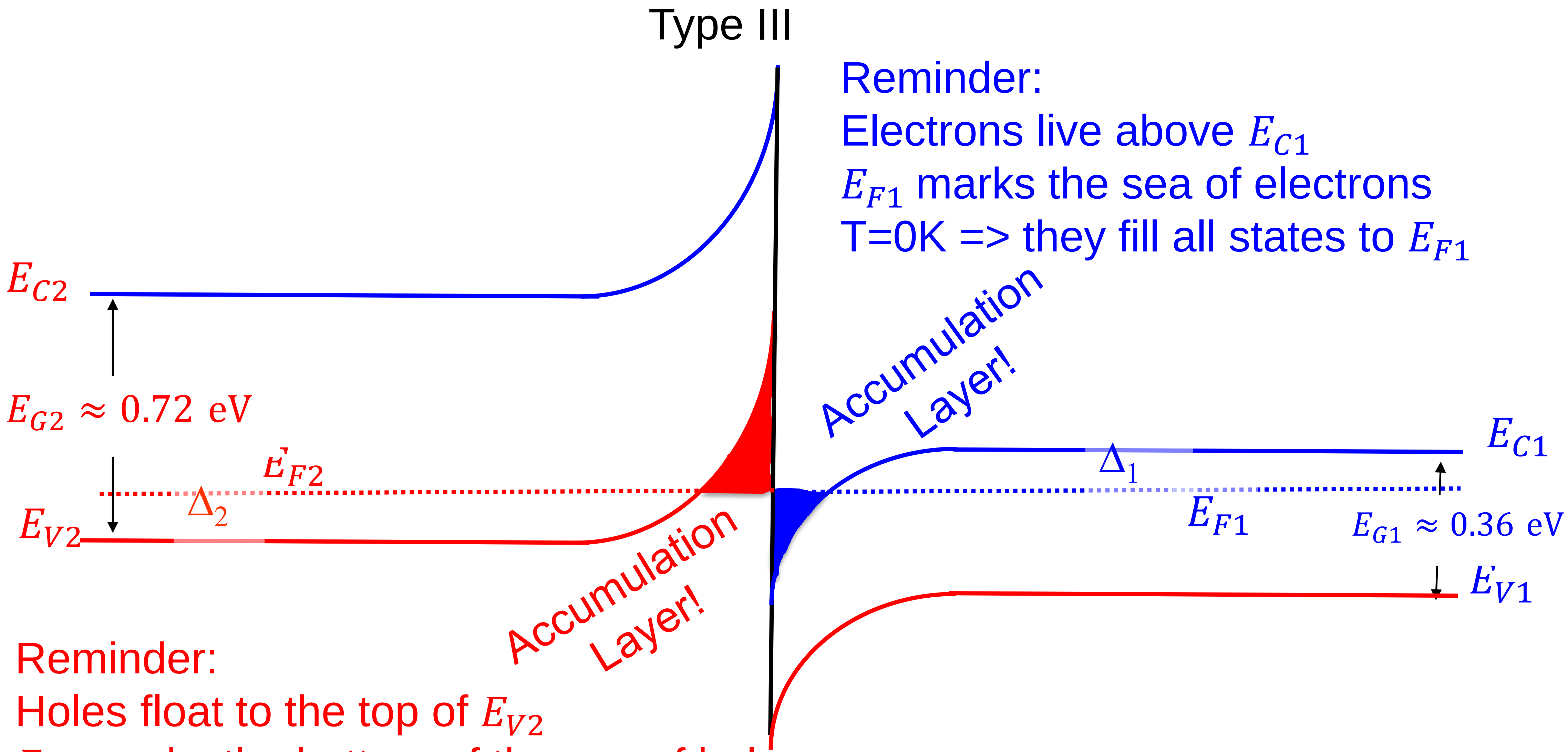
P-GaSb : n-InAs (Type III)

$$E_{g,2} - \Delta_2 + \chi_2 = \Delta_1 + \chi_1 + qV_{bi}$$



P-GaSb : n-InAs (Type III)

