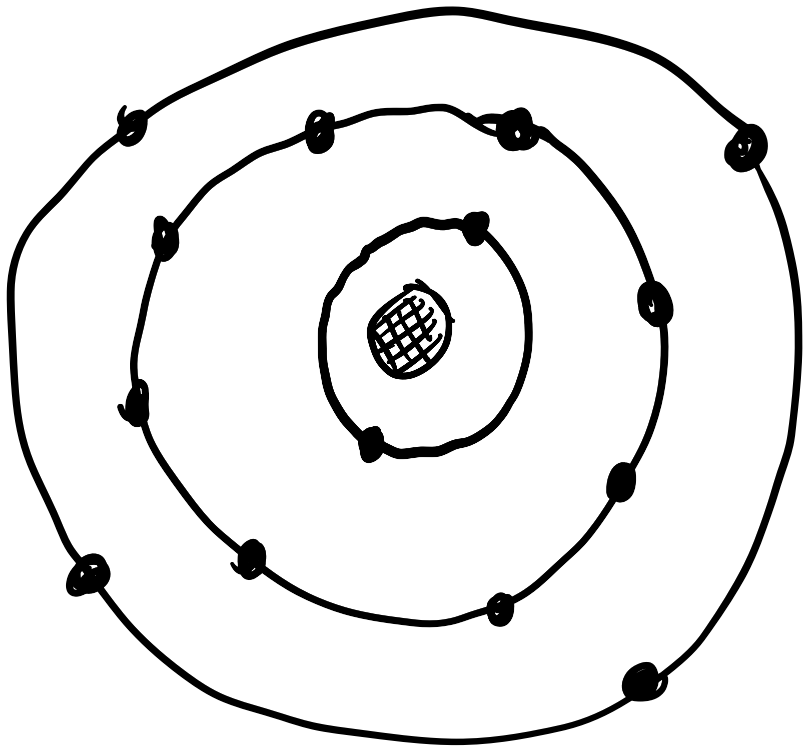
PHYS 231 - Nov. 20, 2023

Semiconductors

Most semiconductor materials are made from Si. Si is 14th element in the periodic table. ⇒ 14 electrons.



