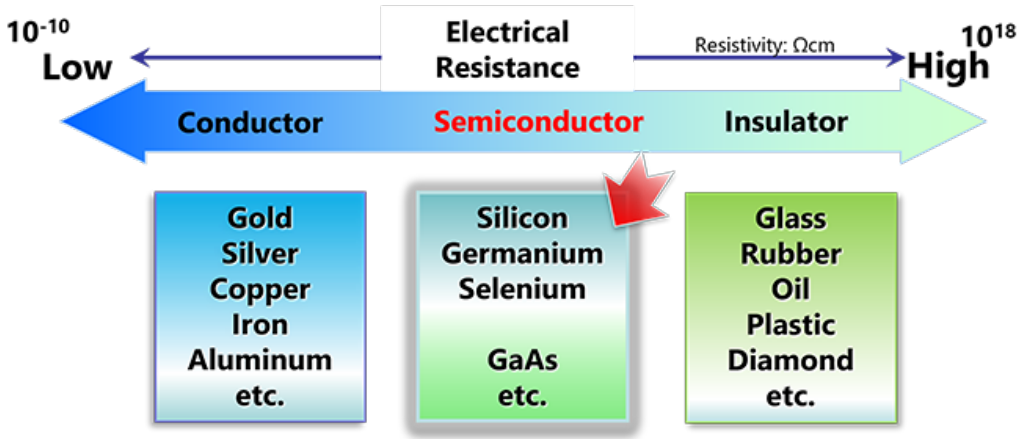
Semiconductor Materials

What are semiconductor materials

- Semi conductor is a term used for a material that has a resistivity somewhere between a conductor and an insulator
- This means it can play the role of both
- Typically, we can control its resistivity using an external source such as heat or external voltage
- This ability to control them makes them essential for everyday electronics

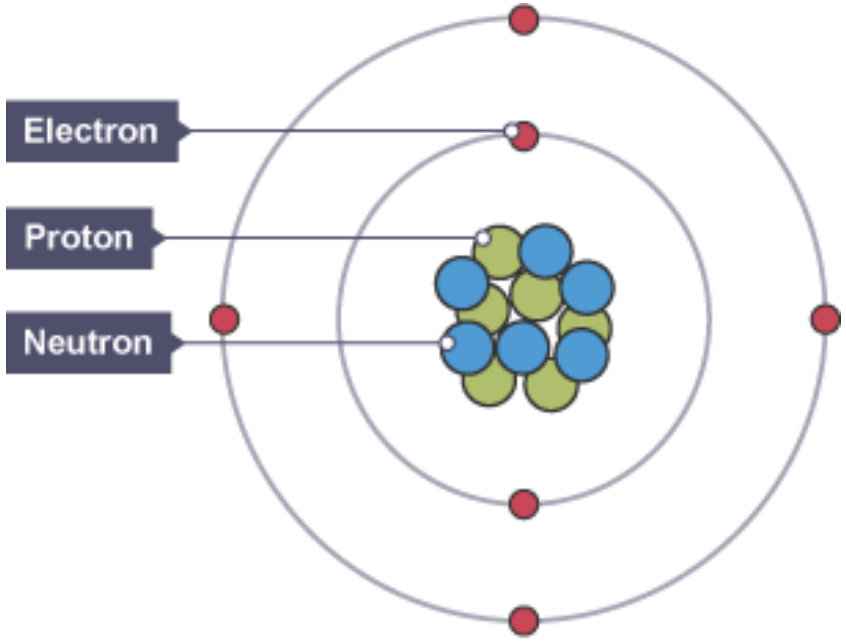


Typical semiconductor materials

- Typically, devices will use either silicon (Si) or germanium (Ge)
- Both silicon and germanium are most common due to their low ‘band gap’
- A low band gap means less power is required to swap it to and from conductive and non conductive states
- They are also used as they are very abundant and found everywhere meaning they are cheap

