

# Diamonds

Sinclair-Stammers/SPL

Industrial diamonds are usually irregular in shape and may be coloured due to impurities

The element carbon exists in a number of allotropic forms, but diamonds have always held a special allure, whether it be for their hardness or for their transparency. This article looks at how they can be made artificially and at some of their uses.

## GCSE key words

Carbon  
Allotrope  
Bonding

**Allotropy is when an element can exist in two or more different forms. The atoms are arranged differently in different allotropes.**

Diamond and graphite can be shown to be allotropes of carbon – both will give only carbon dioxide if burnt in oxygen.

● Read Professor H. Tracy Hall's account of the preparation of diamonds at [www.htracyhall.org/HTracyHall/pdf/19610151.pdf](http://www.htracyhall.org/HTracyHall/pdf/19610151.pdf)

In diamond, carbon atoms are held together by four strong covalent bonds in a rigid three-dimensional network. It is these strong bonds which give diamond its hardness (Figure 1). Natural diamonds are found in geographical formations called diamond pipes, where the high pressures and temperatures occurring at 150–200 km below the surface of the Earth have caused carbon in the rocks to rearrange into diamond. The processes involved are still not fully understood, but it is believed that thousands or even millions of years under stable conditions are needed.

Synthetic, or industrial, diamonds are produced using chemical or physical means in a factory.

## Industrial diamonds

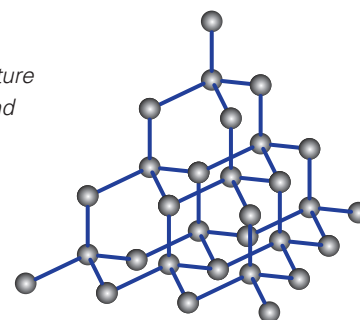
Industrial diamonds were first reported in 1880 by Hannay and again in 1894 by Moissan, who heated iron and graphite in a crucible with an electric furnace. It is thought that these first experiments were fortuitous as the procedure did not prove to be easily reproducible. Although industrial diamonds were first made in commercial amounts in 1953 in Sweden, the results were unpublished. H. Tracy Hall independently synthesised diamonds in 1954 in America and was the first to publish his results in *Nature* magazine.

## Making industrial diamonds

In order to produce the necessary pressures and temperatures, electrically heated presses have been developed which can heat graphite to temperatures higher than 1400°C and subject it to pressures of more than 60 000 atmospheres (Figure 2). A graphite sample is sandwiched between two layers of cobalt in a cylindrical die. This is then squeezed and heated.

Figure 1

The structure of diamond

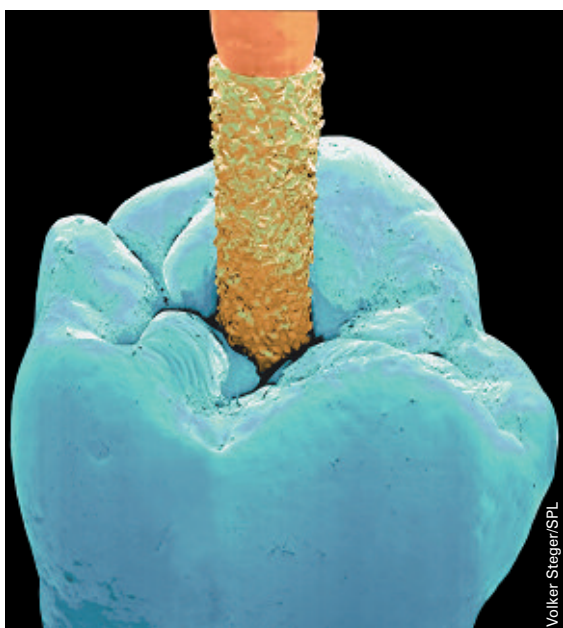


The metal melts and the graphite starts to dissolve, forming a supersaturated solution. Diamond begins to crystallise out under the conditions used.

The diamonds are usually very small as there are many sites upon which the crystals can form. The size and shape of the crystals can be altered by varying the temperature and pressure under computer control. Once the crystals have formed the molten mass is allowed to cool to room temperature and the pressure is reduced slowly to atmospheric pressure. The solid mass of cobalt, unreacted graphite and diamond is broken into pieces and the cobalt removed by dissolving in acid. The diamonds can be separated from the remaining graphite by sieving.

## Grades of industrial diamonds

It is the use of the cobalt, which acts as both a solvent and a catalyst, that makes this process economically viable. Diamonds made this way are usually coloured due to traces of nitrogen atoms trapped within the diamond giant molecule. Different grades of crystal may be used for different purposes – whether it be fragments for a diamond tipped drill, or needle shaped pieces for grinding discs.



