

1.4 (a) The lattice constant of GaAs is 5.65 Å. Determine the number of Ga atoms and As atoms per cm³. (b) Determine the volume density of germanium atoms in a germanium semiconductor. The lattice constant of germanium is 5.65 Å.

- Also, calculate the mass density of a) GaAs and b) Ge.

a) GaAs has the zincblende lattice (similar to diamond lattice)

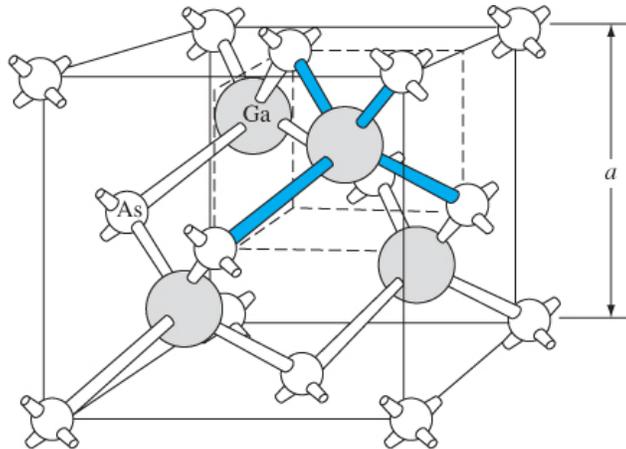


Figure 1.14 | The zincblende (sphalerite) lattice of GaAs.

From Fig 1.14, there are 4 Ga atoms in the lattice (all inside).

$$\begin{aligned} \text{Ga \# density} &= avd_{\text{Ga}} = 4 \text{ atoms} / a^3 = 4 / (5.65 \times 10^{-10} \text{ m})^3 = 2.21776 \times 10^{28} \text{ atoms/m}^3 \\ &\Rightarrow \underline{avd_{\text{Ga}} = 2.21776 \times 10^{22} \text{ atoms/cm}^3} \end{aligned}$$

From Fig 1.14, the number of As atoms in the lattice is

$$\begin{aligned} \# \text{ As} &= 8 \text{ corners} (1/8 \text{ As/corner}) + 6 \text{ faces} (1/2 \text{ As/corner}) = 4 \text{ As atoms.} \\ \text{As \# density} &= avd_{\text{As}} = 4 \text{ atoms} / a^3 = 4 / (5.65 \times 10^{-10} \text{ m})^3 = 2.21776 \times 10^{28} \text{ atoms/m}^3 \\ &\Rightarrow \underline{avd_{\text{As}} = 2.21776 \times 10^{22} \text{ atoms/cm}^3} \end{aligned}$$

From the period table in Appendix C, the atomic mass of Ga is 69.72 and the atomic mass of As is 74.91.

$$\begin{aligned} \text{mass density of GaAs} &= md_{\text{GaAs}} = [avd_{\text{Ga}} (\text{Ga atomic mass}) + avd_{\text{As}} (\text{As atomic mass})] / N_A \\ md_{\text{GaAs}} &= [2.21776 \times 10^{22} \text{ \#/cm}^3 (69.72) + 2.21776 \times 10^{22} \text{ \#/cm}^3 (74.91)] / 6.02214076 \times 10^{23} \\ &\Rightarrow \underline{md_{\text{GaAs}} = 5.326 \text{ g/cm}^3} \end{aligned}$$

For comparison, Table B.4 in Appendix B gives a mass density value of 5.32 g/cm³.

b) Ge has a diamond lattice

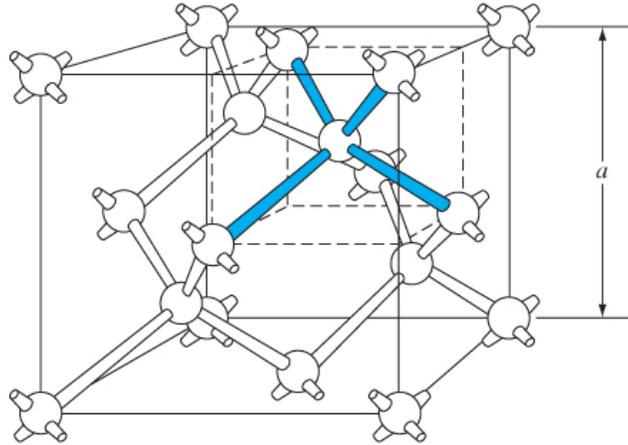


Figure 1.11 | The diamond structure.

From Fig 1.11, the number of Ge atoms is

$$\# \text{ Ge} = 4 \text{ Ge inside} + 8 \text{ corners (1/8 Ge/corner)} + 6 \text{ faces (1/2 Ge/corner)} = 8 \text{ Ge atoms.}$$

$$\text{Ge \# density} = avd_{\text{Ge}} = 8 \text{ atoms} / a^3 = 8 / (5.65 \times 10^{-10} \text{ m})^3 = 4.4355 \times 10^{28} \text{ atoms/m}^3$$

$$\Rightarrow \underline{avd_{\text{Ge}} = 4.4355 \times 10^{22} \text{ atoms/cm}^3}$$

From the period table in Appendix C, the atomic mass of Ge is 72.60.

$$\text{mass density of Ge} = md_{\text{Ge}} = avd_{\text{Ge}} (\text{Ge atomic mass}) / N_A$$

$$md_{\text{Ge}} = 4.4355 \times 10^{22} \#/\text{cm}^3 (72.60) / 6.02214076 \times 10^{23} \Rightarrow \underline{md_{\text{Ge}} = 5.347 \text{ g/cm}^3}$$

For comparison, Table B.4 in Appendix B gives a mass density value of **5.33 g/cm³**.