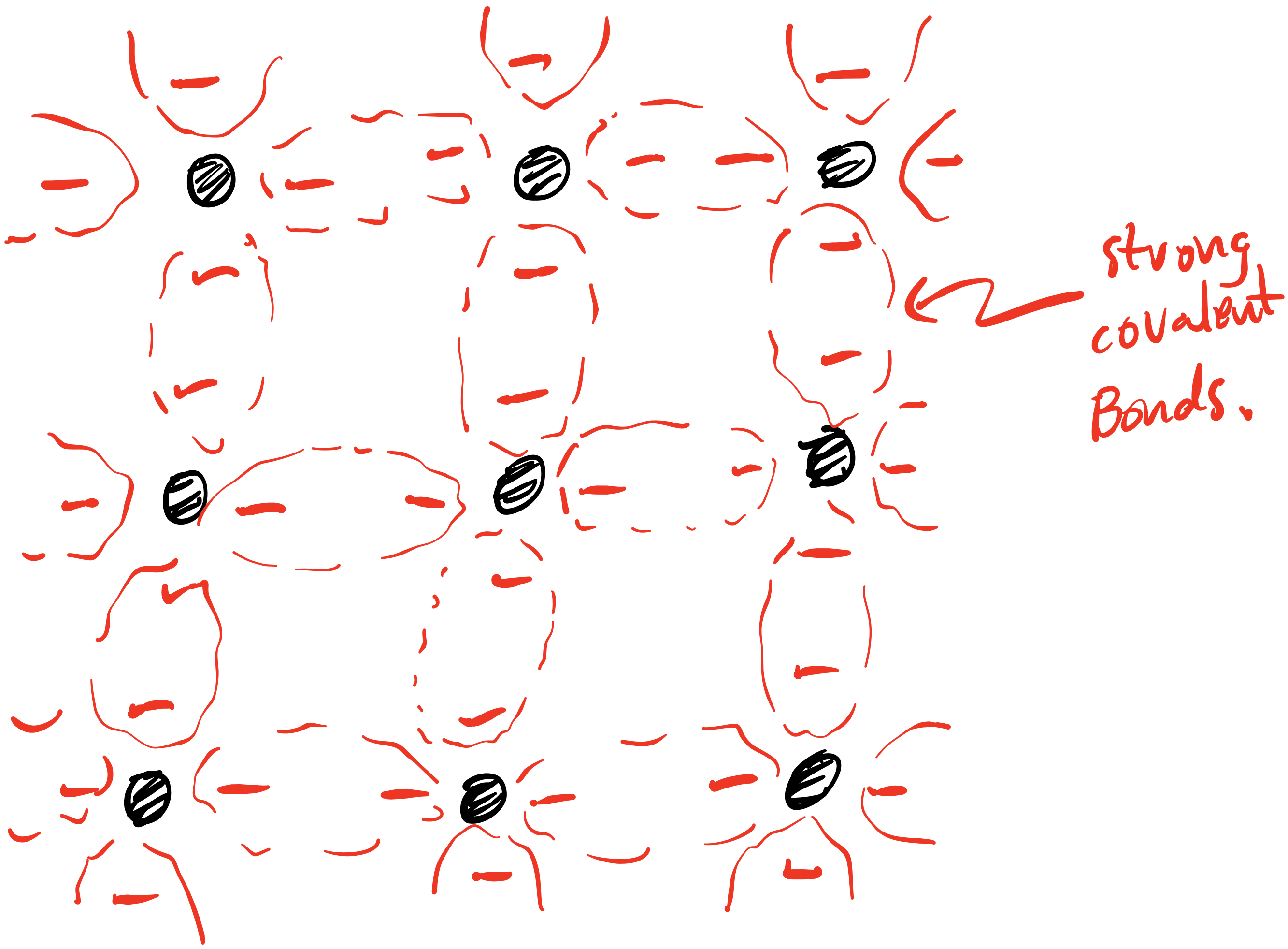
Nucleus has 14 protons & 14 neutrons → charge +14.

Electron configuration of Si

$$1s^2 2s^2 2p^6 3s^2 3p^2$$

Room for 4 more electrons in 3p orbital. → Outer or valence shell is only partially filled.

2-D representation of a piece of solid Si



Charge +4

↳ ⊘ ← represents Si nucleus + 10 "core" electrons in inner shells.