Diamond fragments are used on the tips of dental drills. Here we see a scanning electron micrograph of a dental drill entering a tooth

## Vapour deposition

Vapour deposition allows a diamond film to be 'grown' onto another surface. A variety of different methods are used, but all involve feeding a carbon-containing gas (usually with hydrogen as well) into a chamber. The molecules are energised using microwaves, hot filaments or arcs. A plasma results and the carbon atoms can form as diamond on a surface. Low pressures are used.

Areas 15 cm in diameter can be covered in a layer of diamond. Other elements may be incorporated into the layer in order to give it specific properties. This process is quite slow and the applications for it are few at present. However, as the chemistry behind the process becomes better understood more uses may be found.

Currently, films are being grown on valve rings and cutting tools. University researchers have managed to make a colourless 2 g single crystal diamond by vapour deposition. Researchers hope to make diamonds up to 60 g by this method eventually.

## Applications

The major application for industrial diamonds is as an abrasive. Small fragments of diamond are distributed in cobalt and then fused on to the surface of a cutting tool. This is particularly good when machining non-

### Box 1 Lifegem

It is now possible to create a diamond from the carbon contained in a lock of hair, or in the ash remaining from a cremation. These diamonds can act as a permanent reminder of a person. See [www.lifegem.com](http://www.lifegem.com) for information on the process used and how it is carried out.

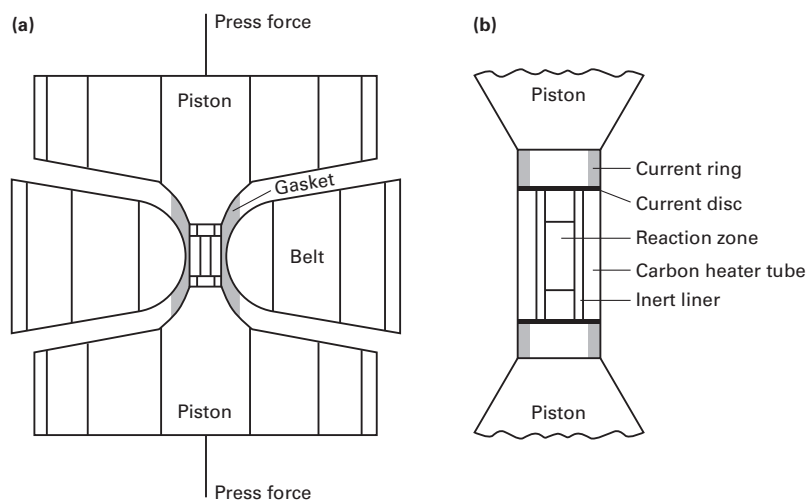


Figure 2 (a) Diamond press and (b) close-up of the reaction chamber

### Box 2 Types of synthetic diamond and their uses

- High pressure/high temperature diamond grit (1  $\mu\text{m}$ –1 mm) – used in grinding and cutting processes.
- High pressure/high temperature polycrystalline compact diamond – diamond particles sintered together at high temperature. Large surfaces can be made for abrasives.
- High pressure/high temperature large single crystal diamond – diamonds up to 10 mm in length used in chemically reactive environments, or for industrial gems.
- Vapour deposition polycrystalline diamonds – flat diamond wafers up to 5 mm thick used as abrasives or in the optical, medical or environmental industries.
- Vapour deposition single crystal diamonds (few millimetres in length) – used as an abrasive or in the electronics industry, or for sensors or detectors.

ferrous metals. Diamond-tipped drills are also used when drilling for oil.

The largest use of industrial diamonds is in the automobile industry. The aluminium alloys used for making cars wear down cutting tools very quickly. Diamond-coated tools are a cost-efficient way of overcoming this. Vapour deposited diamond films have also been used in electrodes in conditions which would normally destroy traditional materials.

Diamonds can be 'doped' with boron and phosphorus to give them transistor-like properties, turning them into n-type or p-type semiconductors. These may be developed further for use in highly corrosive or high temperature environments.

Synthetic gems are also being manufactured at 1500°C and 58 000 atmospheres pressure by coating a tiny sliver of natural diamond in molten carbon. These have a slight yellow tint due to one carbon in every 20 000 carbon atoms being replaced by a nitrogen atom. Rough gems up to 550 mg are grown which can be cut to 300 mg (1.5 carat). These gems are profitable as they are relatively quick to manufacture and the yellow colour is popular.

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**Each year 600 metric tonnes of synthetic diamond are made. Only 26 metric tonnes of diamond are mined each year.**

**A plasma is an ionised gas which is a good electrical conductor.**

**Although diamond is the hardest substance known it is also remarkably brittle – a sudden shock, such as hitting it with a hammer, can cause it to powder.**