Niobium: A Bridge Between China and Brazil

Erik Bethel and Angela Ku
+ 86 (21) 6109-9568 x 8015
ebethel@sinolatincapital.com /aku@sinolatincapital.com

Niobium is a relatively obscure mineral mainly used in MRI machines, high technology, and the steel industry. It has anti-corrosive characteristics in addition to other properties that affect the hardening strength of steel. China is the world's largest producer of steel, and therefore the single-largest consumer of niobium. Brazil has the world's largest reserves of niobium and one Brazilian producer accounts for 60-70% of the world's market share.

In this White Paper, SinoLatin Capital analyzes the element niobium, discusses factors influencing supply and demand, and studies how this obscure element is an important link between China and Latin America.

SinoLatin Capital (www.sinolatincapital.com) is the first financial services firm focused exclusively on M&A and private equity transactions between China and Latin America. The firm is narrowly focused on two industries: natural resources and infrastructure. SinoLatin Capital's partners include both Latin American and Chinese individuals who have executed US$26 billion worth of transactions in their careers. The partners have formerly worked for bulge-bracket Wall St. firms and speak Spanish, English, Portuguese and Chinese. SinoLatin Capital is headquartered in Shanghai, China with offices in New York City and Lima, Peru.

ebethel@sinolatincapital.com
+ 86 (21) 6109-9568 x 8015

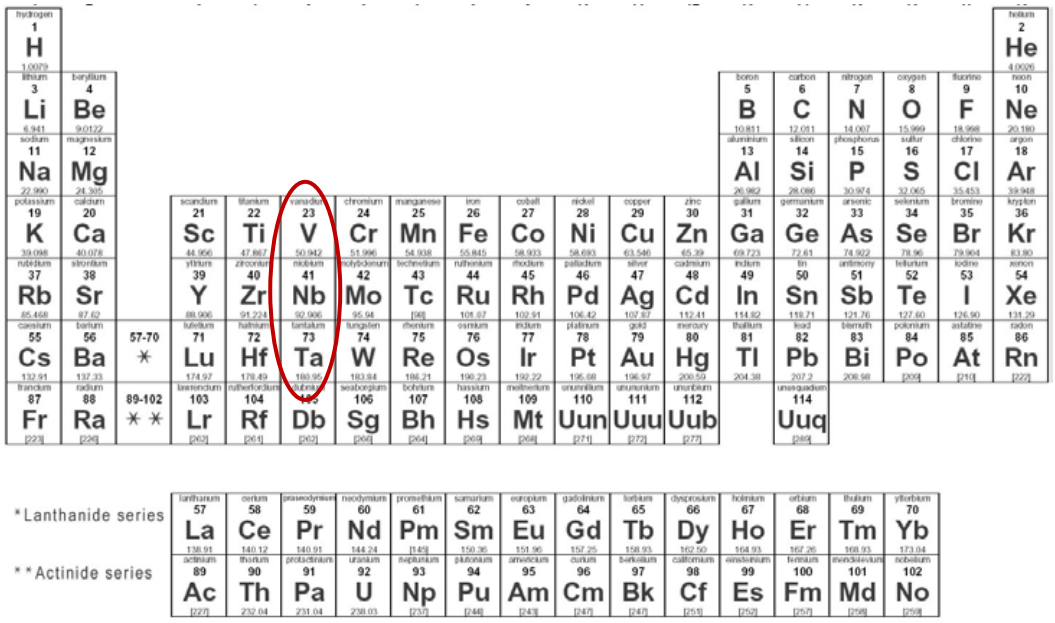
What is Niobium?

Niobium (or columbium) is the chemical element with the symbol Nb and the atomic number 41. It used to be called Columbium. Niobium is named in honor of Niobe, a figure in Greek mythology whose father was Tantalus (for whom the element tantalum is named)

Niobium is a relatively light, ductile transition metal with the symbol Nb and the atomic number 41. The element was discovered in 1801 by the English chemist Charles Hatchett, who originally named the element "Columbium," in honor of Christopher Columbus. Then in 1950, its name was changed to Niobium (Nb) by the International Union of Pure and Applied Chemistry. Despite the name change, many commercial producers still use the term columbium in the United States.

Niobium has similar physical and chemical properties to the element tantalum and they are related mineralogically. In many ways the two elements are difficult to distinguish. Aside from its similarities with tantalum, niobium is also in the same group as vanadium (as shown in Figure 1). Niobium's strengths include: good electrical capacitance, high melting point, and has the highest "magnetic penetration depth" of any element, making it optimal for use in MRI machines and superconductors.