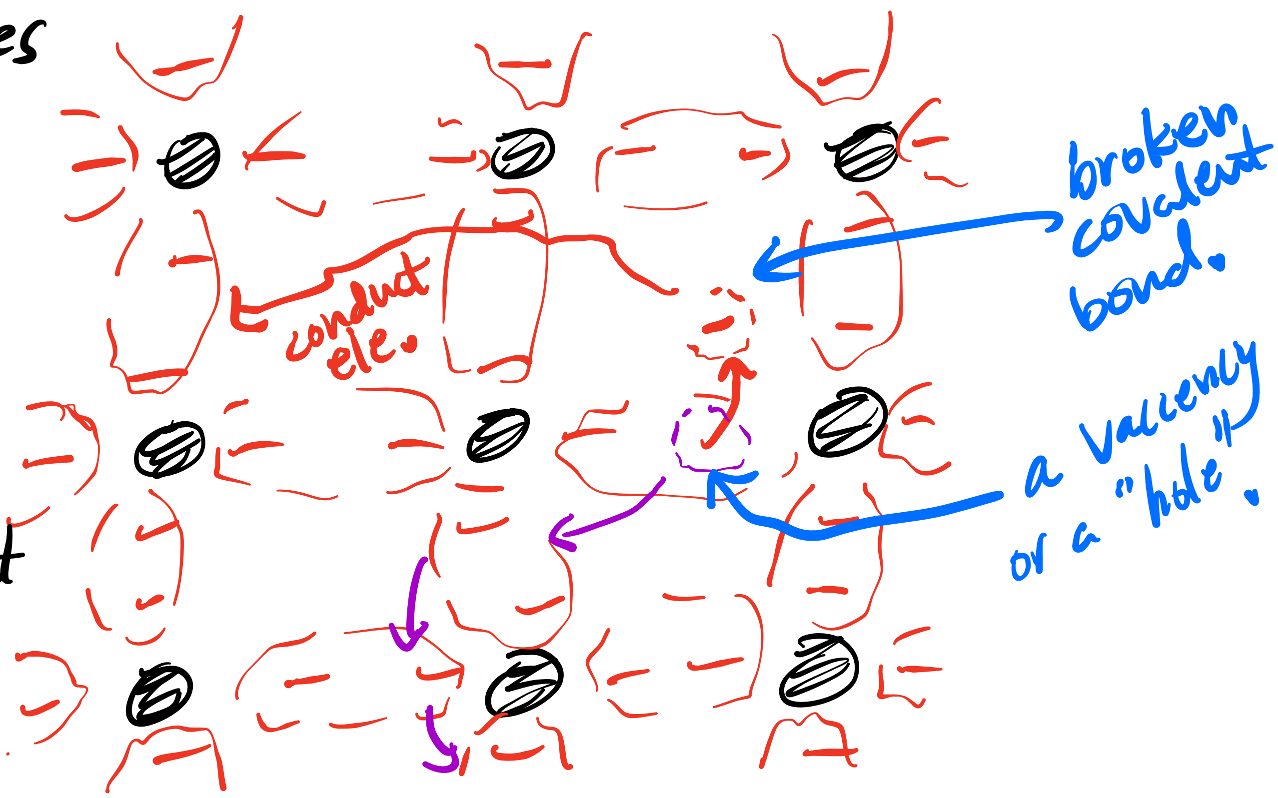
Most valence e^- in Si participating in covalent bonds. No mobile charge available to conduct electricity.

Can create mobile charges by heating Si. Energy Δ required to break a covalent bond is

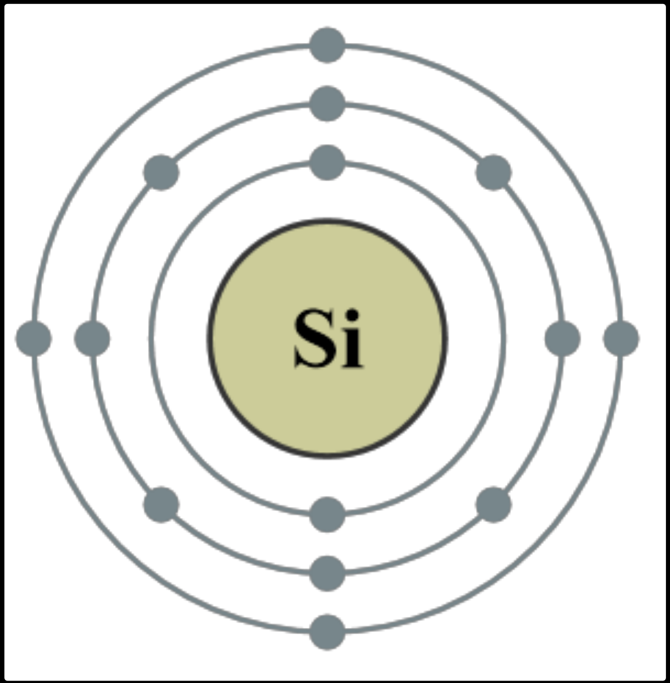
$$\Delta \sim 1.1\,eV = 1.8\times10^{-19}\,J$$

$$\frac{\Delta}{k_B} \approx 12.7\times10^{3}\,K. \quad \left(\begin{matrix}\text{high}\\ \text{temp}\end{matrix}\right).$$