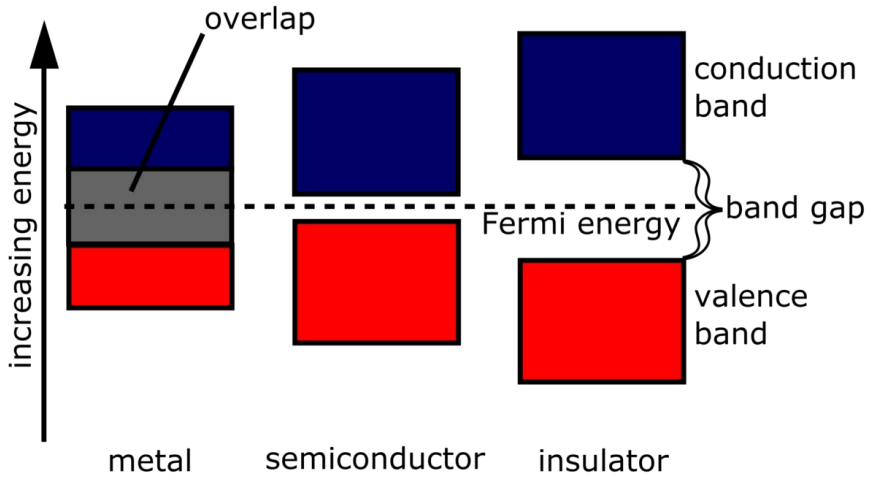
Atomic makeup

- Atoms are made up of bands of electrons
- The outermost band is loosely attached to the atom
- They freely detach and reattach to different atoms
- This is how electricity flows in a wire
- We can refer to the atoms the electron has jumped to as a “hole”



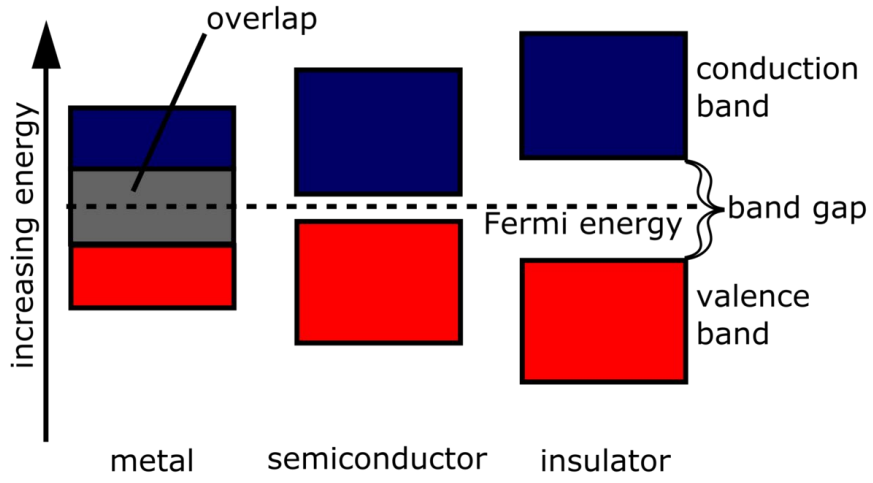
Band Gap

- A band gap is the energy gap (energy required) for an electron to swap from being attached to an atom to jump to a conduction band, where it can move freely and participate in electrical conduction.
- If electrons can easily jump the gap, then it is likely a metal
- If electrons can't jump the gap easily then it is an insulator
- And if the gap is medium but jumpable with some extra power then it is a semiconductor



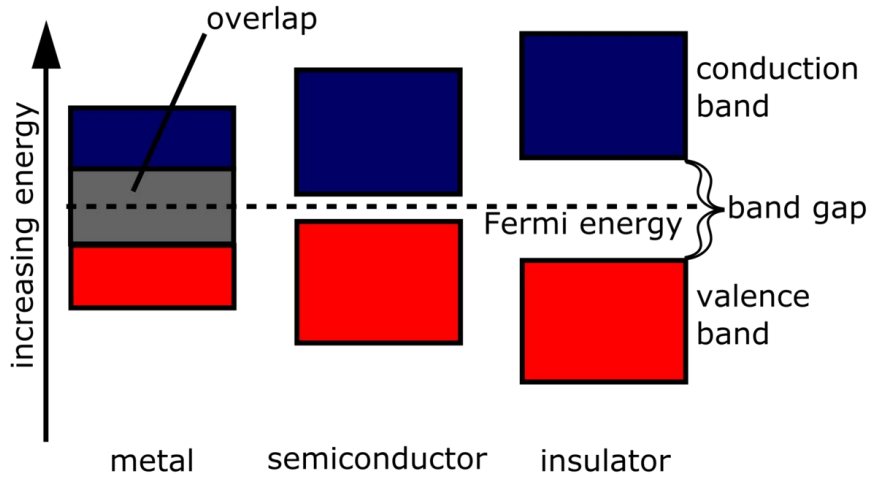
Band Gap

- We measure band gap in electron volts (eV)
- Typical values of band gaps are:
  - **Silicon (Si):** 1.12 eV
  - **Germanium (Ge):** 0.66 eV
  - **Gallium Arsenide (GaAs):** 1.43 eV
- Increasing the temperature of a material reduces the band gap making it easier for the electrons to bridge the gap



