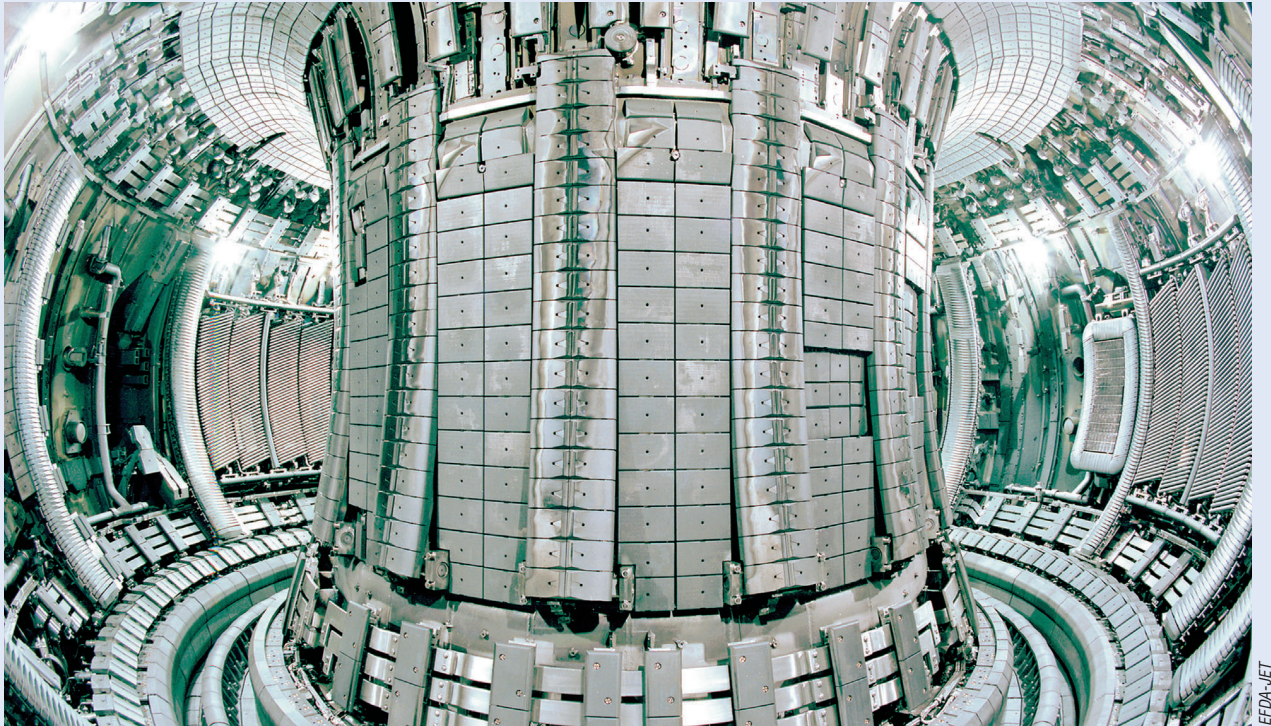


# Beryllium



The future of energy? Beryllium lines the interior of the Joint European Torus reactor built for research into fusion-based power

**Element number four**, beryllium, follows lithium and is situated under magnesium in the alkaline earth group of the periodic table. Like these metals, it has a very low density, at  $1.85 \text{ g/cm}^3$ , but it has a surprisingly high melting point of  $1,287^\circ\text{C}$  (magnesium melts at  $651^\circ\text{C}$ , and lithium at  $179^\circ\text{C}$ ).

It also has other properties which may not be expected: it has excellent thermal conductivity ( $200 \text{ W/mK}$ ) and is strong, stiff and dimensionally stable over a wide temperature range. It is highly permeable to X-rays, which forms the basis of some applications. But, because of its relatively high cost and toxicity issues if handled incorrectly, the metal is only used where it is essential and where substitution results in unacceptable properties.

Beryllium occurs in about 100 minerals, but the important ones are bertrandite ( $\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$ ) and beryl, after which it is named ( $\text{Al}_2\text{Be}_3\text{Si}_6\text{O}_{18}$ ). Aquamarine and emerald are precious forms of beryl. Other minerals include chrysoberyl ( $\text{Al}_2\text{BeO}_4$ ) and phenakite ( $\text{Be}_2\text{SiO}_4$ ).

Beryllium was discovered by Louis Vauquelin in 1798, and was isolated independently in 1828 by Friedrich Wöhler and AA Bussy. But the metal did not become readily commercially available until the 1950s.

World resources are estimated at over 80,000 tonnes of contained metal, according to the US Geological Survey (USGS), with 65% of these in the USA. Proven bertrandite reserves in Utah total about 16,000 tonnes of contained metal. The USA is by far the biggest beryllium miner; it

mined an estimated 100 tonnes of contained metal last year, reports the USGS, out of a world total of 127 tonnes. China mined an estimated 20 tonnes and Mozambique 6 tonnes.

The USA also imports ores, concentrates, compounds, scrap, master alloys and pure metal for processing, and is the world's major producer of beryllium products, including alloys and ceramics. The US Defense Logistics Agency (DLA) has stockpiles of beryllium metal, beryl ore and beryllium-copper master alloy. As of September 2006, it had authorised another 110 tonnes of hot-pressed beryllium powder for disposal, retaining 45 tonnes.

Brush Wellman, based in Cleveland, Ohio, a subsidiary of Brush Engineered Materials, is one of the world's very few fully integrated beryllium producers, from mining to metal products. The company owns 6.55m tons of proven bertrandite reserves (as of 2006), grading 0.267% beryllium. It plans to develop a new bertrandite pit in Utah, to start up in early 2008.

