2. Beryllium

Beryllium has a low density and one of the highest melting points of the light metals. Its high thermal conductivity and diamagnetic properties are also remarkable. Its electrical resistivity is significantly lower than that of copper or aluminium, while its modulus of elasticity is a third higher than that of steel. Beryllium transmits X-rays well, absorbs neutrons, and resists attacks by concentrated nitric acid. Furthermore, it resists oxidation in air at ordinary temperatures. However, a high price, its serious toxic effects on the lungs, and the room-temperature susceptibility to brittle fracture of the metal are drawbacks of beryllium.[1]

Beryllium is mainly (≈ 95%) produced from ores containing 0.3% – 1.5% beryllium. In addition, it can be obtained in small quantities as a by-product (beryl) of emerald extraction.[2] The largest producer of beryllium worldwide is the USA.

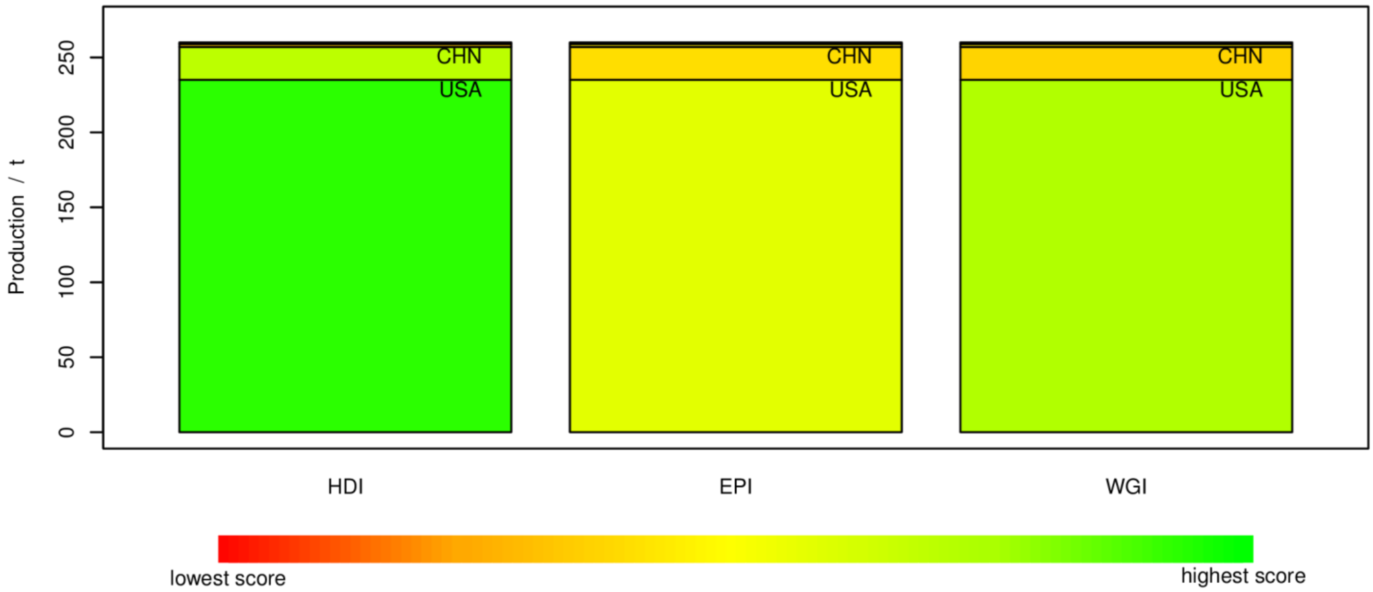

Figure 1: Distribution of beryllium production[3] and corresponding scores of the producing countries in the Human Development Index (HDI)[4], Environmental Performance Index (EPI)[5], and World Governance Indicators (WGI)[6]. Both the EPI and WGI are used to assess supply risks with the EU methodology for determining critical raw materials[7]. USA = United States of America; CHN = China.

Beryllium is one of the most expensive raw materials. Its price increased over the last few years up to approximately 93 US$/kg in 2011 and is recovering from a peak (104 US$/kg) in 2010.[*8]

* Unit value, annual average, beryllium-copper master alloy, dollars per kg contained beryllium: Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%.

