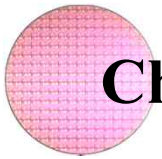

Chapter 1.

Semiconductors: A General Introduction

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Syllabus

Contents

- General Material Properties
- Crystal Structure

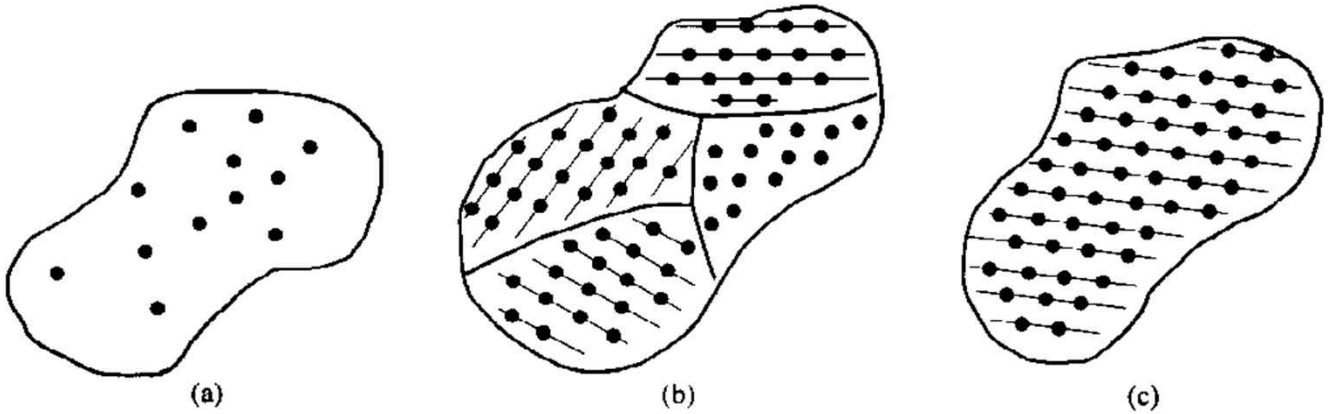
❑ General Material Properties

✓ Examine the general nature of semiconductor materials
✓ Conductivity : insulator → semiconductor → metal

• Composition
✓ Elemental semiconductor: group IV (Si, Ge)
✓ Compound semiconductor: group III & V (or II & VI) (GaAs, ZnSe, and alloys like $Al_xGa_{1-x}As$
✓ Si : the most important of the semiconductors → major ICs including CPU
✓ GaAs : superior electron transport properties and special optical properties → laser diode, LED, and high speed ICs
✓ Binary : two elements
✓ Ternary : three elements

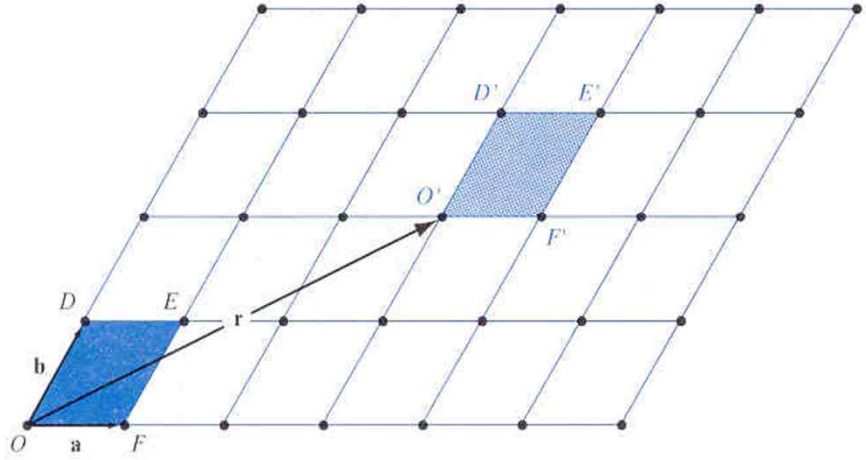
- Purity
  - ✓ Dopants can have a drastic effect on the electrical properties of semiconductors
  - ✓ Typically, dopant atoms at levels ranging from one part per 10^8 to one impurity atom per 10^3 semiconductor atoms will be purposely added to the semiconductor to control its electrical properties

