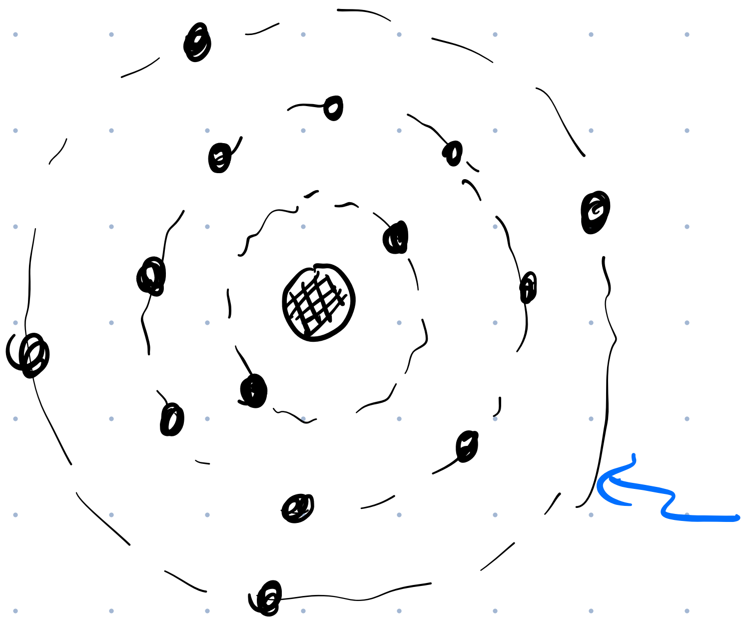
PHYS 231 Nov. 18, 2024

Today: Semiconductor Materials

Most semiconductor materials are Si, Si is 14th element in periodic table ⇒ 14 electron.



Nucleus has 14 protons & 14 neutrons

→ charge +14

Electrons in inner shells are called core electrons.

Electron Configuration of Si

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

shell no.