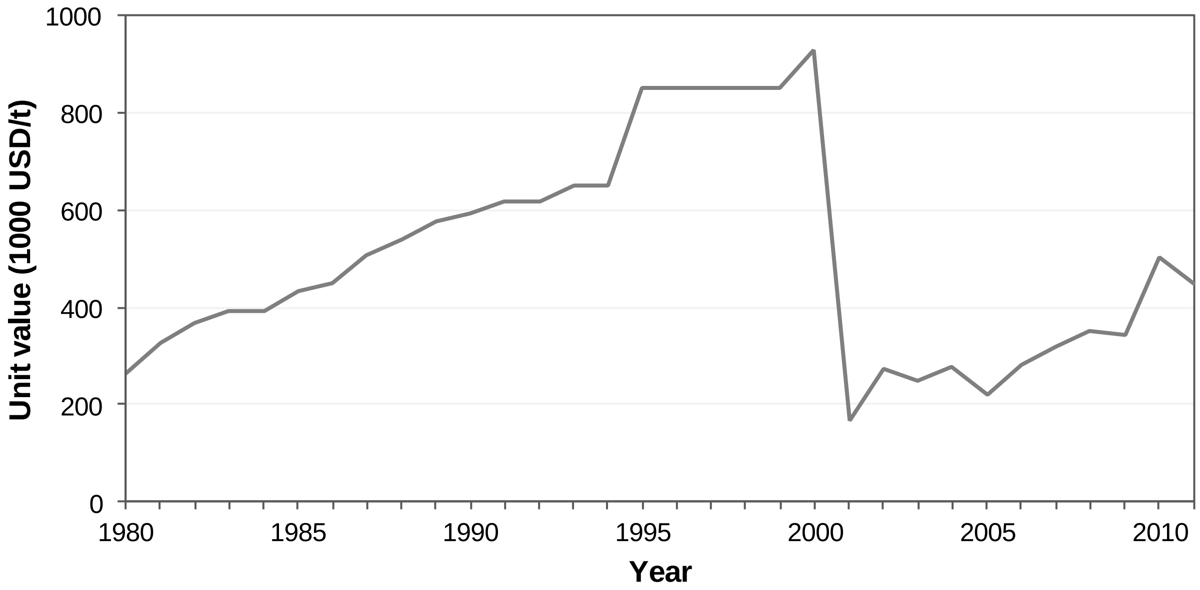

Figure 2: Beryllium price development during 1980 – 2011. The unit value is defined as the value of 1 metric ton (t) of beryllium apparent consumption (estimated).[9]

Uses and substitutability

Mechanical Equipment

With a share of 25%, the manufacture of mechanical equipment represents a key use of beryllium. Due to its high mechanical and thermal properties relative to its weight, especially compared to other materials, beryllium is used as a low-density metal.[1] Beryllium is mainly used alloyed in small amounts with copper and nickel to improve their ability to conduct electricity and heat.[10] Another reason is to age harden the alloy. The main applications of these alloys are the sealing of metal to metal connections, drilling and mineral mining equipment, undersea housings of fiber optic cables, metal casting moulds, springs as well as electrode holders and components of welding robots.[11,12] It is also used in nuclear reactors as a reflector or moderator.[10] A further application is plastic casting moulds.

Since beryllium is only utilized in applications in which its properties are crucial [1], it is hard to substitute in general. Nevertheless, if it is used exclusively due to its mechanical properties, beryllium can be substituted with titanium, magnesium, aluminium and their alloys or with carbon fiber composites. If a thermal improvement is required, beryllium can be substituted with aluminium metal matrix composites with added silicon carbide / boron nitride.[11]

Electronics & ICT

The electronics & ICT sector accounts for 20% of European beryllium end-use. After further processing, it is primarily used to increase the electrical conductivity in: mobile telephone infrastructure equipment, power amplifiers, high substrates for mounting powered civil aviation radar systems as well as computer parts and other electronic equipment.[1,10,11] Furthermore, it improves the mechanical properties of electrical contacts when used as beryllium copper in relays of electronic and telecommunications equipment and monitoring equipment. Copper alloys containing beryllium can be substituted by using nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys instead.

Electrical equipment & domestic appliances

The electrical equipment & domestic appliances sector has a share of 20% and uses beryllium copper because of the properties outlined above. Therefore, it can also be substituted by the use of nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys, especially when used in household appliance temperature and other function controls as well as relays.

Road transport

The road transport sector, which has a share of 15% in European beryllium end-use, mainly uses beryllium copper alloys in automobile connectors for air-bag crash sensor, anti-lock brake systems and modifier for aluminium and magnesium castings [1]. Purpose and substitutability of beryllium is as outlined above. However, the loss of performance upon substitution is generally unacceptable in safety-related applications.

Aerospace[11]

A 13% share of total beryllium consumption goes to use in alloys for aircrafts, mainly because of its mechanical properties. Therefore, beryllium is mainly applied in structural materials. Copper-beryllium is used in aircraft landing gear bearings and can be substituted by certain metal matrix or organic composites, high-strength grades of aluminium, pyrolytic graphite, silicon carbide, steel, or titanium. Other applications are pitot tubes in the aerospace sector and electrical and electronic connectors in aircrafts. There, possible alternatives are copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys, although there is a loss of performance that is generally unacceptable in safety-related applications.