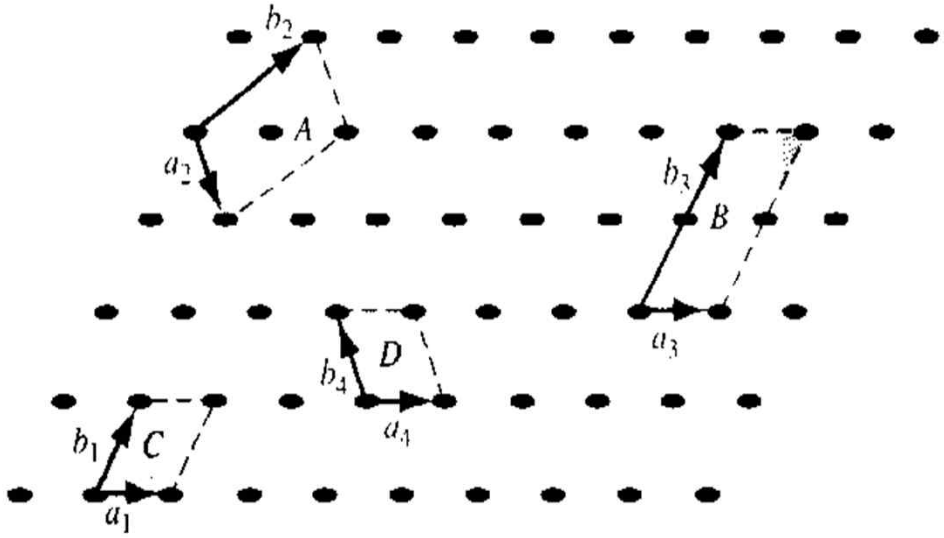
- Structure
  - ✓ Amorphous
  - ✓ Polycrystalline : grain, grain boundary
  - ✓ Single crystal : electrical properties are superior



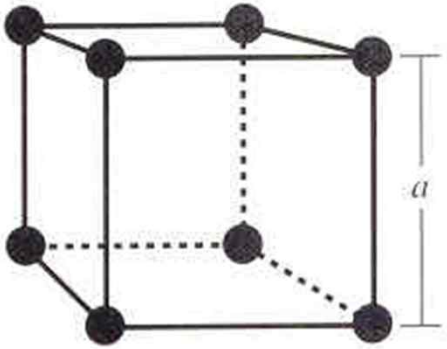
❑ Crystal Structure

- The Unit Cell Concept
  - ✓ Lattice = periodic arrangement of atoms in the crystal
  - ✓ Lattice point = a dot which represents a particular atomic array
  - ✓ Unit Cell = a small volume of the crystal that can be used to reproduce the entire crystal
  - ✓ Primitive cell = the smallest unit cell that can be repeated to from the lattice

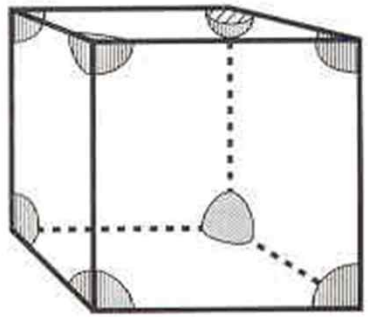




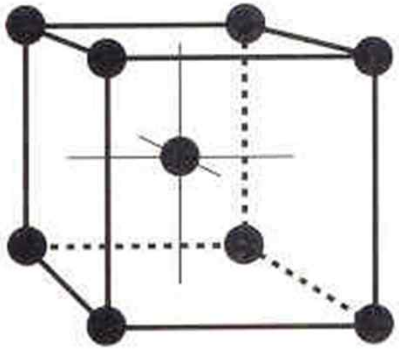
- Simple 3-D Unit Cells
  - ✓ simple cubic = sc, body-centered cubic = bcc, face-centered cubic = fcc