1. Each broken bond creates one mobile electron & one mobile hole.
2. The free e^- & hole can conduct electricity.



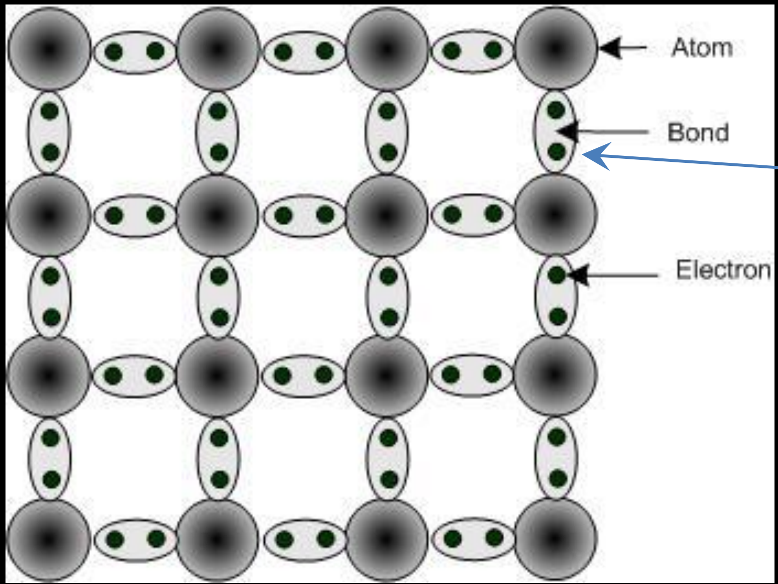
Silicon (Si) and Doping



Silicon electron configuration:

$1s^2 2s^2 sp^6 3s^2 3p^2$

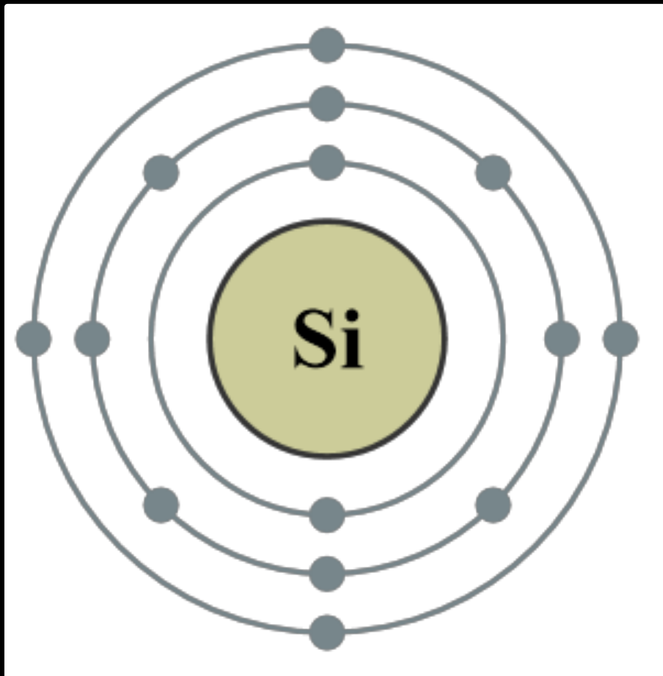
4 valence electrons in 3^{rd} shell



covalent bonds

Since valence most electrons participating in bonds… **relatively poor conductor**