Ores are processed to a beryllium hydroxide-based concentrate, which is converted to beryllium fluoride. This is reduced with magnesium to obtain the metal.

Brush Wellman's primary beryllium production facility in Elmore, Ohio, was closed in 2000 because it was obsolete, while at the same time the company was able to source the metal it needed from the DLA. It also has contracts running to 2012 to buy beryllium-copper master alloy and vacuum-cast beryllium billet from Ulba Metallurgical Plant in Kazakhstan.

However, demand for the metal is such that a new primary facility is being planned for Elmore. This is being majority-funded by the US Department of Defense in order to secure the supply of strategic beryllium products, and it is expected to start up in 2010. It will produce metal of 99.5% minimum purity, and have maximum capacity of 160,000 lb/year (73 tpy). It is being designed to operate efficiently at lower capacities as well, owing to the cyclical nature of metal demand, especially relating to customised projects.

The production and fabrication of beryllium products are highly specialised activities because of the toxicity of the metal and its compounds. In final solid form, the metal and its alloys are unlikely to cause any ill-effects, according to the UK Health & Safety Executive, but adverse reactions such as chronic beryllium disease (CBD) can occur if it enters the body via dust, fumes or soluble compounds. The tightly-controlled conditions employed for processing add to the costs of finished products.

## APPLICATIONS

The most important use for beryllium is in alloys, which accounts for an estimated 75% of US consumption, according to UK analysts Roskill. The second biggest use is ceramics incorporating beryllium oxide (about 15%), and the metal itself accounts for about 10% of demand.

The biggest application is in beryllium-copper alloys (also called beryllium bronze). These are divided into high-strength alloys containing 1.6-2.0% Be and high-conductivity alloys containing about 0.3% Be. These alloys are used where it is important to have high electrical and/or thermal conductivity, high strength and hardness, non-magnetic properties, and good corrosion and fatigue resistance. Typical applications include electrical contacts, springs, spot-welding electrodes, drilling equipment, plastics moulds, landing gear and heavy machinery parts.

Nickel-beryllium alloy is produced as strip, containing 1.85-2.0% Be, 0.4-0.6% Ti and the balance nickel. It has good spring properties at elevated temperatures and is used in applications such as thermostats, bellows, diaphragms, burn-in connectors and sockets.

An interesting development has been high-beryllium binary alloys with aluminium. There are two AlBeMet<sup>®</sup> alloys commercialised by Brush Wellman: AlBeMet 162 containing 62% Be and AlBeMet 140 containing 40% Be. These materials are often referred to as metal matrix composites rather than alloys since the two metals do not combine in any form and remain as separate phases.

With low densities (2.1-2.3 g/cc), high specific stiffness, high thermal conductivities and high mechanical isotropy, aluminium-beryllium materials have been developed for the avionics sector, which has to deal with increasing electronic packaging densities and growing thermal loads. AlBeMet 162 is used for over 340 parts on the F-22 fighter.

Beryllium metal is used in the defence and aerospace sectors as a lightweight structural material in high-speed aircraft, helicopters, missiles, spacecraft and satellites. Since space launch costs exceed \$10,000 per lb, reducing

the weight of launches can significantly reduce costs, while beryllium's strength and dimensional stability at low temperatures is important in space orbit.

Beryllium and AlBeMet have been incorporated in the Space Shuttle (window frames and doors), the Mars Rover, Cassini Orbiter and Hubble Space Telescope, among others.

Beryllium has become the standard material for optics in space. Polished to a mirror finish, it retains strength and stability even where the optics are cooled to near absolute zero for collecting infrared data. The Spitzer Space Telescope launched in 2003 is the largest infrared telescope to date and contains a 0.85-metre beryllium mirror cooled to under 5.5K.

Much larger is the James Webb Space Telescope due for launch in 2013, which will be the successor to the Hubble Space Telescope. Its primary mirror will comprise 18 hexagonal beryllium sections, each weighing 20 kg. The JWST will collect light nine times faster than Hubble, although its 6-metre diameter mirror will weigh only half as much as Hubble's.

Back on Earth, the transparency of beryllium to X-rays finds use in medical and industrial X-ray sources and detectors. The beryllium window, in the form of thin foil, retains the vacuum or inert gas within the source or detector while letting X-rays through.

With its low atomic number, beryllium is also very transparent to energetic electrically-charged particles. It is consequently used in high-energy physics research in synchrotron beamline windows, beampipes and ultrahigh-vacuum chambers.

In contrast to charged particles, beryllium is able to slow down or reflect neutrons, making it suitable for use as a neutron moderator or reflector in nuclear reactors. It is mainly used as the latter, to reflect stray neutrons back into the reactor core.

The Joint European Torus project in the UK – the world's largest nuclear fusion research facility – uses a toroidal reactor lined with beryllium tiles. Their high melting point and neutron absorption properties contribute to the generation of a high-purity plasma.

There are far less esoteric applications, however, where beryllium may even be found in the home. It is being introduced into acoustics for high-performance loudspeaker domes and diaphragms. Its high stiffness (Young's modulus) and low density produce an exceptionally wide frequency response. AlBeMet materials are also used in speaker tweeters and woofers.

Beryllium oxide (beryllia) can be formed into a lightweight and rigid ceramic which is able to dissipate heat more quickly than any other: its thermal conductivity is ten times that of alumina. It is therefore valuable as a substrate for electrical circuits that generate a lot of heat. Its low dielectric constant also allows improved electrical performance, especially at high frequencies.

Beryllia has various other uses, including high-temperature medical components such as the guide bores of laser scalpels and parts of MRI and CAT scanners. ■