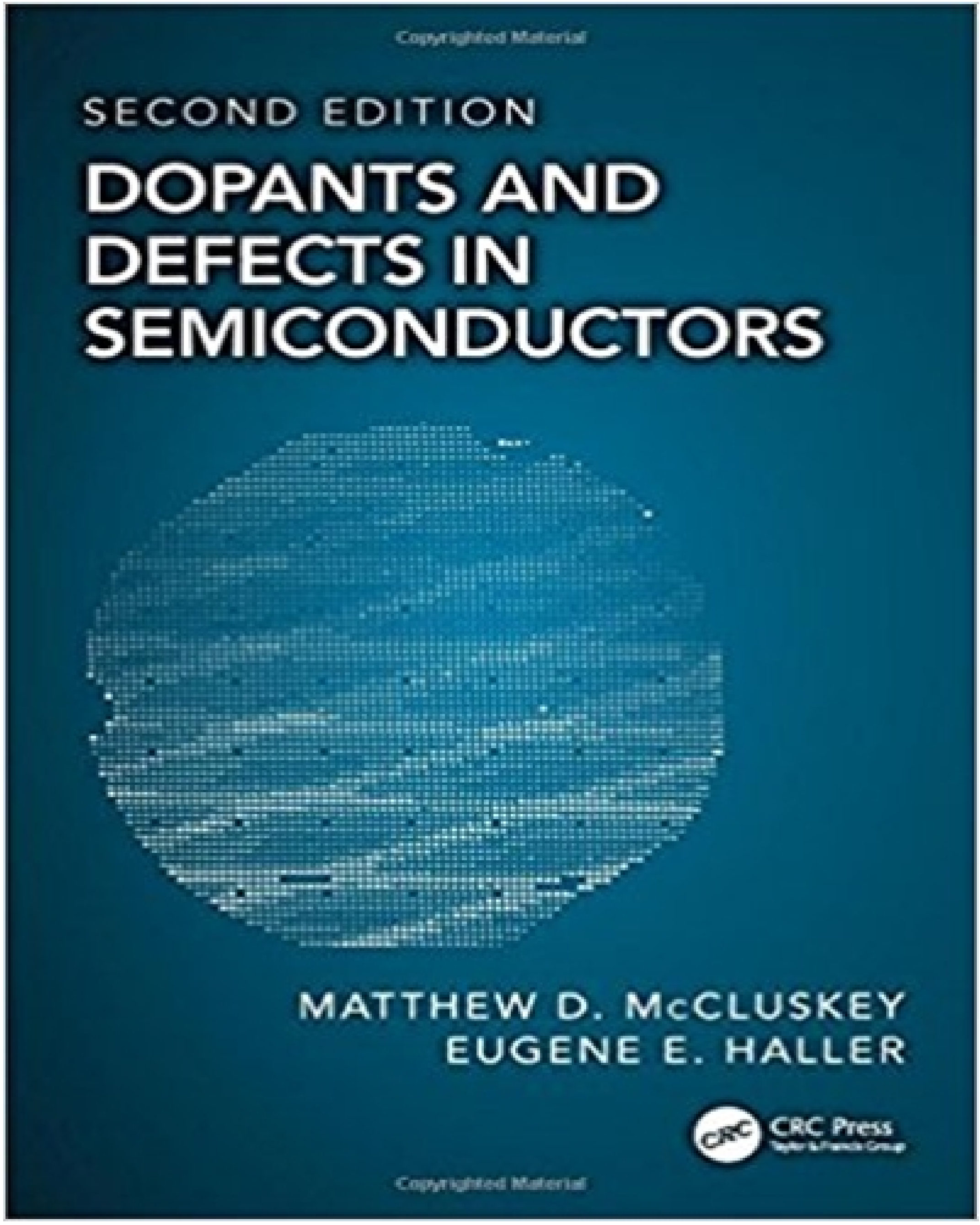
Solutions for Dopants and Defects in Semiconductors 2nd Edition by McCluskey



Solutions

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 0.269.