Silicon (Si) and Doping



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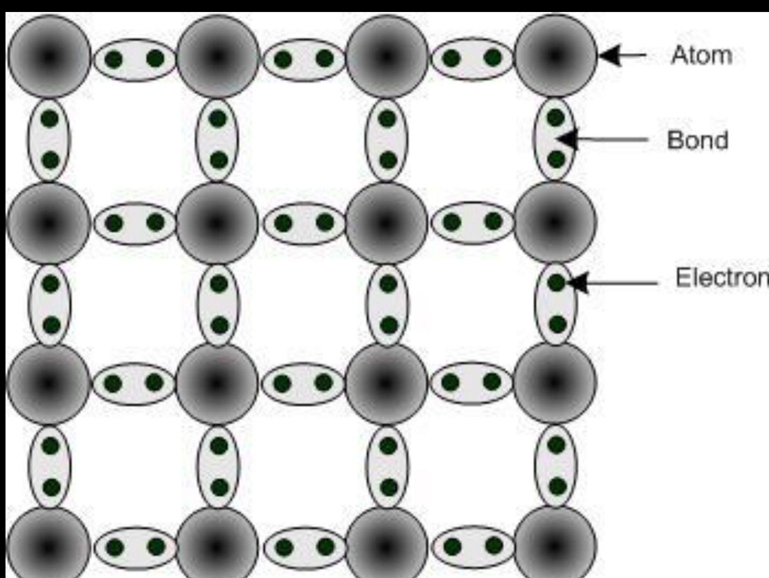
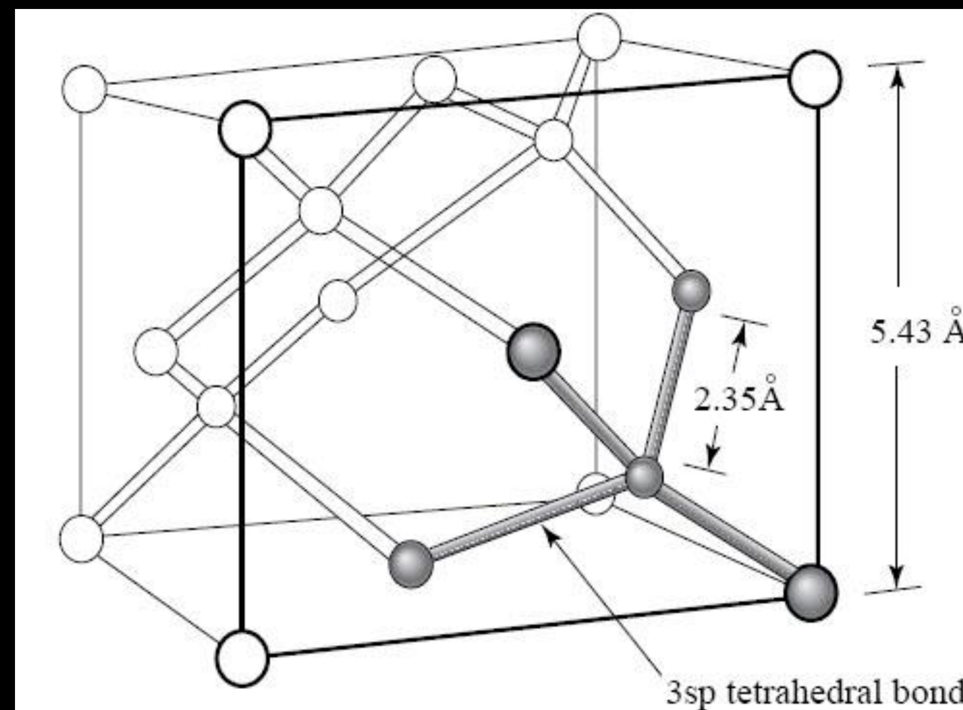


Actual crystal structure of Silicon



Concentration of free e^- & holes at room temp. is very low. ∴ Si is a poor conductor.

We can manipulate the Physical Properties (conductivity) of Si via "doping".

Try to replace an occasional Si atom with something that has either 5 valence e^- or 3 valance e^-.

<u>n-type doping</u> (use dopants w/ 5 valence e^-).

Use P as dopant which has 5 valence electrons. Electron config. of P:

$$1s^2 2s^2 2p^6 3s^2 3p^3$$

Doping concentration typically can vary from 1 dopant per 1000 Si to 1 dopant per 10^9 Si.

