# BERYLLIUM

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Beryllium is very light, strong, has a high melting point of 1,280°C, is resistant to acids and has a high thermal conductivity. These characteristics make it very useful in a number of applications, either as a metal, as part of an alloy or as a ceramic. These advantages are offset by high processing costs, which mean that beryllium products are expensive and tend to be used where there are no practical alternatives or where performance is critical.

The majority of world beryllium ore production, an estimated 82% in 2002, takes place in the US, as shown in Table 1. Most of the remaining output comes from China and Brazil. Mining of beryllium minerals may also have taken place in Madagascar, Portugal and Zambia but no official production statistics are available. Beryllium ore production in Russia and Kazakhstan stopped during the 1990s. Beryllium mining has also been recorded in Argentina, Namibia and Zimbabwe prior to 1996.

Brush Wellman is the sole US beryllium ore producer and mines bertrandite in Utah. In China, the Ningxia Non-ferrous Metals Smeltery (NNMS) has been reported as mining beryllium ores. In Brazil, Esmeralda de Conquista, part of the Mineração Badin Group, has reportedly stockpiled its production of beryl since the early 1990s but may have restarted exports in 2001. Piteiras Mineração of Minas Gerais produces beryllium concentrate based on industrial beryl and gems, which is further processed to produce emerald and industrial beryl.

**Production by main companies**

Brush Wellman of the US is the only known fully-integrated beryllium company in world. The NNMS of China is reported to produce beryllium from raw materials but this has not been confirmed.

In May 2000, Brush Wellman became a wholly-owned subsidiary of a holding company, Brush Engineered Materials. Brush Wellman is now part of the Metal Systems Division of Brush Engineered Materials, which is further divided into Alloy Products, Technical Materials and Beryllium Products.

The amount of bertrandite ore processed by Brush Wellman fell from 113,000 t in 1998 to 48,000 t in 2001. The bertrandite is used to produce beryllium hydroxide concentrate at the company's Delta plant in Utah. The concentrate is then used to produce beryllium metal and alloys at Elmore, Ohio, ceramic grade powder at Lorain in Ohio and strip and wire products at Reading in Pennsylvania. Ceramic powder from Lorain is also supplied to the company's plants in Tucson, Arizona and Newburyport, Massachusetts. The Electrofusion Products plant at Fremont, California, is a fully integrated producer of beryllium windows.

 

In 2001, reported sales by the Metal Systems Division were US$295.7 million compared with US$378.2 million in 2000. Alloy Products accounted for 73.6% of sales, Technical Materials 17.1% and Beryllium Products 9.3%. The main reasons for the fall in sales were declining demand in the telecommunications and computer electronics markets.

Other important US beryllium product companies are NGK Metals, Starmet and Advanced Industries International, which use raw materials supplied by Brush Wellman. Starmet, formerly known as Nuclear Metals Inc., jointly developed beryllium-aluminium alloys with Lockheed. Starmet later developed a family of beryllium-aluminium alloys under the trade name Beralcast®. In October 2000, Advanced Industries International purchased the National Beryllia Division of General Ceramics, which was the second largest US producer of beryllium oxide ceramics.

NGK Metals Corp., part of NGK Insulators of Japan, is one of the largest producers of beryllium-copper alloy castings, strip, rod, bar and plate products in the world from its plants in France, Japan and the US. By 2000, the company expected to be capable of producing 600 t/mth of beryllium copper products following a series of investments. In 1998, NGK Metals spent US$12 million on its Sweetwater plant in the US, mainly on the installation of the world's first beryllium-copper alloy continuous caster, which raised production capacity to around 100 t/mth. In October 2000, the company commissioned a mill-hardening furnace at its Chita plant in Handa City, Aichi Prefecture in Japan, which increased capacity to 400 t/mth. The Chita plant melts and casts beryllium-copper into billets. In France, NGK has been reported to be adding a new pickling line and to be considering the addition of a new mill-hardening kiln to its Coueron plant. The capacity of the plant was estimated to rise to 100 t/mth following the investment.