$$E_{g,2} - \Delta_2 + \chi_2 = \Delta_1 + \chi_1 + qV_{bi}$$

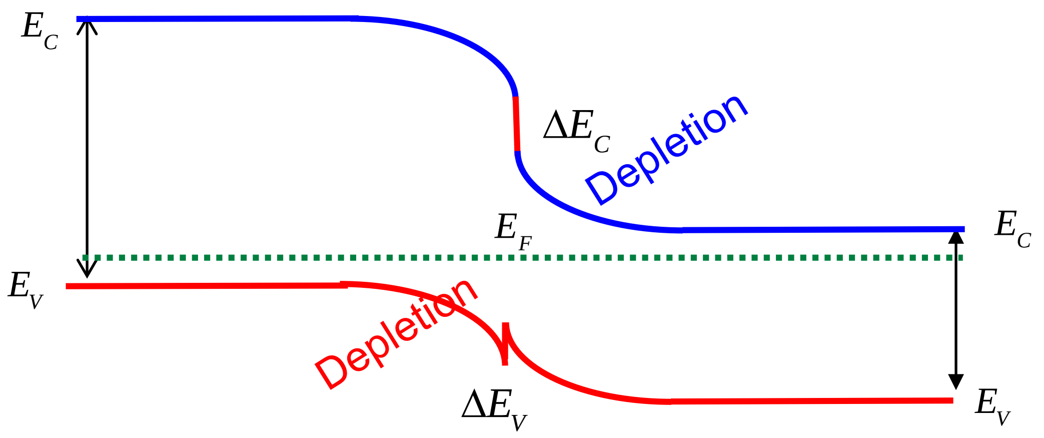


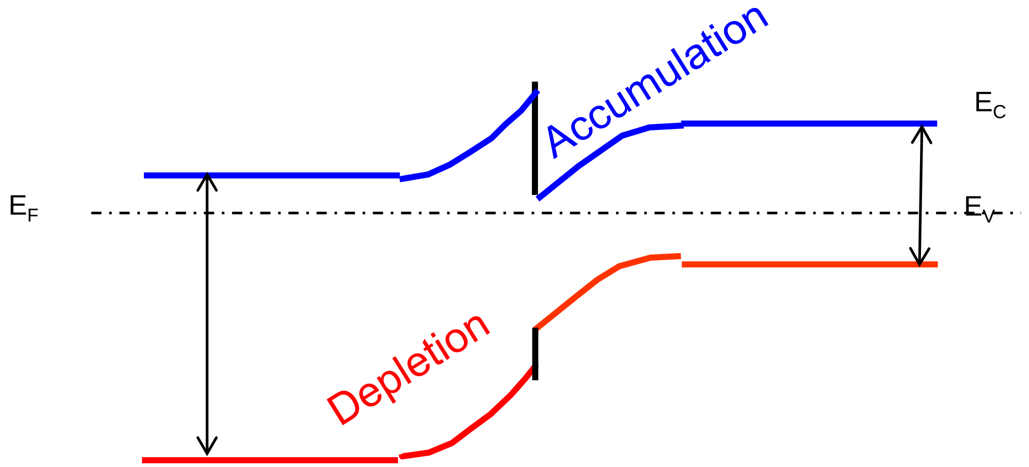
Reminder:
Electrons live above E_{C1}
E_{F1} marks the sea of electrons
T=0K => they fill all states to E_{F1}

Reminder:
Holes float to the top of E_{V2}
E_{F2} marks the bottom of the sea of holes
T=0K => holes fill all states above E_{F2}