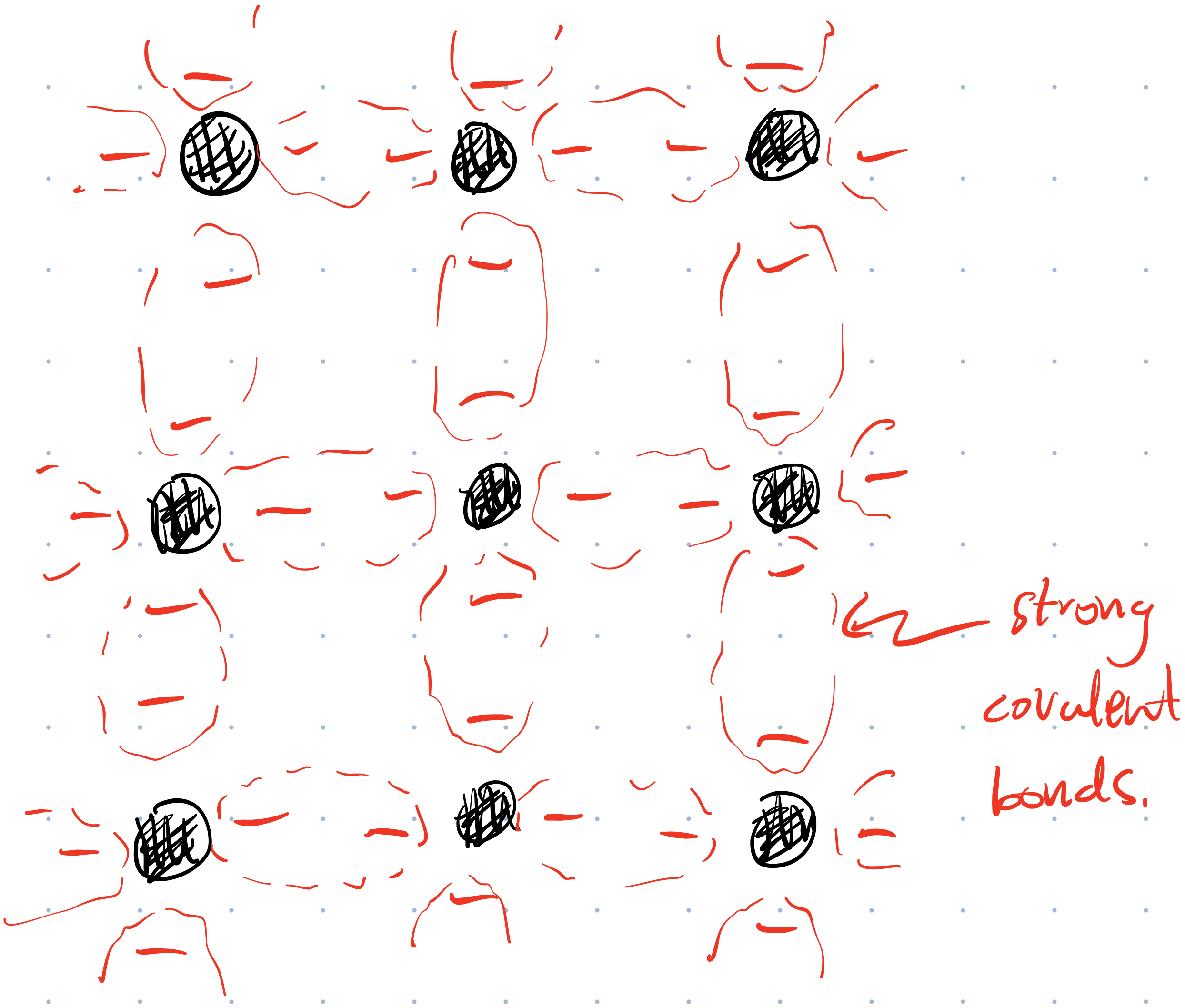
orbital

no. of e^- in the orbital

There is room for 4 more electrons in 3p orbital (it can take 6, but we've only placed 2).

Outer or valence shell is only partially filled.

2-D representation of a piece of solid Si.



● represents Si nucleus + 10 core electrons

← charge +4

Each Si atom in the solid has 4 nearest neighbours.

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

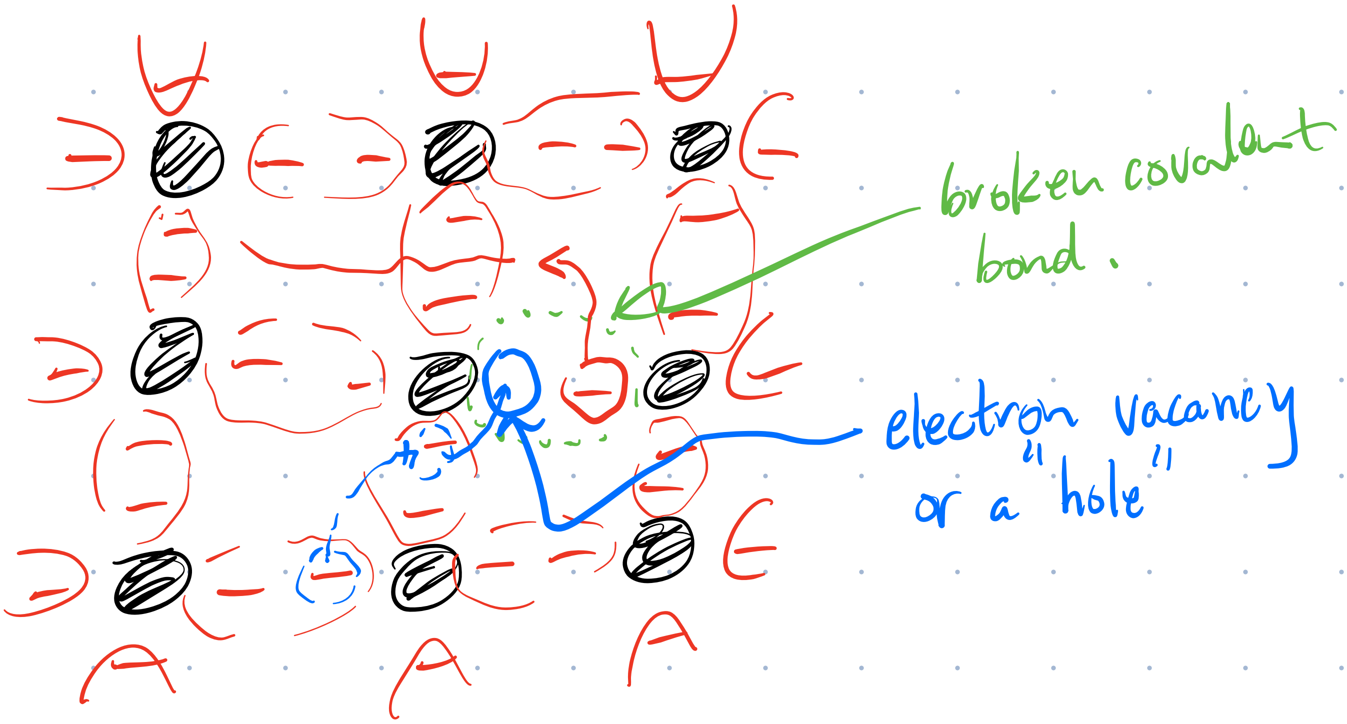
Can create mobile charges by heating Si. Energy Δ required to break a covalent bond is :