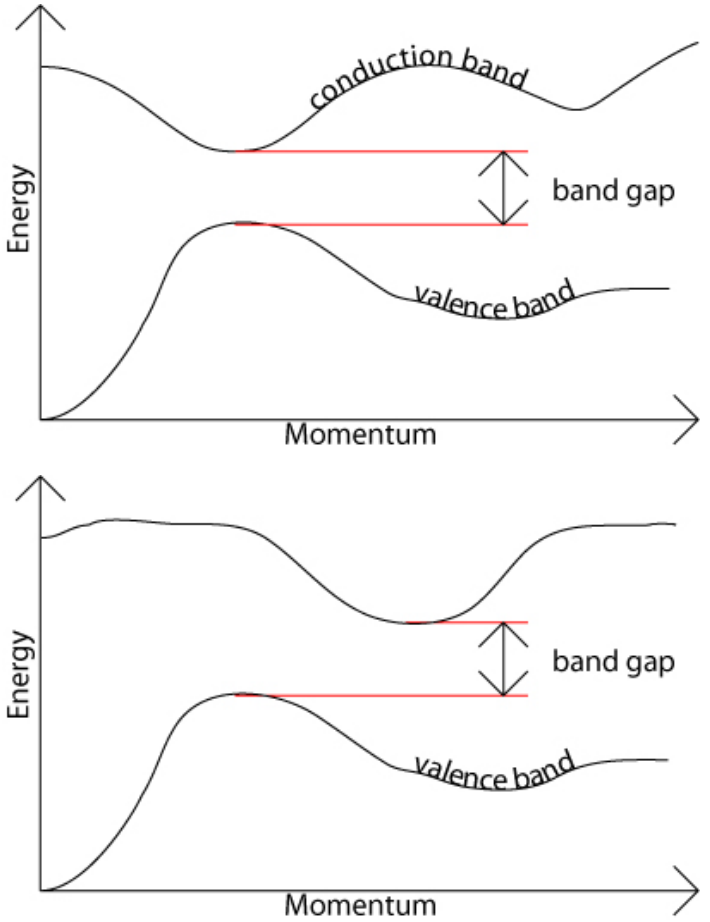
Band Gap

- The lower the band gap the more appropriate it is for high-speed electronics due to the speed in which it switches on and off
- However, you have the trade off that it reduces robustness meaning its not ideal for high voltage and high temperature applications



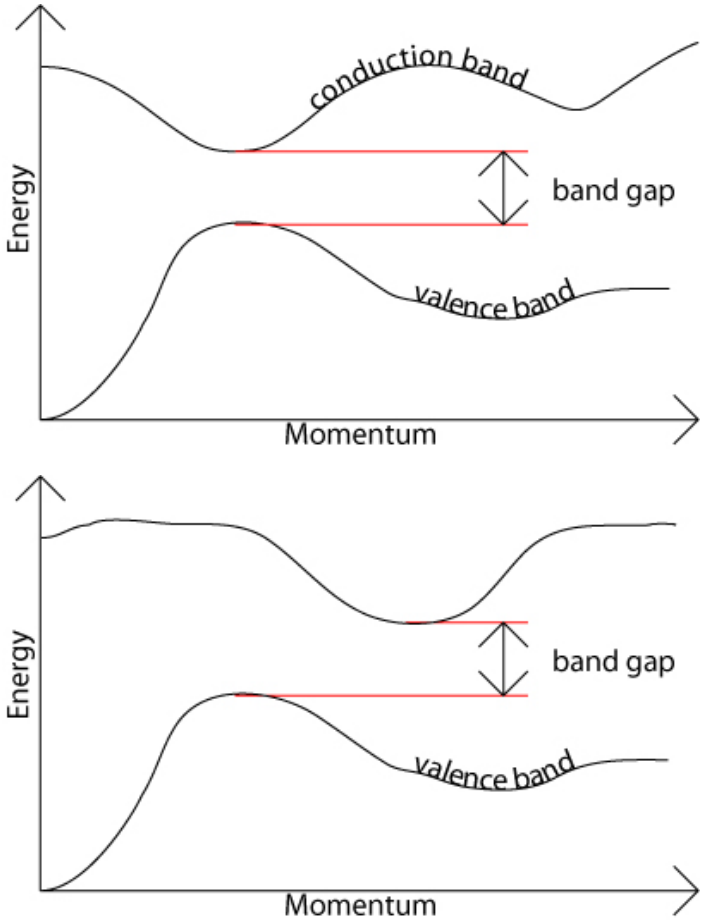
Band Gap

- Semi conductor materials come in two main forms;
- Direct Band Gap materials are where the lowest conduction band and the highest valence band are aligned in momentum space
- Indirect Band Gap materials are where the lowest conduction band and highest valence band are misaligned and thus something else is needed to change that momentum



