NIOBIUM

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Niobium was identified in 1801 by Charles Hatchett, an English chemist, in a mineral specimen from Connecticut that was sent to the British Museum in 1753 by Connecticut Governor John Winthrop. This element was originally named columbium, after Christopher Columbus, in honour of it being discovered in a mineral from America.

Niobium is used in a wide variety of applications, ranging from the production of superconducting alloys to its use for the strengthening of high-strength, low-alloy (HSLA) steels. The consumption of niobium in 2002 has shown a slight decrease over 2001 levels, resulting in a total consumption estimated at about 56 Mlb (25,400 t). Approximately 88% of the total demand for niobium is for HSLA steel applications, where niobium is added to molten steel in the form of ferro-niobium. This is produced directly from pyrochlore concentrates mined in either Brazil or Canada.

A slight downturn in demand last year is attributed to the chemicals and vacuum-grade ferro- and nickel-niobium markets (electronics, air and land-based turbines), countered by an apparent increase in demand in the niobium-titanium, niobium-zirconium, and niobium-copper markets.

Producers in this segment of the business instituted a 35% increase in production capacity for pyrochlore concentrates during the previous two years, indicating a significant upside for raw material availability if there is a sudden increase in demand.

Niobium and tantalum are Group Vb elements that exhibit similar properties and are related mineralogically, physically, and chemically. They always occur together in nature. The economically-significant minerals containing niobium are pyrochlore and columbite, with small quantities (relatively speaking) obtained as a by-product from the processing of tantalite, tin slag and struverite. Pyrochlore is a niobium-rich mineral, low in tantalum content. Columbite can be processed directly into a ferro-niobium-tantalum alloy with a 10:1 to 12:1 ratio of niobium to tantalum. Columbite is also processed via solvent-extraction chemistry to separate the niobium from the tantalum prior to conversion into finished products ranging from vacuum-grade ferro- and nickel-niobium, to niobium chemicals (primarily niobium oxide and carbide), pure metal and alloys.

There are important properties of niobium that lead to its use in specific applications, namely, its high melting point (2,477°C), the high resistance to corrosion of the pure metal and specific alloys, the magnetic properties of specific alloys, and the grain-refining attributes and increased strength imparted to steel and super-alloys. Useful properties of niobium compounds include the hardness of niobium carbide, and the electronic and optical properties of niobium oxide and other specific compounds such as lead perovskite formulations and lithium niobate.

Production

The world's largest deposit of pyrochlore is located at Araxá, Brazil, where an open-pit mine is operated by Companhia Brasileira de Metalurgia e Mineração (CBMM). The mine supplies about 70% of the world demand for niobium products and the deposit contains an estimated 460 Mt of ore averaging 2.5% niobium oxide. The capacity of this mining operation is about 84,000 t/y of pyrochlore concentrate. The barium pyrochlore mineral is upgraded to a 65% concentrate by reducing the phosphorus, sulphur, and lead contents of the concentrate. The process involves pelletising the concentrate with coke and a binder then sintering the pellets in a steel belt furnace. The sinter is crushed and fed to an electric arc furnace with charcoal and iron powder to produce HSLA-grade ferro-niobium.

This new facility is able to produce 75,000 t/y of HSL-A grade ferro-niobium.

CBMM's facilities also produce high-purity niobium oxide (150 t/y), which is the feedstock for the production of vacuum-grade ferro- and nickel-niobium and high- purity niobium metal, the latter being produced via the direct aluminothermic reduction of the oxide, followed by electron-beam melting of the resultant ingots. Vacuum-grade ferro- and nickel-niobium capacity is 1,000 t/y. Production capacity for high purity niobium metal is 60 t/y.

The second-largest producer of pyrochlore is Mineração Catalão de Goiás (MCG), at the Catalão mine in Brazil. This deposit is similar in geology to the Araxá deposit, with a niobium oxide content of 1.34% in run-of-mine ore. Physical processing, coupled with flotation, is used to upgrade the pyrochlore mineral to a nominal 57% niobium oxide concentrate. Conversion results in a production of about 3,600 t/y of HSLA-grade ferro-niobium.

The third significant producer is Cambior Inc., a pyrochlore operation located at the Niobec mine in Chicoutimi, Québec, Canada. The mine is owned as a 50:50 joint venture between Cambior and Mazarin Inc. Mazarin manages the production operations and Cambior is responsible for marketing the ferro-niobium product. The typical product contains 66% niobium. Capacity is rated at 5,000 t/y of FeNb.

The pyrochlore mineral concentrate at the Niobec Mine, a hard-rock mine with run-of-mine ore at 0.65% niobium oxide, is upgraded to a nominal 60%+ niobium oxide content before conversion to HSLA-grade ferro-niobium. Mine reserves have been increased by 25% to 11.9 Mt during 2001-2002, a 16-year reserve at the current mining rate.