$$\Delta \sim 1.1 eV = 1.8 \times 10^{-19} J$$

$$\frac{\Delta}{k_B} \simeq 12.7 \times 10^{3} \quad (\text{high temp}).$$

Since $\frac{\Delta}{k_B} << T_{rm} \approx 300K$, Si is not a good conductor @ room temp.

At room temp. very few covalent bonds break (but more than zero).



1. Each broken bond creates ~~mobile~~ mobile electrons and mobile holes.

2. The mobile e^- & holes can conduct electricity (est. current).

We can manipulate the electronic properties of Si via "doping".

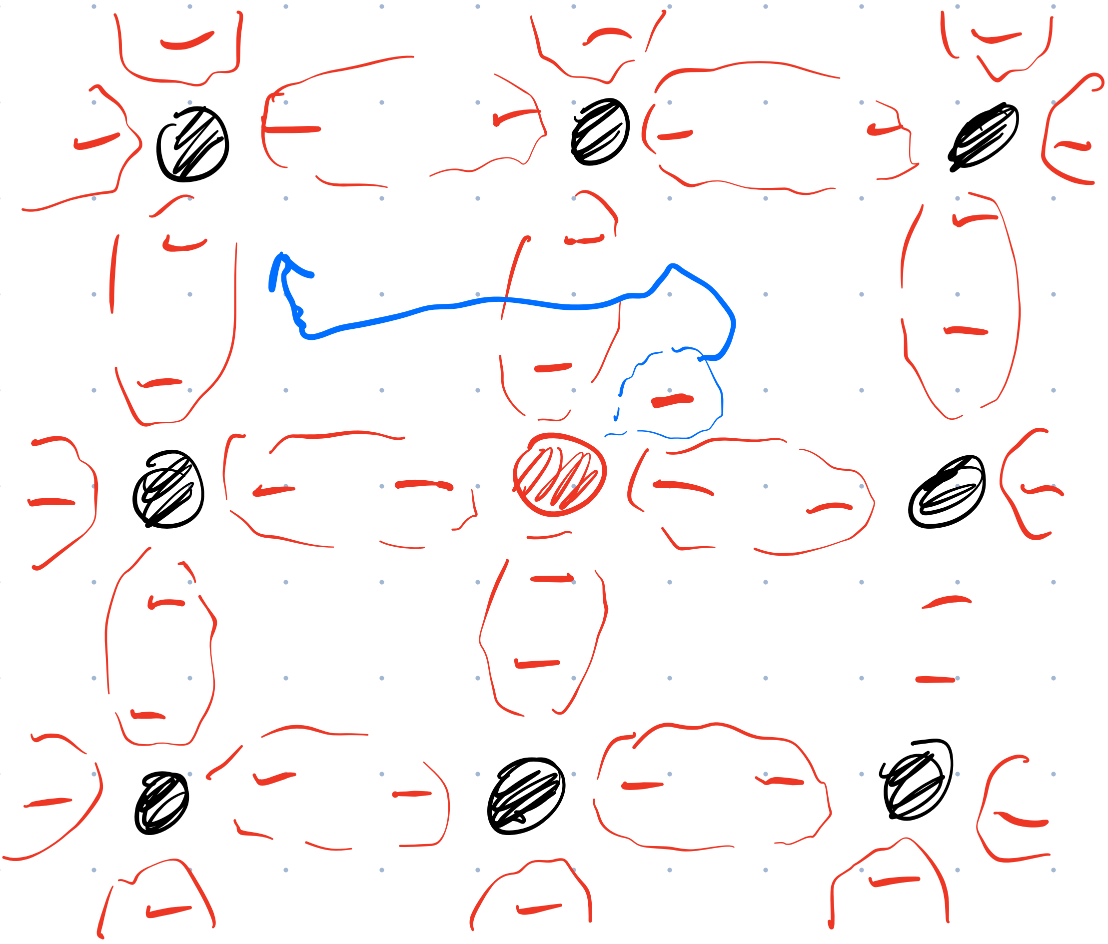
Try to replace an occasional Si atom with something that has either 5 or 3 valence e^-.

