Chapter 2

2.1 GaAs:C$_{As}$ — Single acceptor

Si:Se — Double donor

Ge:Cu — Triple acceptor

GaAs:N$_{As}$ — Isoelectronic

GaAs:Cu$_{Ga}$ — Double acceptor

Si:Zn — Double acceptor

ZnO:Al$_{Zn}$ — Single donor

ZnS:Cu$_{Zn}$ — Single acceptor

GaAs:Si$_{Ga}$ — Single donor

2.2 Because Zn is a double acceptor, the net acceptor concentration is $1\times10^{17} - 7\times10^{16}$ cm^{-3} = 3×10^{16} cm^{-3}. It is _p-type_.

2.3 The fraction of occupied donors (_neutral_) is

$$f(E) = \frac{1}{e^{(E-E_F)/kT} + 1} = \frac{1}{e^{-1.0} + 1} = \underline{0.731}$$

The fraction of unoccupied donors (_positive_) is $\underline{0.269}$.

2.4 $N_d = 3\times10^{16}$ cm^{-3}

$N_a = 8\times10^{16}$ cm^{-3}

(a) $[N_d^+] = [N_a^-] = \underline{3\times10^{16}}$ cm^{-3}

(b) _p-type_

2.5 $N_d = 5\times10^{16}$ cm^{-3}

$N_a = 1\times10^{16}$ cm^{-3}

The donor binding energy is 40 meV.

(a) $[N_d^+] = \underline{1\times10^{16}}$ cm^{-3}

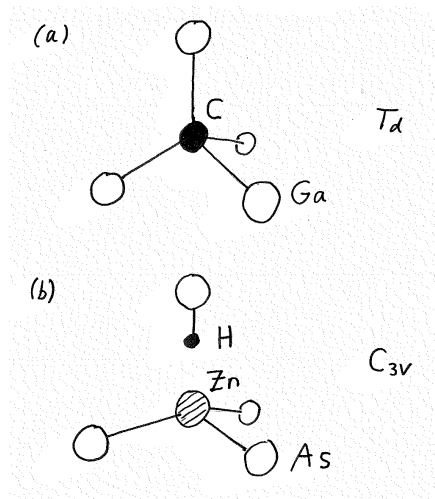(b) $[N_a^-] = \underline{1\times10^{16}}$ cm^{-3}

(c) Fermi level is at the donor level, _40 meV below the conduction-band minimum_.

2.6 Compensation: Donors give electrons to acceptors. Example: Si_{Ga} donors compensate C_{As} acceptors in GaAs.

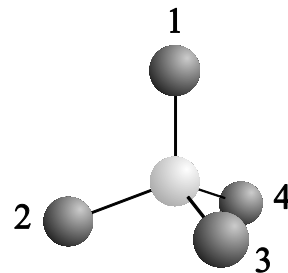Passivation: An impurity such as hydrogen forms a neutral complex with a donor/acceptor. Example: Hydrogen passivates the boron acceptor in silicon.

2.7 (a) Carbon acceptor in GaAs, (b) zinc-hydrogen complex in GaAs:

2.8 Threefold rotations

"1" axis: $(1,2,3,4) \rightarrow (1,4,2,3)$

$\rightarrow (1,3,4,2)$

"2" axis: $\rightarrow (3,2,4,1)$

$\rightarrow (4,2,1,3)$

"3" axis: $\rightarrow (4,1,3,2)$

$\rightarrow (2,4,3,1)$

"4" axis: $\rightarrow (2,3,1,4)$

$\rightarrow (3,1,2,4)$

Twofold rotations

Axis bisecting 1,4: $\rightarrow (4,3,2,1)$

Axis bisecting 1,3: $\rightarrow (3,4,1,2)$

Axis bisecting 1,2: $\rightarrow (2,1,4,3)$

Reflections

1-4 plane:	$\rightarrow$ (1,3,2,4)
1-3 plane:	$\rightarrow$ (1,4,3,2)
1-2 plane:	$\rightarrow$ (1,2,4,3)
2-3 plane:	$\rightarrow$ (4,2,3,1)
3-4 plane:	$\rightarrow$ (2,1,3,4)
2-4 plane:	$\rightarrow$ (3,2,1,4)

<u>Improper rotations</u>

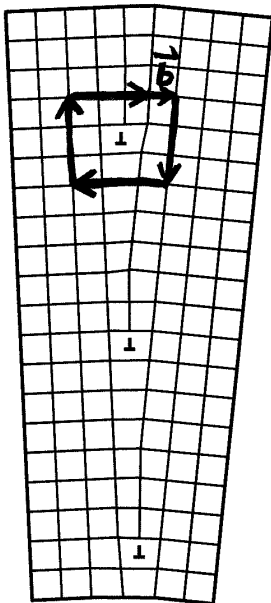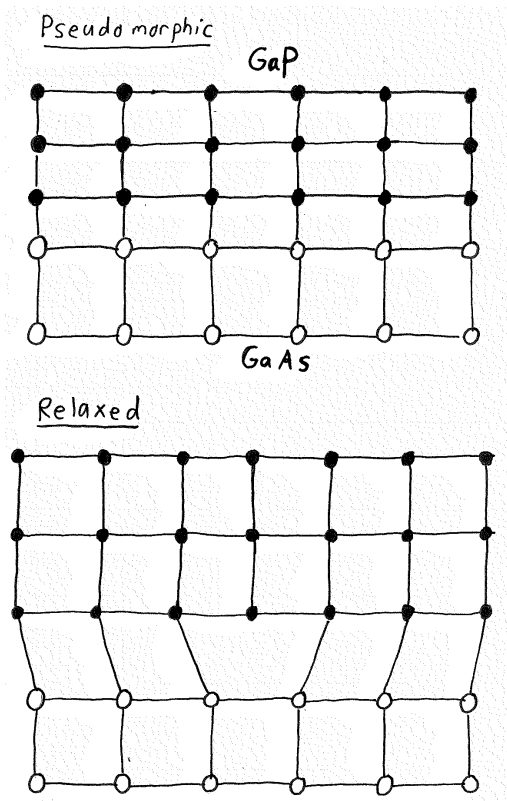| Axis bisecting 1,4: | $\rightarrow$ (3,1,4,2) |
	$\rightarrow$ (2,4,1,3)
Axis bisecting 1,3:	$\rightarrow$ (2,3,4,1)
	$\rightarrow$ (4,1,2,3)
Axis bisecting 1,2:	$\rightarrow$ (4,3,1,2)
	$\rightarrow$ (3,4,2,1)

2.9 Burgers circuit and Burgers vector:

2.10 Ratio of the lattice constants = 5.65/5.45 = 1.0367.

(a) (The lattice constant difference has been exaggerated for clarity)

Pseudomorphic

GaP

GaAs

Relaxed

(b) Over n lattice constants, the two materials are in registry.

$5.65(n - 1) = 5.45n$

$0.2n = 5.65$

$n = 28$

$5.45n = 153$ Å. There is 1 dislocation in this interval.

1 dislocation $/ (1.53 \times 10^{-8} \text{ cm})^2 = \underline{4 \times 10^{11} \text{ cm}^{-2}}$