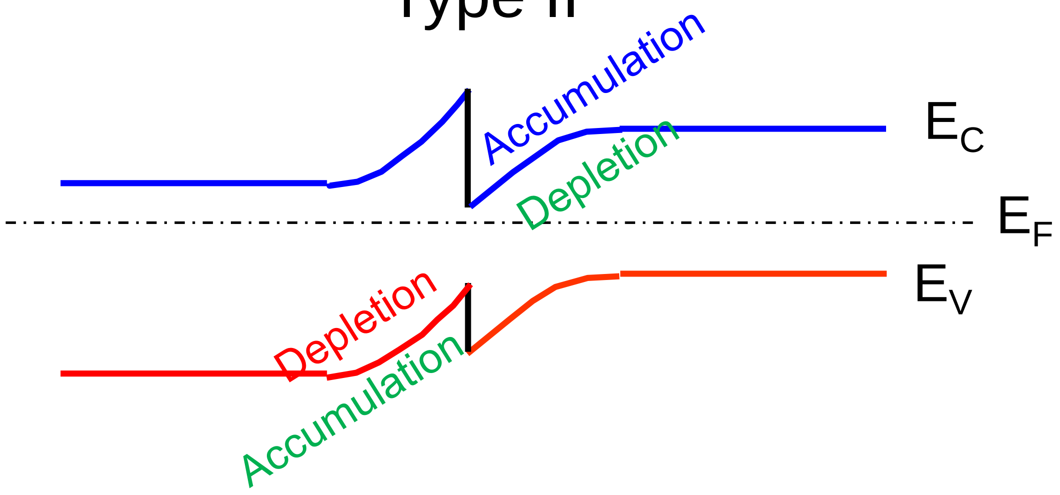
Type I,II, III

Type I

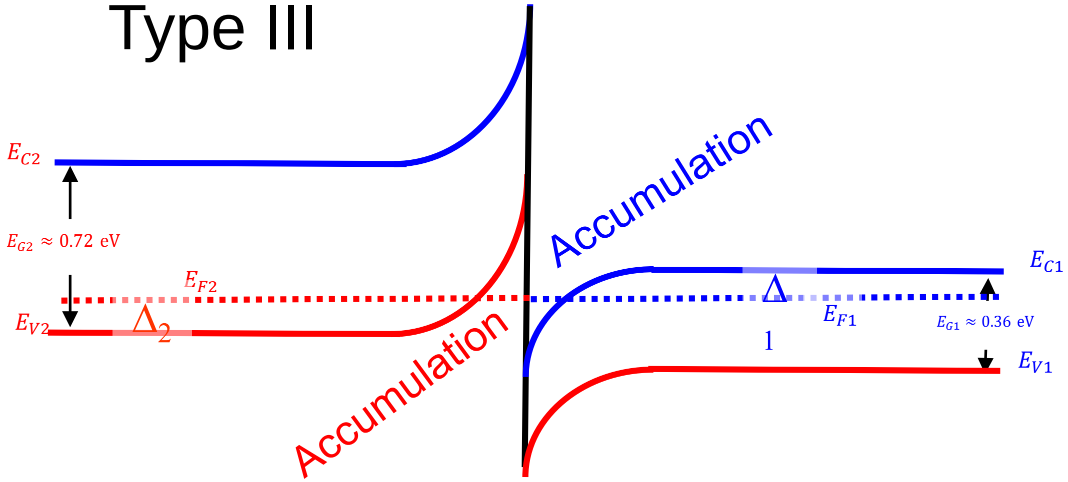




Type II



Type III



Summary

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

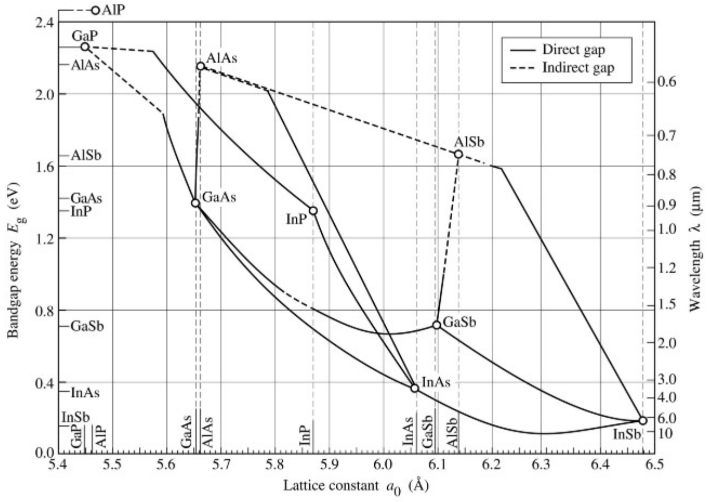
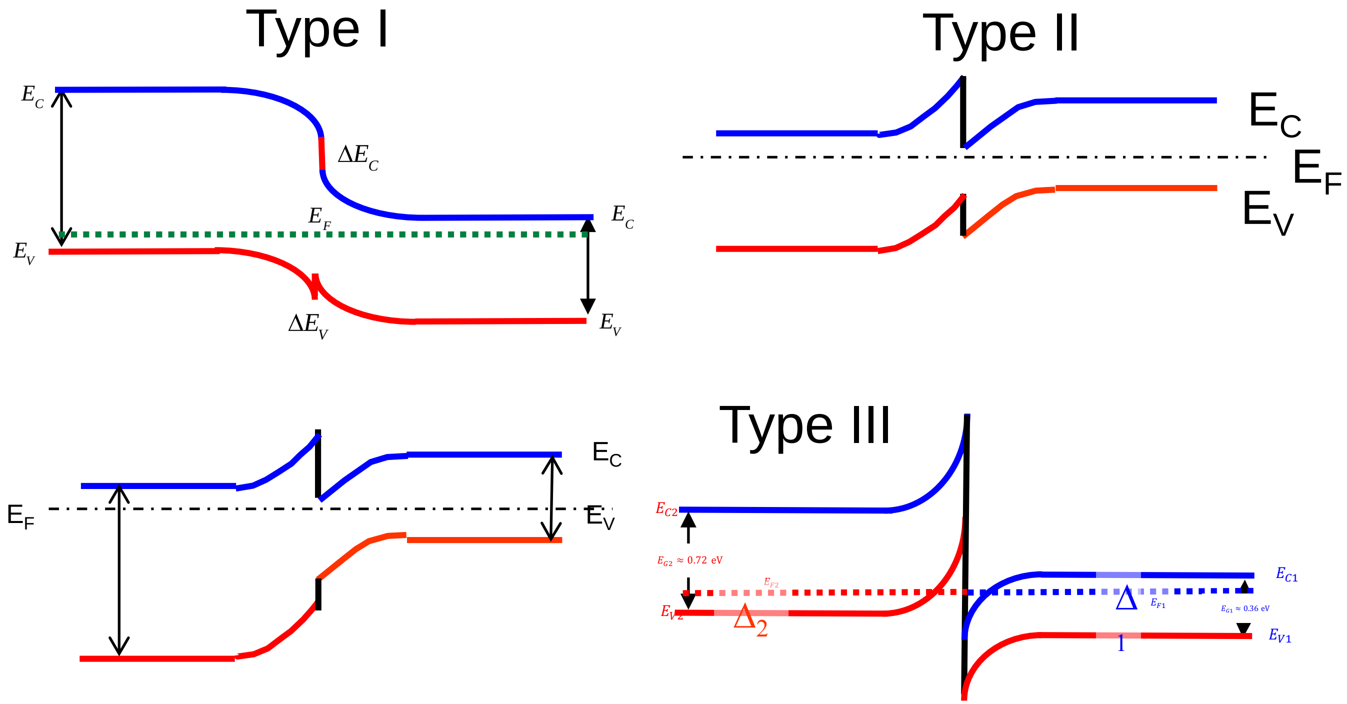


Fig. 7.6. Bandgap energy and lattice constant of various III-V semiconductors at room temperature (adopted from Tien, 1988).



1. HBTs offer a solution to the limitations of poly-Si bipolar transistors.
2. Equilibrium solutions for HBTs are very similar to those of normal BJTs.
3. Depending on the alignment, there could be different types of heterojuctions. Each has different usage.

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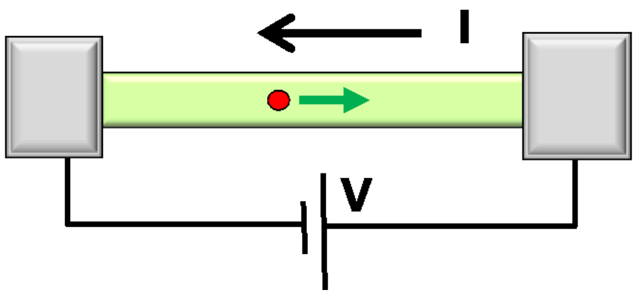


