Semiconductors

1 Conductors, insulators and semiconductors

- Conductors have loosely bound electrons in their outer electron orbits. If even a small voltage with applied, the electrons will start to move, generating a current. Conductors have low resistance. (Examples: copper, iron)
- Insulators have tightly bound electrons, and it takes an immense voltage to generate a current. They have very high resistance. (Example: plastic, rubber)
- Semiconductors are between conductors and insulators; they don't have the free electrons of a conductor, but some voltage will free the outermost electrons for current flow. (Examples: Silicon, Germanium)

Semiconductors are substances with outer electrons that are not free to move, but require little energy to free them for conduction.

2 Intrinsic Conduction

Silicon and germanium have a valency of 4. An atom in a pure silicon crystal forms exactly four covalent bonds with four other silicon atoms.

At room temperature, the electrons have a some thermal energy that cause some of them to move away from their original place in the crystal. If a voltage is applied, these electrons will flow in a small current called intrinsic current.

Intrinsic current depends on thermal energy, but the current also generates heat. In germanium, you will find that the intrinsic current generates heat, and the heat generates further intrinsic current, until the germanium gets so hot it is destroyed. This is called thermal runaway. Silicon is not so prone to thermal runaway, and for this reason, it is used in electronics far more widely than germanium.

3 Extrinsic Conduction

We can change the conductivity of a semiconductor crystal by adding impurities to it. Elements such as phosphorus, arsenic, aluminium or indium are roughly the same size as a silicon atom, but if slotted into the crystal structure (about 1 every ten thousand million atoms), they change the conductivity. This is known as **doping**. The movement of charges through a doped semiconductor is called extrinsic conduction.

4 n-type Semiconductors

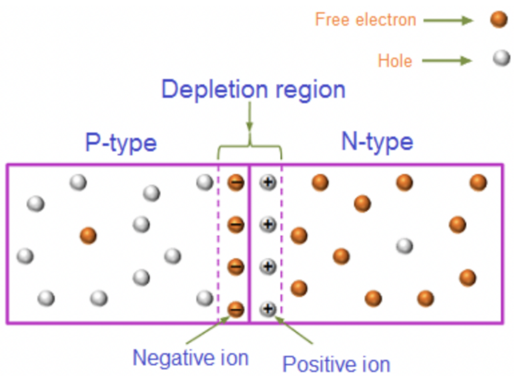
Silicon has a valency of four, while phosphorus has a valency of five. If a silicon crystal is doped with a phosphorus atom, there is one extra electron (a negative charge) that is not bonded in the crystal. A voltage will cause the free electrons to move. This is called in n-type semiconductor (n for negative).

5 p-type Semiconductors

Silicon has a valency of four, while aluminium has a valency of three. If a silicon crystal is doped with an aluminium atom, there is an electron missing from the normal structure. This vacancy is called a 'hole', and can be thought of as a positive charge. A series of 'holes' in a crystal structure forms a path for free electrons to travel through, giving the impression of positive charges moving in the opposite direction. This is called a p-type semiconductor (p for positive).

6 Diodes & Rectifiers

Imagine we put an n-type semiconductor and a p-type semiconductor against eachother. This is called a **p-n junction**. You'll find that some of the free electrons in the n-type semiconductor 'jump' into the holes near the border of the p-type junction. Conversely, some holes will therefore move over to the n-type side. The end result is a sort of 'buffer' of positive charge on the n-type side, and negative charge on the p-type side. This buffer is called a **depletion layer**.



Let's now connect a battery such that the positive terminal is connected to the p-type side, and the negative terminal to the n-type side. This configuration is known as being **forward biased**. Electrons in the n-type are repelled by the negative terminal and start to flow through the depletion layer, towards the positive terminal of the battery. Meanwhile, the holes are attracted to the negative terminal and move opposite to the electrons.

There is a minimum voltage that needs to be applied for current to be able to flow through the depletion layer. This is called the activation voltage. For silicon it turns out to be about 0.6V, and for germanium it's about 0.1V.

Now imagine switching the terminals, such that the negative terminal is connected to the p-type and the positive to the n-type side. This configuration is called **reverse bias**. The electrons in the n-type side are still repelled by the negative terminal, and flow away from the border p-n junction, and the holes in the p-type side will also flow away from the border. Not only does no current flow: the depletion layer gets wider as long as voltage is applied in this direction.

This is the mechanism by which a diode works: current can only flow in one direction, and not the other.

This idea can be used to convert AC to DC. When AC is passed through a diode, only the current that flows in the direction of the forward bias is allowed through, and the output will be DC. This process is called rectification, and circuits that rectify current are called **rectifiers**.

7 LEDs, photodiodes, and ICs

A Light Emitting Diode (LED) is a diode that emits light when it is connected in forward bias. They are often used as indicators in circuits, and also make for very energy efficient lights.

Photodiodes are diodes that conduct more current when light falls on them: they become resistors in darkness, and conductors in brightness.

An Integrated Circuit (IC) can be thought of as a premade circuit. They are manufactured in special labs on thin silicon 'wafers' and can contain many thousands of electronic components, configured to perform a specific function.