The Ulba Metallurgical Plant (UMP) in Kazakhstan was the largest beryllium product manufacturer in the former Soviet Union. The plant mainly used beryllium concentrate from mines in Russia. UMP stopped importing beryllium concentrate from Russia in the mid 1990s, partly because it had accumulated considerable stocks of material. This eventually led to the end of Russian beryllium concentrate production during 1997, as producers no longer had a market for their concentrates. There has been no reported production of beryllium concentrate from ore in Kazakhstan since 1993. UMP reportedly holds sufficient stocks of beryllium concentrate to support production for decades.

In 2000, UMP restarted production of beryllium metal, followed in 2001 by technical-grade beryllium hydroxide and beryllium copper. According to the National Statistical Agency of Kazakhstan, UMP produced 737 t of beryllium products in 2001, an increase of 71% on 2000 output.

UMP is currently in the middle of a US$25 million five-year investment programme, scheduled for completion in 2005, of which US$13 million is to be spent on the beryllium business. This includes the following developments:

- beryllium-copper master alloy (BCMA) capacity to be increased by 3,000 t/y using carbothermic reaction technology;
- development of digestion and refining production methods for beryllium hydroxide to international standards;
- introduction of new techniques to convert beryllium concentrates using existing capacity of up to 200 t/y; and
- beryllium copper product range to be extended and capacity raised by up to 1,000 t/y.

In September 2002, UMP and OJSC Moscow Nonferrous Metals Processing Plant (OJSC MZOCM) established OJSC Beryllium. The 50:50 joint venture was founded to increase sales of beryllium-copper rolled products in Russia. UMP will produce copper-beryllium billets for rolling, and OJSC MZOCM will manufacture copper-beryllium flat-rolled products.

In China, NNMS is reported to be the only producer of beryllium from raw materials. Ningxia Orient Tantalum Industry Co. (NOTIC), partly owned by NNMS, and Shuikoushan Nonferrous Metal Co. (SNMC) produce various forms of beryllium products. In 2002, SNMC was reported to have expanded significantly its beryllium production capacity. The combined capacity of the three companies has been estimated at 500 t/y gross weight of beryl or about 20 t/y of beryllium, mainly in the form of beryllium-copper alloys.

**Applications**

Alloys are the most common form of beryllium product, accounting for around 75% of US consumption. In the US, ceramics (15%) incorporating beryllium oxide, also known as beryllia, are the next most important form of beryllium followed by metal (10%).

Beryllium-copper is the most commonly used type of beryllium alloy. Beryllium-copper alloys are divided into high strength, typically containing between 1.6% and 2% Be, and high conductivity, containing around 0.3% Be, types. High-strength alloys are used in telecommunications applications and high conductivity alloys in automotive markets. Beryllium copper is also used in drilling equipment, aircraft landing gear and other heavy industrial machinery where its properties outweigh its expense.

Beryllium-aluminium alloys are becoming increasingly important in terms of beryllium consumption as they can contain up to 65% Be compared with the 0.3% and 2% typically present in beryllium-copper. Applications for beryllium-aluminium alloys include aerospace, hard disc drives and brakes.

Beryllium oxide ceramics have excellent electrical insulation properties and a high thermal conductivity. These characteristics, together with a high melting point of 2,570$^{o}$C and resistance to chemical attack, mean that beryllium oxide ceramics have a wide variety of applications in the electronics sector. These include heat sinks for electronic and microelectronic applications. The telecommunication and computer industries use beryllium oxide ceramics in substrates, where performance and the need for high levels of reliability and heat dissipation outweigh the cost.

Beryllium metal is used in military aircraft, spacecraft, inertial guidance systems, high performance brakes and space optical systems because of its strength, low weight and stability over a wide range of temperatures. Other uses for beryllium metal include in reflectors for research nuclear reactors and x-ray windows.