n-type doping (use dopant atoms w/ 5 valence e^-).
(electron doping)

Use P as dopant which has 5 valence e^-.
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

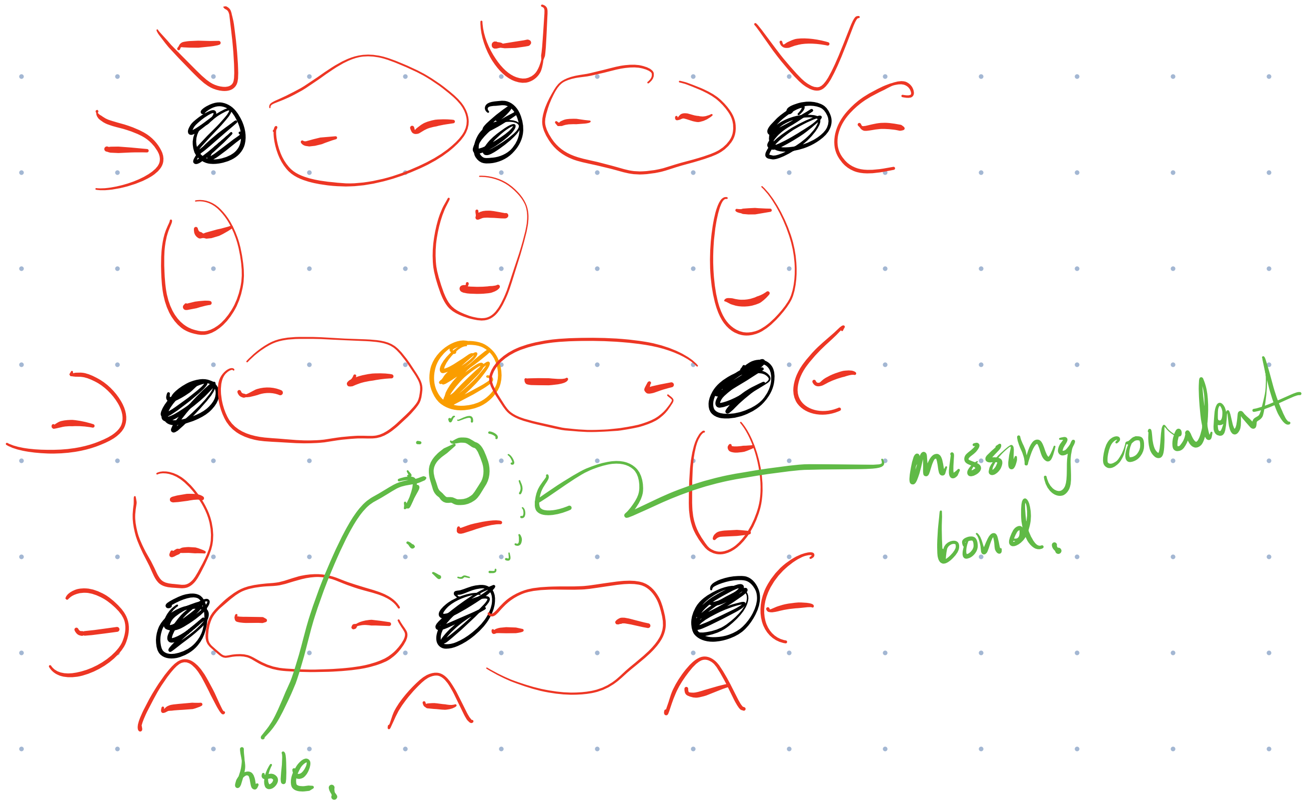
▨ P nucleus + 10 core electrons. Charge +5