Niobium is the primary element in columbite, with tantalum as an impurity, usually in a 10 to 12:1 ratio of niobium to tantalum on a contained-oxide basis. Processors of this mineral either accept the tantalum values in their ferro-niobium alloy or process the mineral concentrate through solvent extraction to separate the niobium and tantalum prior to conversion to ferro-alloy or other purified niobium chemicals.

Metallurg has been processing niobium and tantalum minerals and slags from its Mibra mine near São João del Rei in Rondonia State in Brazil, and from mineral concentrates acquired from local producers as well as sources external to Brazil. A solvent extraction system at the Fluminense subsidiary is used to achieve separation of the niobium and tantalum that are processed and sold as oxides. Niobium oxide production was about 350 t in 2002.

Niocan has announced that production of pyrochlore from its Oka, Québec deposit will commence in late 2004 or early 2005. Proven reserves indicate a 17- year minimum life at the planned rate of operation. The ferro-niobium would be sold via already negotiated purchasing agreements with major customers in Japan, North America, and Europe.

The Pitinga tin mine in the Amazonas region of Brazil is operated by Mamoré Mineração e Metalurgia, part of the Paranapanema Group. The ore is processed into a cassiterite concentrate for the recovery of tin, and a cassiterite-columbite concentrate from which a ferro-niobium-tantalum alloy is produced. This is sold to industry and has an assay value of 50% niobium and 5% tantalum. Production is estimated at about 2.0 Mlb (900 t) of niobium per year. A solvent extraction circuit has also been installed and is producing both tantalum and niobium oxides, with production of niobium oxide estimated at about 500 t/y. The slag from the processing of cassiterite concentrates contains both niobium and tantalum oxides recovered from the columbite impurity. The inventory of niobium oxide in these slags is estimated at 25 to 30 Mlb.

The large pyrochlore deposit in central Gabon, known as the Mabounié Project, is 35% owned by Cluff Mining. The indicated resource is 16.72 Mt of ore at an average grade of 1.75% Nb_2O_5, and there is an indicated reserve of 292,000 t of niobium oxide. Negotiations are under way for one of the joint-venture partners to purchase Cluff Mining's 35% ownership.

Because niobium always occurs with tantalum, any potentially large tantalum project is also going to be a potential source for niobium as the mineralisation always includes both elements. Two examples of deposits currently under review for tantalum which fit into the category of being niobium producers, having at least 10 times the quantity of tantalum content as the niobium content, are the Ghurayyah Project in Saudi Arabia (Tertiary Minerals plc) and the Motzfeld deposit in Greenland (Angus & Ross plc).

The largest processors of tantalite, columbite and other niobium source materials are companies such as H.C. Starck, Cabot Supermetals, Mitsui Mining and Smelting, and Ningxia Non-ferrous Metals Co. The niobium in these mineral sources requires that a solvent extraction circuit be employed to separate and purify the tantalum and niobium constituents prior to the production of various niobium compounds, metal and alloys. These companies generally manufacture a niobium product line where individual chemical impurity levels are measured at well below 50 parts per million, with some products being of optical quality. When used as an additive for the manufacture of certain alloys in aircraft and land-based turbine applications, requirements for niobium metal, or vacuum-grade ferro- or nickel-niobium, specify exceedingly small percentages of low-temperature melting-point elements such as lead, tin, and zinc.

The chemical processing of niobium in mineral concentrates into oxide, carbide, and chloride, plus conversion, usually of oxide into various forms of metal and alloys, generally directs the resultant products into niche applications requiring high-value products.

Other companies involved with the processing of niobium raw materials and production of chemicals, niobium metal and various alloys are A.S. Silmet, Wah Chang, Osram Sylvania, Zhuzhou Cemented Carbide Works, Reading Alloys, Conghua Tantalum & Niobium, Duoluoshan Sapphire Rare Metal Co., F & X Electro-Materials Ltd., and Jiujiang Tanbre Smelter.

A summary of niobium raw material production from 1999 through 2002 are shown in Table 1.

Consumption

Shipments for all niobium-containing products totalled an estimated 53 Mlb in 2002.

The largest niobium-product segment by volume is the HSLA ferro-niobium material that saw shipments of 49.28 Mlb of contained niobium in 2001 compared with an estimated 46.85 Mlb in 2002. Shipments of HSLA-grade ferro-niobium represented about 88% of the total niobium shipments in 2002. Shipments of HSLA-grade steel decreased about 5% from the 2001 levels.

HSLA-grade steel is used in the production of pipeline for the oil and gas industry, automotive steel for car bodies and exhaust systems, and microalloyed steels for structural applications. The US and Europe consume about 73% of the total HSLA ferro-niobium production.