Si nucleus + 10 core electrons. Charge +4

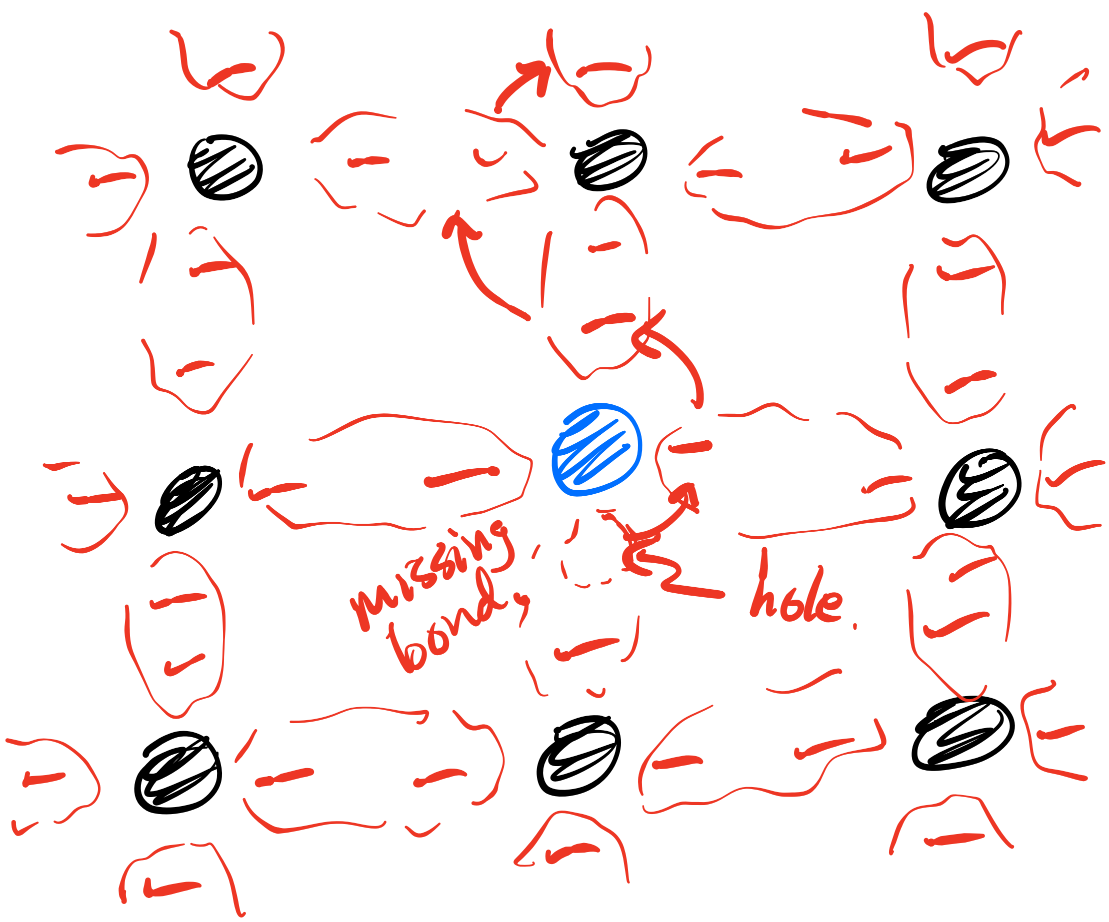
P nucleus + 10 core electrons. Charge +5

The extra valence e^- in the dopant is *not* participating in a covalent bond. It is only weakly attached to the host atom. It is free to move throughout the Si material to conduct electricity.

p-type doping — using a dopant w/ 3 valence electrons.

Eg. dopant is Boron B

Electron config. $1s^2 2s^2 2p^1$



Si nucleus + 10 core e^-. Charge +4

B nucleus + 2 core e^-. Charge +3

Doping is used to introduce "majority" charge carriers. When a covalent bond is broken due to thermal energy, the free e^- & hole that are created are called "minority" charge carriers.

Modern semiconductor devices are made by joining n-type & p-type doped semiconductors w/ a sharp jcn.