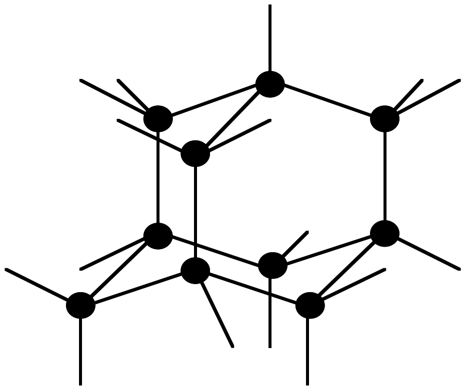
SEMICONDUCTORS and SUPERCONDUCTORS

Semiconductors are substances with a small electrical conductivity which increases with temperature.

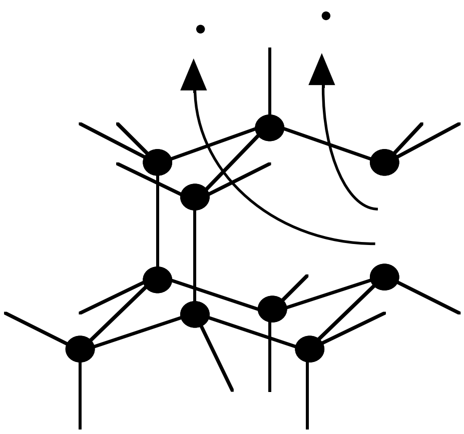
Diamond is a **non-conductor**.



● = Carbon

The high electronegativity of Carbon traps the electrons in the C-C bonds.

Silicon also has the diamond structure but a lower electronegativity than Carbon. Si-Si bonds are weaker than C-C bonds. Electrons can be dislodged from the bonds in Silicon by heating. When a voltage is applied, these 'free' electrons can migrate through the lattice resulting in electrical conductivity.



● = Silicon

• = electron

The higher the temperature the more bonds break and the greater the conductivity. Silicon is therefore a 'semiconductor'.

Semiconductors (or metalloids) lie at the division between the metals and the non-metals in the periodic table:

B	C	N	O	F	Ne
Al	Si	P	S	Cl	Ar
Ga	Ge	As	Se	Br	Kr
In	Sn	Sb	Te	I	Xe
Tl	Pb	Bi	Po	At	Rn

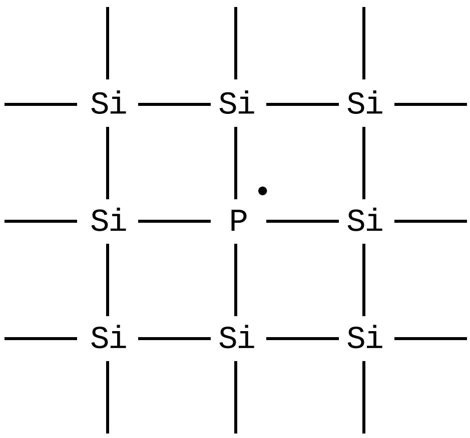
Electrons can also be dislodged from the bonds in semiconductors by light energy - the 'photovoltaic effect'. This is used in solar cells to convert sunlight into electricity.

DOPING

Adding trace amounts of other elements to a semiconductor (doping) can increase the conductivity. There are two different ways of doing this resulting in n-type or p-type semiconductors. We will consider the doping of Silicon to illustrate these two types.

n-type

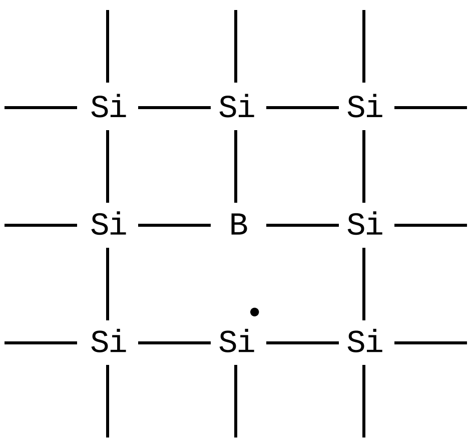
We will add trace amounts of Phosphorus to Silicon. Phosphorus has FIVE outer electrons so there is one left over once the bonds with Silicon have formed:



This 'extra' electron can move freely through the lattice enhancing the conductivity of Silicon. The extra electron between the P and Si creates a small **negative** charge in that area hence the name 'n-type'.