The superconducting alloy segment, primarily niobium-titanium and niobium-zirconium, has shown a very significant increase when one compares 2001 shipments of 700,000 lb of contained niobium to 820,000 lb in 2002. The most likely explanation for this increase is some increase in shipments of niobium-titanium used for the construction of the magnetic coils for the Large Hadron Collider (LHC) project at Cern, near Geneva, Switzerland. Another reason for the increase is due to requirements for second-generation magnetic resonance imagery (MRI) equipment. Niobium-titanium is the primary material used in the construction of the magnetic coils for MRI equipment utilised in medicine for the detection of anomalies in soft tissue. No radiation is involved.

The rate of consumption for the segment comprising chemicals and vacuum-grade ferro- and nickel-niobium, comparing 2001 with 2002, has seen a decrease of about 27%. Niobium chemicals, primarily niobium oxide, are used in a wide variety of applications including: lenses with high refractive index; high dielectric, multilayer ceramic capacitor (MLCC) formulations; and in the manufacture of lithium niobate for surface acoustic wave (SAW) filters. Niobium carbide is used in the manufacture of cutting tools and in wear-resistant applications. The vacuum-grade ferro- and nickel-niobium are used in the production of nickel-based super-alloys where compositions range from 1% to 5% niobium. These alloys are used in aerospace and aircraft turbines, with land-based turbines also consuming significant quantities of niobium. The total amount of niobium consumed in 2002 was about 4.9 Mlb.

Capacitor applications for a very high surface area niobium monoxide, NbO, have become contenders for placement on circuit boards. Capacitors are available up to ratings of 470 microfarad (mfd) rated capacitors. Advantages include: good stability under thermomechanical stress and higher temperature peak solder reflow conditions with no sensitivity to mechanical weakness; no piezo effect, as seen with high CV barium titanate; lower ESR at higher temperatures; 95% reduction in failure rates due to ignition compared with tantalum; reduced voltage derating requirements in low impedance circuits; and high resistivity short-circuit failure mechanism.

The last group of niobium products comprises the pure metal and wrought forms of the pure metal, such as sheet, rod, and tubing utilised in applications such as corrosion-resistant equipment for the chemical processing industry, sputtering targets, and cathodic protection systems. This segment consumed about 530,000 lb in 2002, which is about 1% of the total worldwide demand for this element.

Another application is the use of niobium metal powder in solid-state capacitors as a competitor for tantalum and aluminium in specific circuitry requirements. Technical papers presented during 2002 suggest that many of the major obstacles of performance and reliability have been overcome. Technical advances, such as nitrogen doping, and the use of the organic semiconductor for the cathode are being utilised to offset the problem of the more severe dielectric breakdown of the niobium oxide film. The potential area of replacement by niobium is in the low voltage ratings, specifically those at four, six and ten volts at ratings up to 470 mfd, with products generally marketed as replacements for aluminium capacitors (Table 2).

Pricing

There are no published prices for pyrochlore concentrates. These concentrates are consumed by those companies that mine and upgrade this mineral. Niobium-bearing minerals and products are not traded on the London Metal Exchange. The Tantalum-Niobium International Study Center has no knowledge or comment concerning any published prices of these mineral concentrates or the accuracy of that information should it become available.

HSLA-grade ferro-niobium reportedly has had stable pricing over the past 20 years, broadly in the range of US$6.50-7.50/lb of contained niobium. Prices for niobium oxide, other niobium chemicals, niobium metal and various alloys derived from either pyrochlore or other niobium-bearing sources are highly variable and depend on product specifications, volume, and processing considerations.

Table 1.

Niobium Raw Material Production (Mlb contained niobium oxide)				
	1999	**2000**	**2001**	**2002[e]**
Pyrochlore and columbite concentrates	70.62	72.52	98.89	107.8
Tantalite, struverite, Tin slag	2.57	1.20	1.51	1.0
Total	**73.17**	**73.72**	**100.40**	**108.8[e]**

Source: Tantalum-Niobium International Study Center. e: estimated
The 2002 data is based on actual data collected from the membership of the Tantalum-Niobium International Study Center for the first six months of 2002 plus estimates for the second six month period of the year.

Table 2.

Niobium Product Shipments (Mlb contained niobium)				
	1999	**2000**	**2001**	**2002[e]**
Chemicals, VG FeNb, NiNb	4.91	6.32	6.74	4.9
Pure Nb metal as mill products, ingot,				
powder, scrap	0.33	0.48	0.61	0.5
Alloys of NbTi, NbZr, NbCu	1.02	1.18	0.70	0.8
HSLA – FeNb	44.36	44.91	49.28	46.9
Total	**50.62**	**52.89**	**57.32**	**53.1[e]**

Source: Tantalum-Niobium International Study Center. e: estimated.
The 2002 data is based on actual data collected from the membership of the Tantalum-Niobium International Study Center for the first six months of 2002 plus estimates for the second six month period of the year.