The extra valence e^- in the dopant is not participating in a covalent bond. It is only weakly attached to its host atom. It easily detaches and moves throught the material.

p-type doping (hole doping)

Use a dopant w/ 3 valence e^-.

Eg. is Boron B. Electron config. is $1s^2 \underbrace{2s^2 2p^1}_{\text{2nd shell is valence shell.}}$



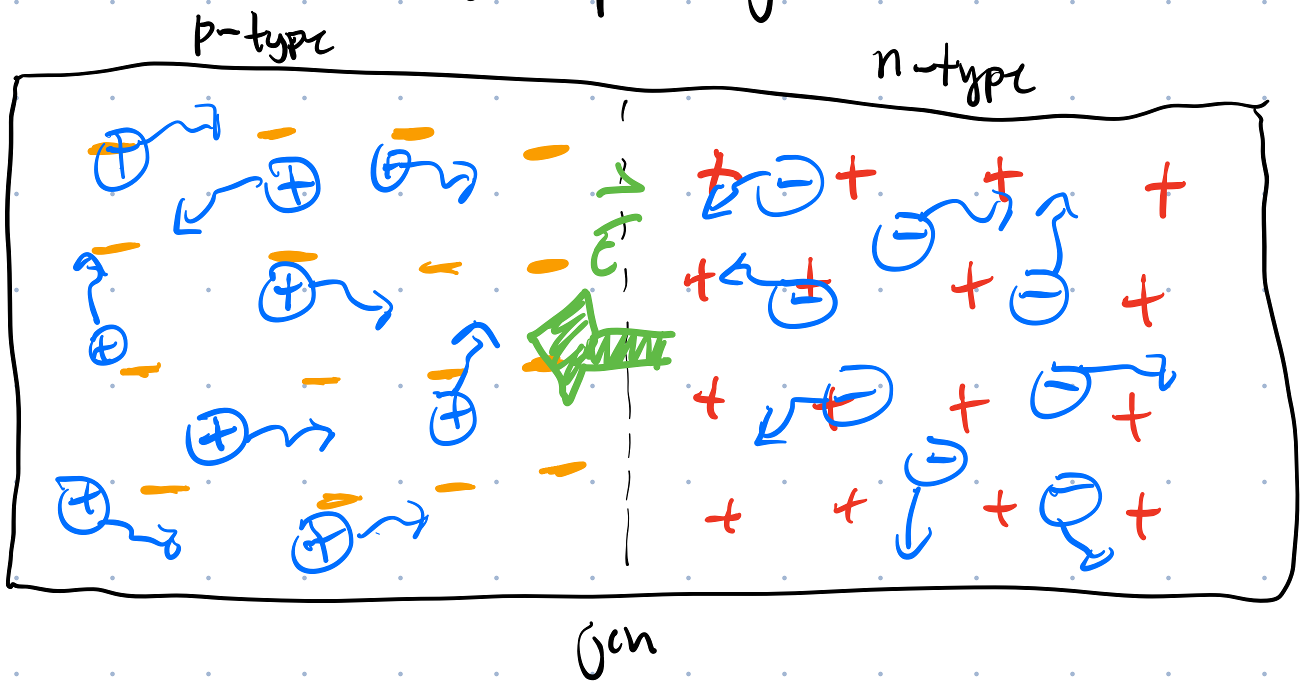
● Si nucleus + 10 core e^-. Charge +4.

● 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 (diodes & transistors) are made by joining n- & p-type doped semiconductors w/ a sharp jcn.

Diode has a single p-n jcn.



− fixed neg. ions.

+ fixed pos. ions

⊕ mobile holes

⊖ mobile electrons.