**Trade**

US companies play a pivotal role in world trade in beryllium; either exporting beryllium products or importing raw or scrap materials for processing. The US Government imposes import tariffs of 3.7% on beryllium oxide or hydroxide, 5.5% on wrought beryllium and 8.5% on beryllium waste and scrap from countries with normal trade relations. All other forms of beryllium can be imported free of tariff.

The majority of reported world beryllium trade is in the form of waste, scrap, powder, wrought and unwrought material. The most commonly traded type of beryllium material is almost certainly beryllium-copper alloy but data are not generally available.

UMP supplies a 4% beryllium-copper master alloy (BCMA) and other beryllium products to Brush Wellman under a long-term supply contract signed in 2000. UMP has also concluded supply agreements with Chinese organisations and in February 2003 exported an unknown amount of beryllium products to China. UMP is reported to be planning to arrange “extremely large deliveries” of beryllium to China in the future and sees the Chinese market as “very important”.

In 2001, 185 t of crude beryllium products were exported from Brazil, the first such exports since 1995. The majority, 89%, was exported to the US, probably to Brush Wellman for use as feedstock. This was probably beryl from Esmeralda de Conquista.

The only known significant reported trade in beryllium oxide is between US and Chinese companies and consumers in Japan.

**Stocks**

The US Government has long held quantities of beryllium in the National Defense Stockpile (NDS) in order to guarantee supplies to the defence industry in times of conflict. These and stocks of other strategic metals and minerals have been progressively reduced over the past decade. In December 2002, the revised Annual Material Plan (AMP) was announced, which set out the maximum amount of sales from the NDS up to September 2003. This included 4,000 short tons of beryl ore, 40 short tons of beryllium metal and 1,000 short tons of BCMA.

**Market trends**

Consumption of beryllium is forecast to rise over the long-term but rising demand is unlikely to encourage the development of new sources of beryllium raw materials as current beryllium producers have access to sufficient resources.

Demand for beryllium, especially in the form of alloys, fell in 2001 and 2002 following a fall in consumption by the telecommunications and computer industries. This fall is likely to be temporary but beryllium producers became increasingly reliant on these markets in the late 1990s. In 2000, telecommunications and computers accounted for 49% of the revenue of Brush Engineered Materials compared with 32% in 2002.

The reduction in demand by the telecommunication and computer industries may encourage beryllium product companies to diversify into new markets.

The miniaturisation of electronic products requires the use of strong materials, such as beryllium-copper alloys, able to cope with higher operating temperatures. The rise in the electronic content of automobiles, and higher voltages, will lead to higher demand for beryllium-copper alloys. The use of beryllium-aluminium alloys in aerospace applications is growing, especially in defence projects, but from a low base. Demand for beryllium oxide ceramics for use as substrates is also increasing as ever more powerful computer chips generate larger amounts of heat that must be rapidly dissipated. Beryllium metal consumption is unlikely to increase significantly in the immediate future and will probably remain concentrated in defence applications, such as refits of the F-16 and the new F22.

Table 1: World Production of Beryllium Ores (t gross weight)

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|
| Brazil | 6 | 7 | 5 | 11 | 13 | 12 | 12 |
| China[e] | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| Madagascar[e] | 11 | 28 | 30 | 20 | 25 | 25 | 25 |
| Portugal[e] | 5 | 5 | 5 | 4 | 4 | 5 | 5 |
| Russia[e] | 70 | 70 | - | - | - | - | - |
| US | 5,260 | 5,770 | 6,080 | 5,070 | 4,510 | 2,480 | [e]2,500 |
| Zambia[e] | 4 | 3 | 3 | 3 | 3 | 3 | 3 |
| **World Total** | **5,856** | **6,383** | **6,623** | **5,608** | **5,052** | **3,025** | **3,045** |

e:- estimated.