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

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

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

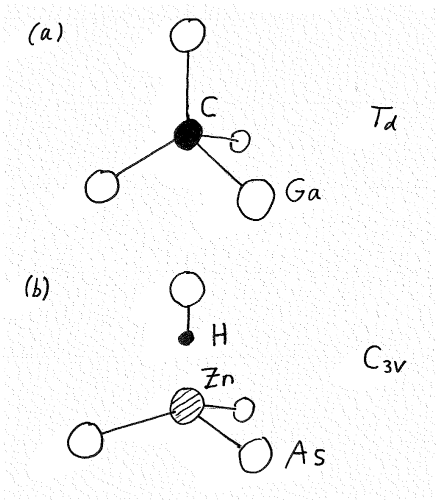
(b) $[N_a^-] = 1\times10^{16}$ cm^{-3}

(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) → (1,4,2,3)

→ (1,3,4,2)

"2" axis: → (3,2,4,1)

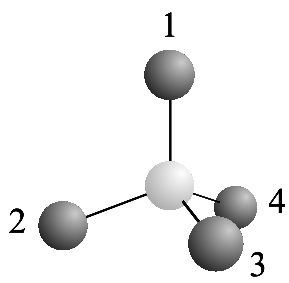
→ (4,2,1,3)

"3" axis: → (4,1,3,2)

→ (2,4,3,1)

"4" axis: → (2,3,1,4)

→ (3,1,2,4)



Twofold rotations

Axis bisecting 1,4: → (4,3,2,1)

Axis bisecting 1,3: → (3,4,1,2)

Axis bisecting 1,2: → (2,1,4,3)

Reflections

1-4 plane: → (1,3,2,4)

1-3 plane: → (1,4,3,2)

1-2 plane: → (1,2,4,3)

2-3 plane: → (4,2,3,1)

3-4 plane: → (2,1,3,4)

2-4 plane: → (3,2,1,4)

Improper rotations

Axis bisecting 1,4: → (3,1,4,2)

→ (2,4,1,3)

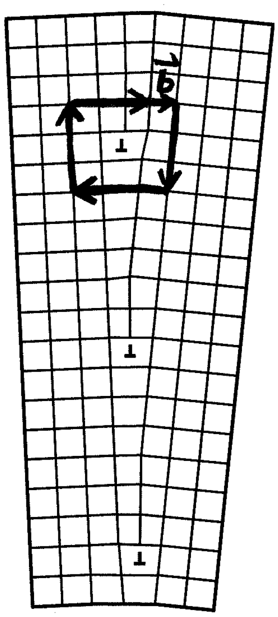
Axis bisecting 1,3: → (2,3,4,1)

→ (4,1,2,3)

Axis bisecting 1,2: → (4,3,1,2)

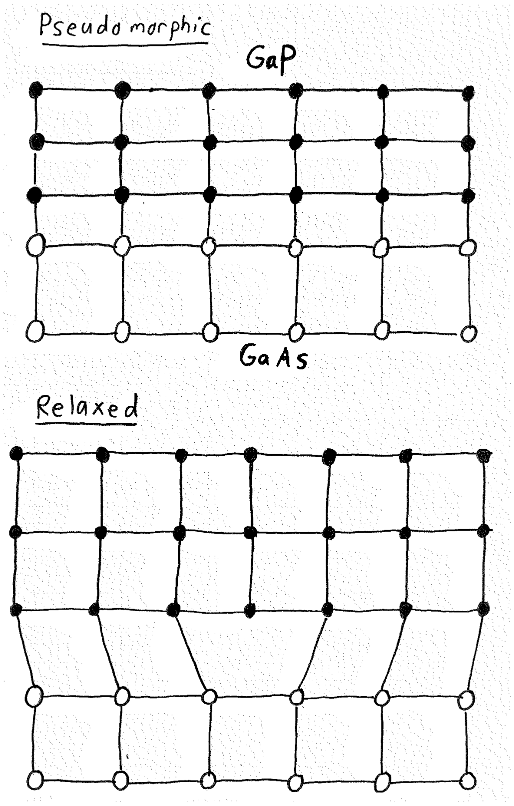
→ (3,4,2,1)

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)



(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 / $(1.53\times10^{-8}\text{ cm})^2$ = $\underline{4\times10^{11}\text{ cm}^{-2}}$