# *Dopants and Defects in Semiconductors 2nd edition McCluskey Solutions Manual*

SKU: 9781138035195-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$^{-3}$ = $3\times10^{16}$ cm$^{-3}$. It is *p*-type.

**2.3** The fraction of occupied donors (neutral) is

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

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.

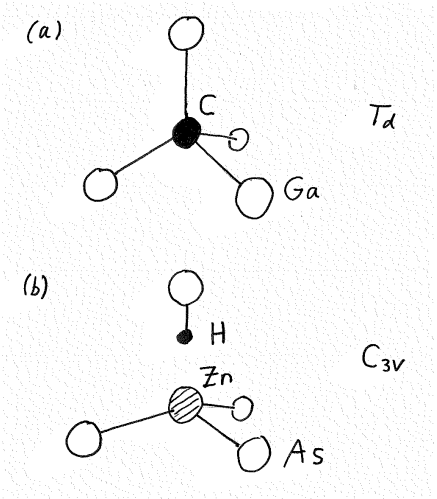


Dopants and Defects in Semiconductors 2nd edition McCluskey Solutions Manual

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

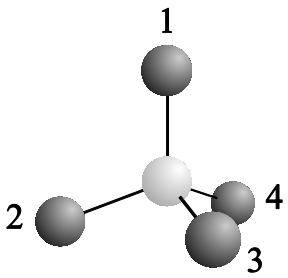
Passivation: An impurity such as hydrogen forms a neutral complex with a donor/acceptor. Example: Hydrogen passivates the boron acceptor in silicon.

**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



Dopants and Defects in Semiconductors 2nd edition McCluskey Solutions Manual

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)

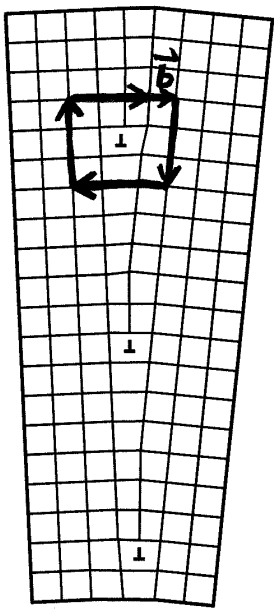
Axis bisecting 1,3: → (2,3,4,1)

→ (4,1,2,3)

Axis bisecting 1,2: → (4,3,1,2)

→ (3,4,2,1)

**2.9** Burgers circuit and Burgers vector:

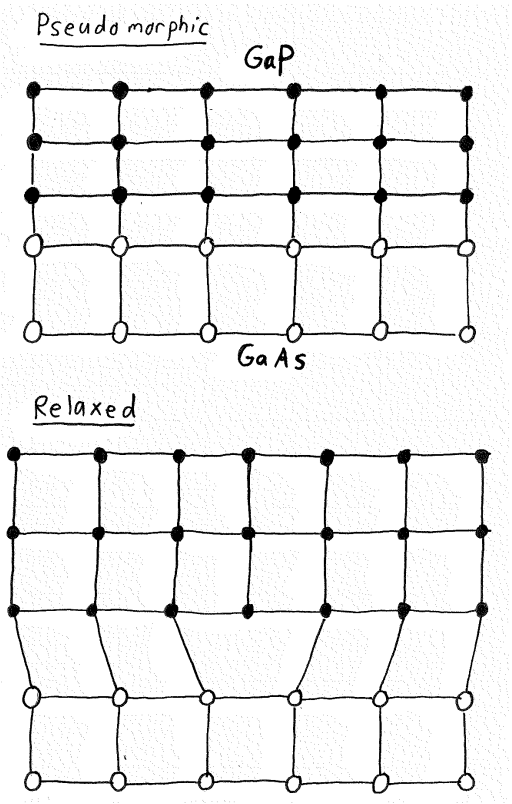



**2.10** Ratio of the lattice constants = 5.65/5.45 = 1.0367.

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



Dopants and Defects in Semiconductors 2nd edition McCluskey Solutions Manual




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



Dopants and Defects in Semiconductors 2nd edition McCluskey Solutions Manual