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 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 HSLA (high strength, low alloy) steels. The consumption of niobium in 2001 has shown an 8.4% increase over 2000 levels, resulting in a total consumption of 57.32 Mlb. Approximately 86% of the total demand for niobium is for HSLA steel applications: the niobium is added to the molten steel in the form of ferro-niobium that is produced directly from pyrochlore concentrates mined in either Brazil or Canada.

Producers in this segment of the business demonstrated a 35% increase in production capacity for pyrochlore concentrates 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 superalloys. 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. This open-pit mine is operated by Companhia Brasileira de Metalurgia e Mineração (CBMM), which supplies about 70% of the world demand for niobium products. This mine contains 460 Mt of ore at 2.5% niobium oxide. An investment of US$78 million in 2000 increased capacity in the pyrochlore concentration facilities from 50,000 t to 84,000 t/y. The barium pyrochlore mineral is upgraded to a 65% concentrate that is converted via aluminothermic reduction to HSLA grade ferro-niobium. In 2000, the capacity for ferro-niobium was increased from 30,000 to 45,000 t/y.

These 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.

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 pyrochlore operation is located at the Niobec mine in Quebec, Canada. The mine is operated as a 50:50 joint venture between Cambior, which is responsible for the marketing activities of the joint venture, and Mazarin Mining Corp., which is responsible for operation of the mine and production of ferro-niobium.

The pyrochlore mineral concentrate is produced from a hard-rock mine with run-of-mine ore at 0.68% niobium oxide being upgraded to a nominal 60%+ niobium oxide content before conversion to HSLA grade ferro-niobium. Production of ferro-niobium increased to a total of about 3,000 t/y of contained niobium following the completion of a two-phase expansion in 2001 equivalent to a ferro-niobium production capacity of 4,250 t/y.

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 the 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 2001.

The Pitinga tin mine in the Amazonas region of Brazil is operated by Mamoré Mineração e Metalurgia of the Paranapanema Group. The ore is processed into a cassiterite concentrate (tin recovery) and a cassiterite-columbite concentrate from which a ferro-niobium-tantalum alloy is produced for sale to the industry with an assay of 50% niobium and 5% tantalum content. Production is estimated at about 2 Mlb/y of niobium. A solvent extraction circuit has also been installed and is producing both tantalum and niobium oxides. 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 27 Mlb.

Other large potential mining operations being evaluated currently are the Mabounié deposit in Gabon (Cluff Mining); the Mt Weld Deposit in Australia, a weathered pyrochlore containing an estimated 278 Mt at 9% niobium oxide (Lynas Corporation); the Dubbo zirconia project, also in Australia (Alkane Exploration); and the Tarsky phosphate-niobium deposit in the Motyginsjy region of Krasnoyarsk, which has been commissioned by Severstal, the largest steel producer in Russia. An ore concentration complex is planned along with a unit to produce ferro-niobium.

The largest processors of tantalite, columbite and other niobium source materials are companies such as H.C. Starck, Cabot Performance Materials, 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 ppm, with some products being of optical quality. Niobium metal or vacuum-grade ferro- or nickel-niobium purity requirements demand exceedingly small percentages of low-temperature melting point elements, such as lead, tin, and zinc when used as an additive for the manufacture of certain alloys in aircraft applications. This segment of the industry generally focuses on 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, and Reading Alloys.

A summary of niobium raw material production from 1998 through 2001 is shown below.

Niobium Raw Material Production (Mlb contained niobium oxide)

	1998	1999	2000	2001
Pyrochlore and columbite concentrates	76.53	70.60	72.52	98.89
Tantalite, struverite, tin slag	0.92	2.57	1.20	1.51
Total	**77.45**	**73.17**	**73.72**	**100.40**

Source: Tantalum-Niobium International Study Center

The year 2001 showed an approximate 35% increase in pyrochlore production indicating there is very significant capacity in reserve for raw materials if there is a sudden surge in demand.

Consumption

The shipments for all niobium-containing products totalled 57.32 Mlb in 2001.

The most significant growth segment is the HSLA ferro-niobium material that saw shipments of 49.28 Mlb of contained niobium in 2001 compared with 44.91 Mlb in 2000, equivalent to a growth rate of 9.7%. The HSLA grade of ferro-niobium represents 86% of the total niobium shipments in 2001.

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 NbTi and NbZr, has shown a very significant decrease when one compares 2000 shipments of 1.18 Mlb of contained niobium to 0.70 Mlb in 2001. The most likely explanation for this decrease is the completion of shipments for the contracted quantities of NbTi and niobium metal used in the construction of the magnetic coils for the Large Hadron Collider (LHC) project at Cern, near Geneva, Switzerland. This project has consumed about 400 t of niobium-titanium alloy and 23 t of pure niobium. Niobium-titanium is also the primary material used in the construction of the magnetic coils for Magnetic Resonance Imagery (MRI) equipment utilised in medicine for the detection of anomalies in soft tissue.

The growth rate for the segment composed of chemicals and vacuum-grade ferro- and nickel-niobium, comparing 2000 to 2001, has been an increase of 6.6%. Niobium chemicals, primarily niobium oxide, are used in a wide variety of applications including lenses with high refractive index; high dielectric, multilayer ceramic capacitor formulations; and in the manufacture of lithium niobate for Surface Acoustic Wave (SAW) filters, commonly used in electronic circuitry. 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 superalloys 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 by this segment last year was 6.74 Mlb.

The last group of niobium products are the pure metal and wrought forms of the pure metal, such as sheet, rod, and tubing that are utilised in applications such as corrosion-resistant equipment, sputtering targets, and cathodic protection systems. This segment consumed about 600,000 lb in 2001, which is about 1% of the total worldwide demand for this element.

Another application is the use of niobium powder in solid-state capacitors as a replacement for tantalum in specific circuitry requirements. Technical papers presented during 2001 suggest that the major obstacles of performance and reliability are being carefully studied. Technical advances have been discovered to offset, at least partially, the problem of dielectric breakdown of the niobium oxide film. The potential area of tantalum replacement by niobium is in the low voltage ratings, specifically, those at 4, 6, 10 and perhaps 16 volts. It is still unclear whether the amount of penetration of niobium into tantalum requirements for capacitors will have a significant impact on the demand and growth rate for tantalum.

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 twenty years, broadly with a 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 depending on product specifications, volume, and processing considerations.

Niobium Product Shipments (Mlb contained niobium)

	1998	1999	2000	2001
Chemicals, VG FeNb, NiNb	4.87	4.91	6.32	6.74
Wrought Nb, Nb alloys as mill products, powder, ingot, and scrap				
Pure niobium	0.38	0.33	0.48	0.61
Alloys as NbTi, NbZr, NbCu	0.85	1.02	1.18	0.70
HSLA-grade FeNb	53.06	44.36	44.91	49.28
Total	59.16	50.62	52.89	57.32

Source: Tantalum-Niobium International Study Center