p-type

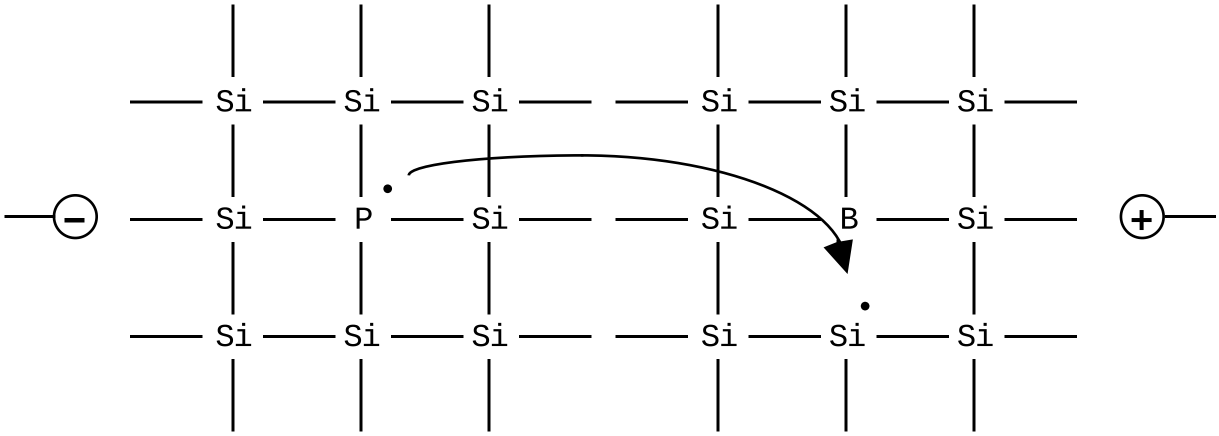
We will add trace amounts of Boron to Silicon. Boron has three outer electrons - insufficient to make four bonds with Silicon. One electron on Silicon is left over:



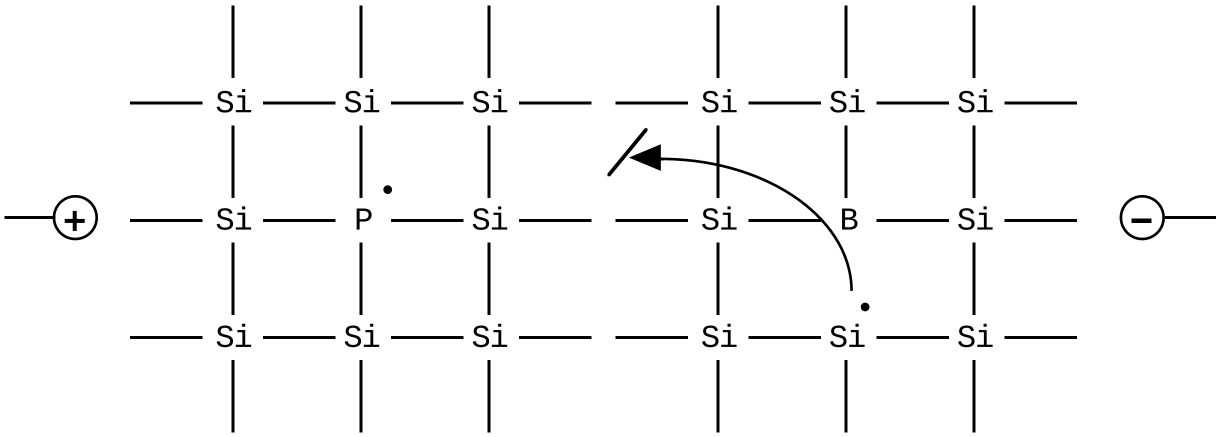
This 'extra' electron can move freely through the lattice enhancing the conductivity of Silicon. The lack of an electron between the B and Si atoms creates a small **positive** charge in that area and is often called a 'positive hole' hence the name 'p-type'.

It is more interesting to consider what happens when we join an n-type and p-type semiconductor together and try to pass an electric current through the junction.

Electrons will flow from n-type into p-type: the extra electrons in the n-type move into the positive holes in the p-type.



Electrons, however, cannot flow from p-type to n-type - there is no vacant orbital for the electron to go into!



The p-n junction will therefore allow current to flow through it in one direction only. This device, known as a rectifier, forms the basis of the modern electronics industry.

SUPERCONDUCTORS

Semiconductors should not be confused with superconductors. Superconductors are materials that have almost zero electrical resistance at temperatures near 0 K.

Mercury becomes superconducting at temperatures below 4 K.

Achieving temperatures near 0 K is difficult and costly so using these materials as superconductors is impractical.

Recently superconductors have been discovered which have zero resistance up to temperatures above the boiling point of liquid Nitrogen (77 K) - temperatures which are less costly to attain.
e.g. $YBa_2Cu_3O_7$ becomes superconducting below 92 K.

C_{60} doped with Potassium and Rubidium is also superconducting at these more manageable temperatures.

Superconductors may have future applications in power transmission and electrically powered forms of transport.

[http://imr.chem.binghamton.edu/labs/super/superc.html]