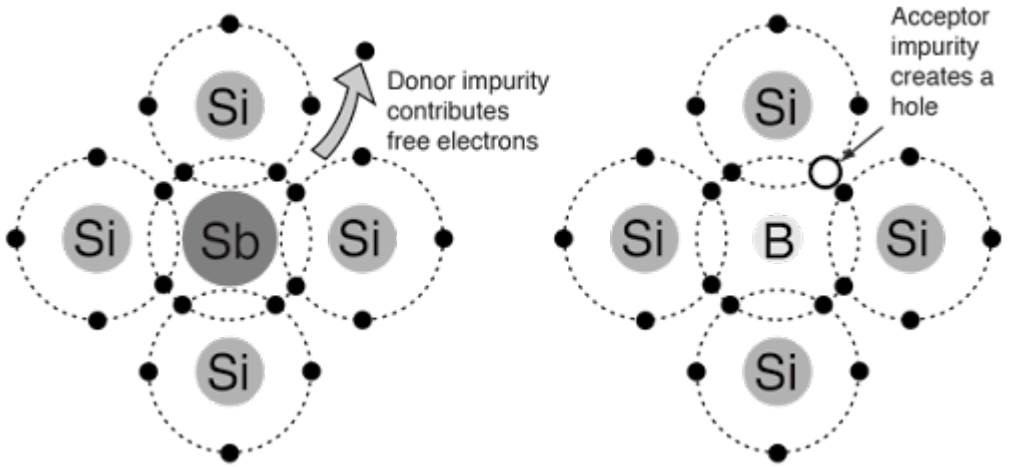
Band Gap

- A Direct Band Gap just interacts with a photon (light) either releasing one or absorbing one when an electron jumps
- This makes them ideal for LEDs and lasers
- For an Indirect Band Gap, the electron interacts with a photon and a phonon to compensate for the momentum difference
- This makes them ideal for other components as it doesn't produce much light instead it produces heat



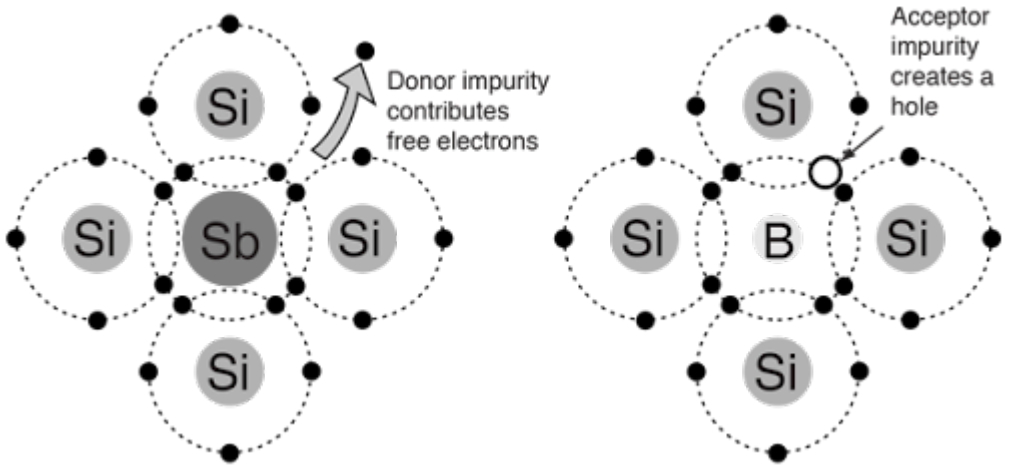
Doping

- The process of doping involves adding impurities to a semiconductor materials, this mostly involves adding conductors to the semiconductor
- This gives the semiconductor electrical properties and improves conductivity
- 100% semiconductors are bad at carrying charge as they have few electrons and free holes
- The addition of the impurities adds more electrons and holes making a better electric component



P vs N

- **P-Type (Positive-Type) Doping** adds more holes to the material (more atoms with free electron spots).
- **N-Type (Negative-Type) Doping** adds more electrons to the material.



Forming a PN junction

- When we make a PN junction we stick two materials together, a P doped semiconductor and an N doped semiconductor
- The two doped regions mix in the middle and cancel each other out making a “depleted region”
- In the depleted region there are no free charge carriers meaning this region acts like an insulator
- We can push through this region with an external voltage which grabs the electrons and carries them through the region, however as 1 side is positive, and the other is negative we can only go one way