Beryllium metal is used for example in gyroscope gimbals and yokes for use in guidance, navigational and targeting systems as well as in satellite mounted directional control devices for astronomical and other telescopes and instruments to provide GPS locations signals among others. Beryllium metal can be substituted with copper alloys in these applications.

Because of the above mentioned mechanical properties. Beryllium metal, which is used in the aerospace sector as satellite structural components or as alloying agent in producing beryllium copper, can be substituted with certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium, magnesium, aluminum and their alloys, carbon fiber composites.[11]

Others

Other final consumer goods make up 7% beryllium consumption due to the fact that it is relatively transparent to X-rays. Copper beryllium is used in medical isotope production nuclear reactors; life fire sprinkler water control valve springs and X-ray lithography for the reproduction of micro-miniature integrated circuits. Furthermore it is used in X-Ray transparent windows, and mirrors for terrestrial and space mounted astronomical telescopes. Beryllium oxide is necessary in ceramic applications, medical excimer laser beam focusing and its control components.[11]

Summary

Beryllium, being a very expensive metal, tends to be used only where its properties are needed and no reasonable substitute can deliver the desired result. In particular in safety related applications (e.g. anti-lock brake systems in cars, some aerospace), reduced performance/durability is unacceptable.

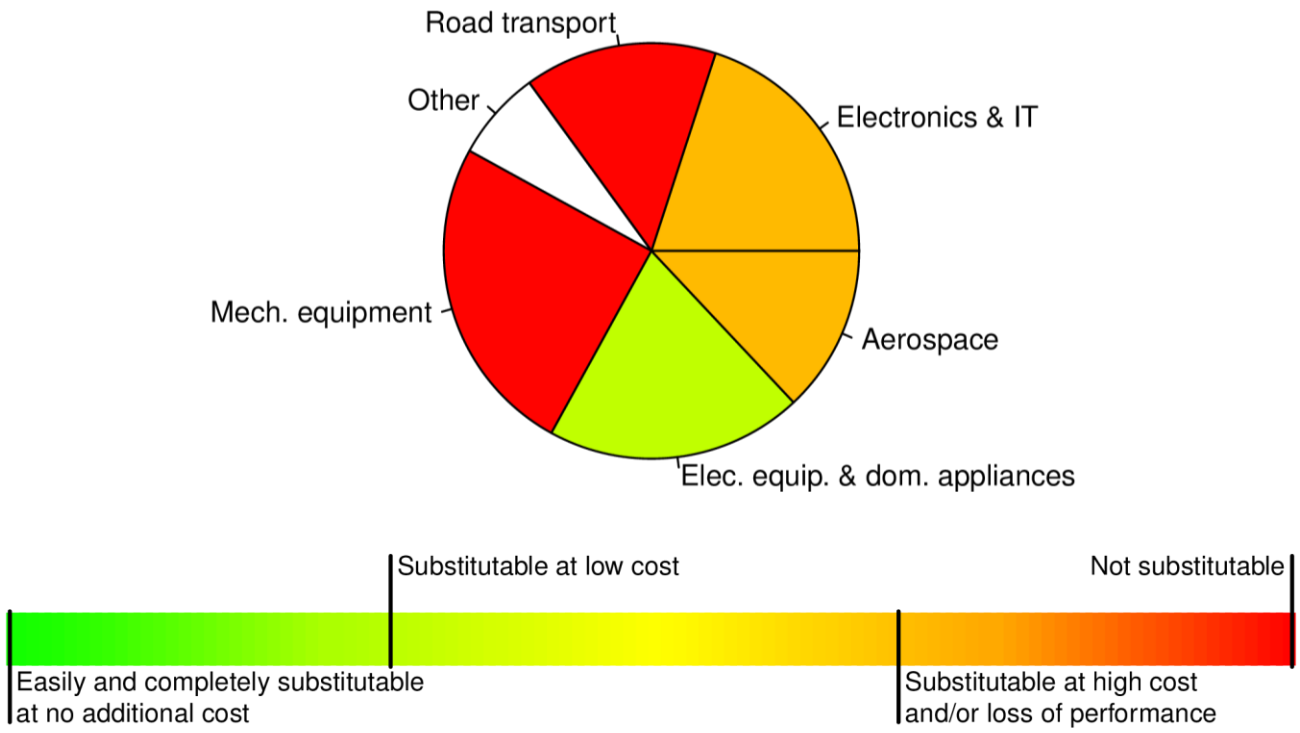

Figure 3: Distribution of end-uses and corresponding substitutability assessment for beryllium. The manner and scaling of the assessment is compatible with the work of the Ad-hoc Working Group on Defining Critical Raw Materials (2010).

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