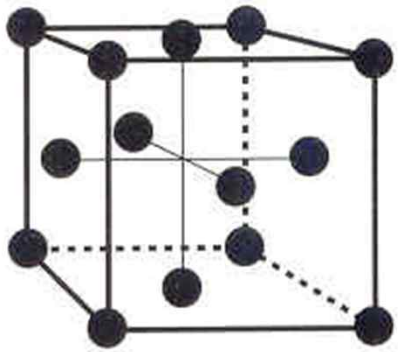
(a) Simple cubic



(b) Pedantically correct simple cubic

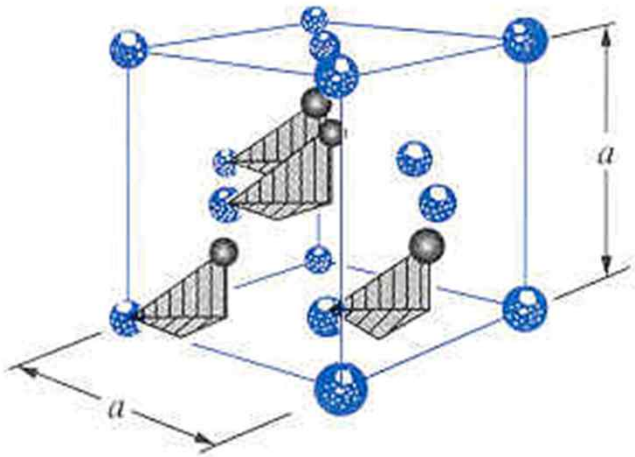


(c) bcc

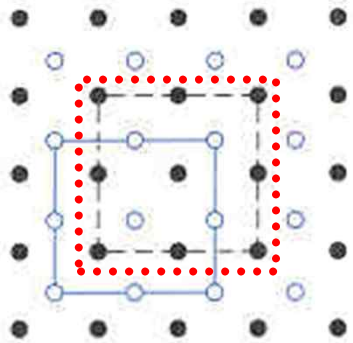


(d) fcc

- Semiconductor Lattices
  - ✓ The diamond structure



(a)