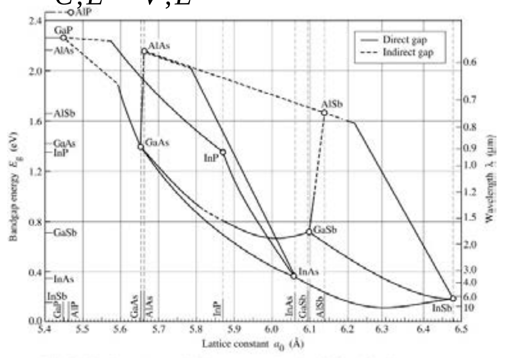
$$I = G \times V$$
$$= q \times n \times v \times A$$

charge density velocity area

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

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

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



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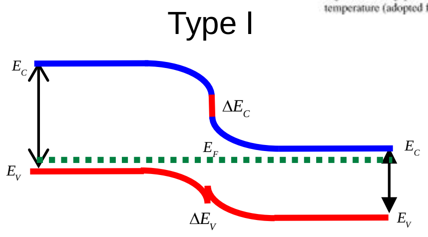

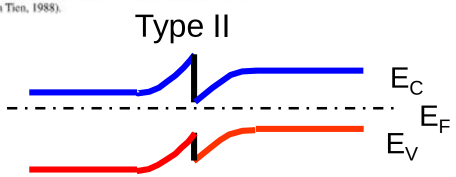

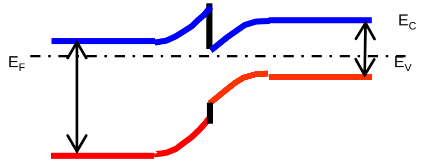

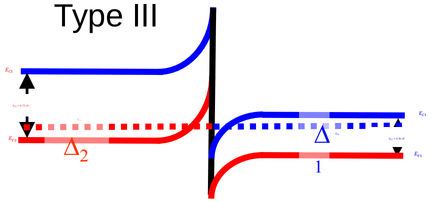

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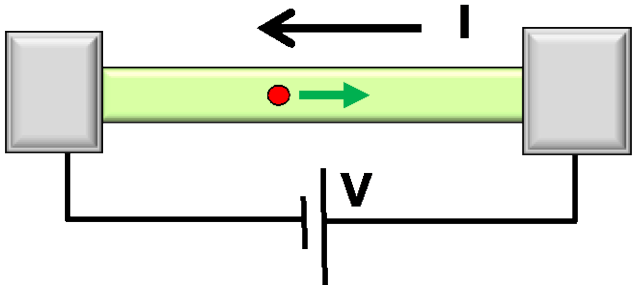

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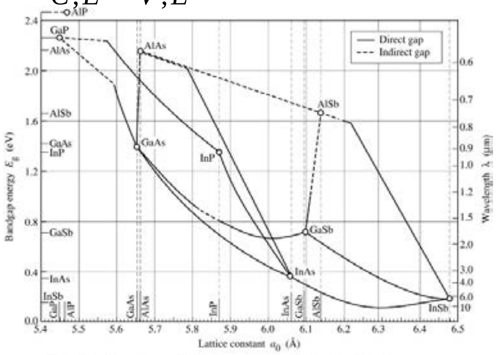

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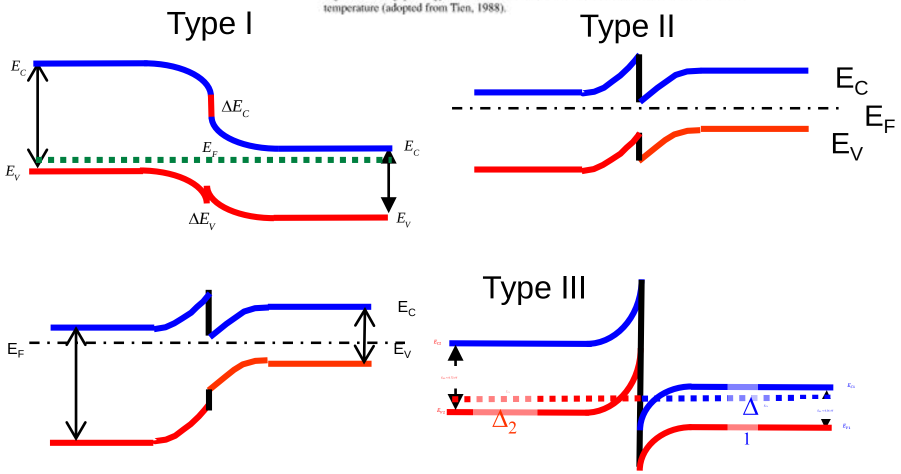

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