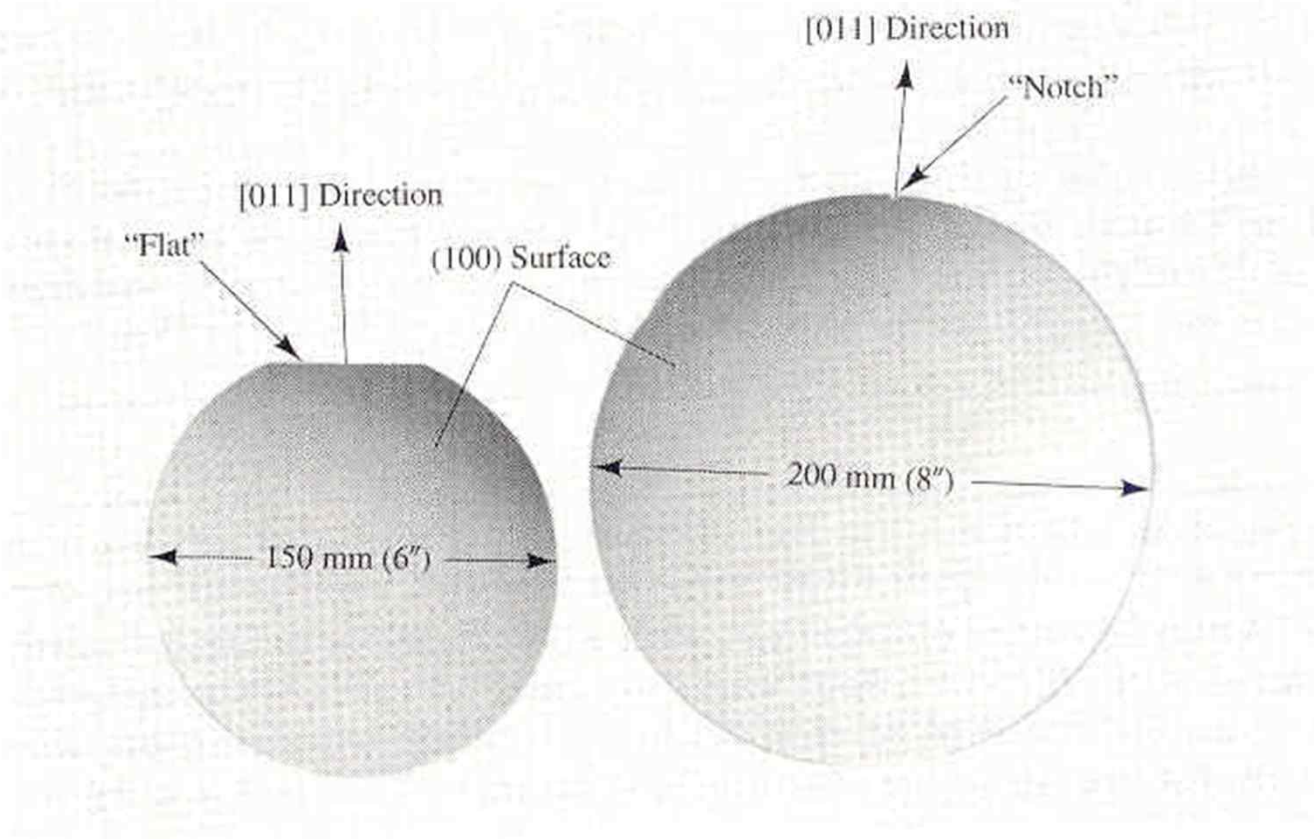


(b)

For Si,
8 atoms in a cell
a=5.43 Å
(1 Å =10^{-8} cm)
$8/a^3=5.22\times10^{22}$ cm^{-3}

(a) A unit cell of the diamond lattice constructed by placing atoms ¼, ¼, ¼ from each atom in an fcc; (b) top view (along any <100> direction) of an extended diamond lattice. The colored circles indicate one fcc sublattice and the black circles indicate the interpenetrating fcc.

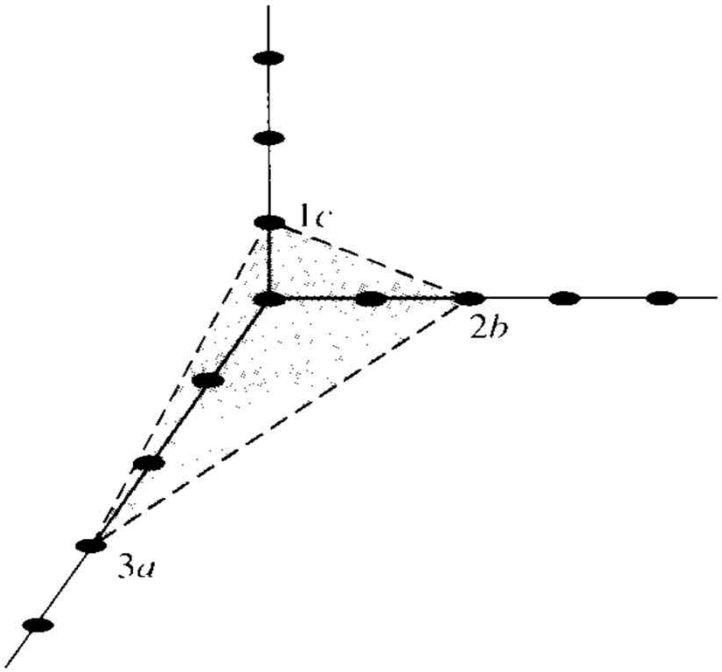
- Miller Indices



Single crystal silicon wafers (6” and 8”) typical of the starting substrates

✓ Indexing procedure:

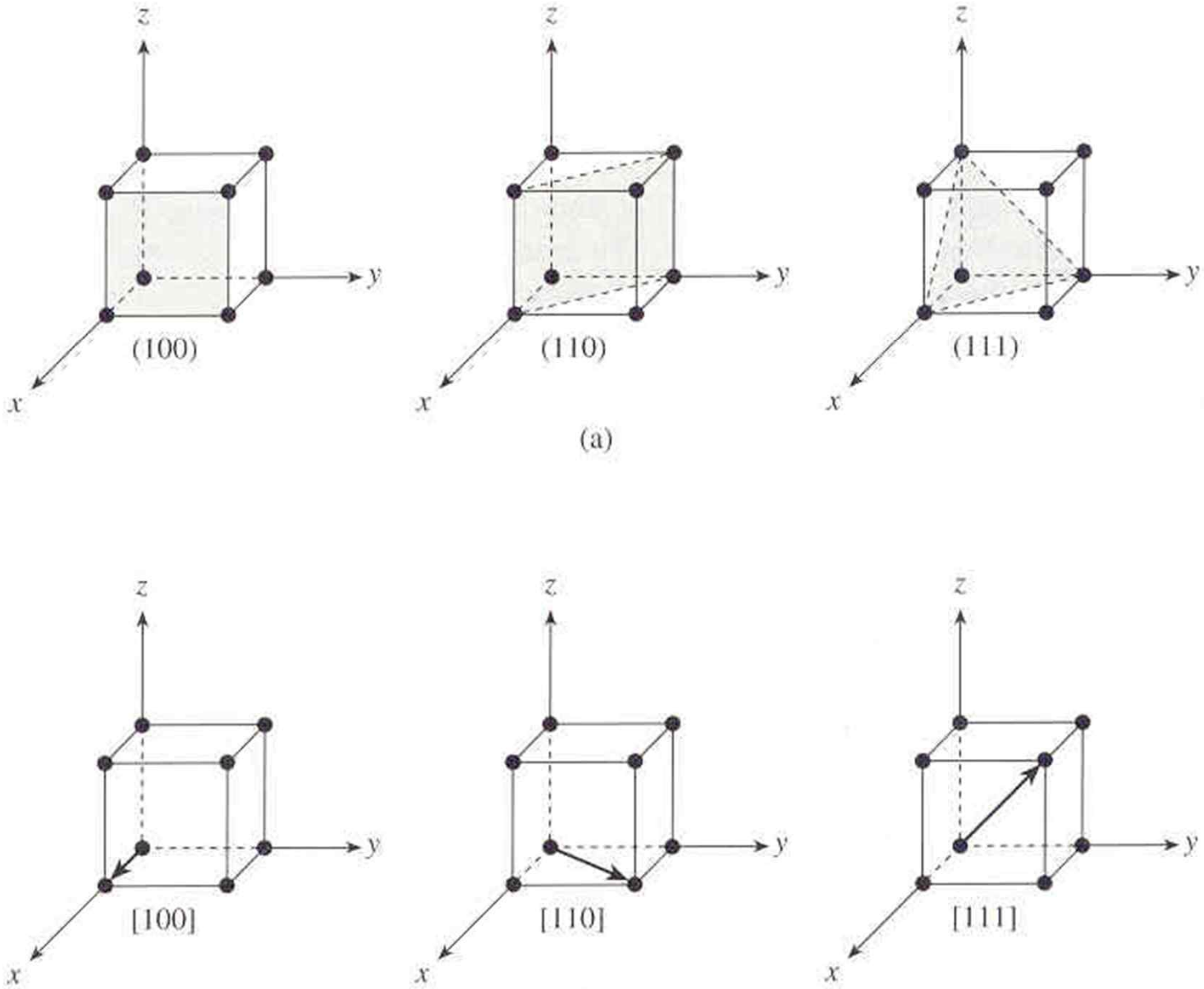
Intercept set in the order x, y, z
Invert the intercept values
Convert the 1/intercept set to the smallest possible set of whole numbers
Enclose the whole number set in curvilinear brackets



p=3, q=2, s=1

$\left(\frac{1}{3},\frac{1}{2},1\right) \rightarrow (236)$ plane

Miller indices


z
y
x
(100)
(110)
(111)
(a)
[100]
[110]
[111]
(b)

Summary