Figure 1: Niobium is in the same group as tantalum and vanadium



Where is Niobium Found?

Niobium is primarily found in a mineral known as pyrochlore, and over three-quarters of the world's niobium production currently comes from Brazil.

Niobium does not occur freely in nature. It is primarily found in pyrochlore, a niobium-rich, complex mineral of calcium and sodium that also contains iron, titanium, rare earths and other elements. Pyrochlore, in the form $NaCaNb_2O_6F$, is the most important mineral for niobium extraction and production. As niobium and tantalum are similar elements, they occur together in nature. Niobium can also be found in columbite, which is a niobate of iron and manganese that can be processed directly into a ferroniobium-tantalum alloy with a 10:1 to 12:1 ratio of niobium to tantalum.

Over three-quarters of the world's niobium production currently comes from Brazil, with most of the remainder coming from eastern Canada. The rest is made up by small amounts of production from Western Australia, China and Central Africa. There are also large, yet unexplored reserves in the Democratic Republic of Congo, Nigeria, Colombia and Russia. A relatively large amount of niobium is recovered in recycling, primarily as a by-product of recycling other metals associated with niobium. Niobium is not generally shipped as a mineral concentrate, but it is instead converted to ferroniobium (FeNb), an alloy of iron and niobium.

Brazil:

It is impossible to think of niobium as anything other than a "Brazil-play." And the top producer has a 60-70% market share.

The world's largest deposit of pyrochlore is located at Araxá, in Minas Gerais State, Brazil, and is owned by *Companhia Brasileira de Metalurgia e Mineração (CBMM)*. CBMM's mine, with grades running between 2.5 - 3.0% Nb_2O_5, is operated as an open-pit, without much need for drilling or explosives. The Araxá deposit contains about 460 million tons, enough reserves to supply current world demand for about 500 years. Production at Araxá today supplies between 65% and 70% of the world demand for niobium products.

Companhia Brasileira de Metalurgia e Mineração (CBMM):

- CBMM was started in the late 1950s and early '60s as a firm focusing on the commercialization of products from a newly discovered ore body containing niobium
- Its market share is 60 to 70% — larger in some markets, smaller in others. CBMM sells more niobium or niobium-derived products than the rest of its competitors together
- Predominantly family-owned business, although the US corporation Unocal, through one of its subsidiaries, holds a minority position. The Brazilian state of Minas Gerais also owns a 25% stake.
    - The Moreira Salles Group, which holds the majority position in CBMM, also has a major stake in Unibanco, one of the largest banks in Brazil
- CBMM does not have a very typical management structure. There are essentially two shareholder groups. One is Unocal, the US based energy company, and the other is the Moreira Salles Group. Unocal has no management responsibility. CBMM does not have a board of "outside" directors.

There are other important niobium miners, but their market share is considerably smaller.

The world's second-largest deposit of pyrochlore is also found in Brazil, the Catalão open pit mine, operated by *Anglo American's Mineração Catalão de Goiás (MCG)*. This deposit is similar in geology to that of Araxá, with a niobium oxide content of 1.34%. It is estimated that the mine has proven reserves of about 18 million tons. After processing and conversion, production is about 3,500 t/y of HSLA-grade ferroniobium. Anglo American's market share is estimated to be between 14 - 18%.

In Brazil, there are two other smaller niobium operations, *Metallurg* and *Mamoré*. When taken together, the two mines produce less than 10% of total niobium supply. Metallurg, owned by *Companhia Industrial Fluminense*, processes niobium, tantalum minerals and slag from its Mibra mine near São João del Rei in Brazil's Rondonia State, from mineral concentrates acquired from local producers and outside Brazil. *Mamoré Mineração e Metalurgia*, a member of the Paranapanema Group, operates the Pitinga tin mine in the Amazonas region of Brazil. The ore is processed into a cassiterite-columbite concentrate (for tin recovery) and the

columbite-containing slag is processed to yield a ferroniobium-tantalum alloy containing 50% niobium and 5% tantalum.

Canada:

The third major deposit of pyrochlore is the Niobec Mine in northeastern Quebec, Canada, owned by IAMGOLD. Previously, the Niobec mine was owned by Cambior, which was acquired by IAMGOLD in 2006. The mine is the only producer of niobium in North America and produces between 12% and 14% of the world's supply of niobium. The Niobec mine has reserves of 24.3 million tons averaging 0.66% Nb_2O_5.

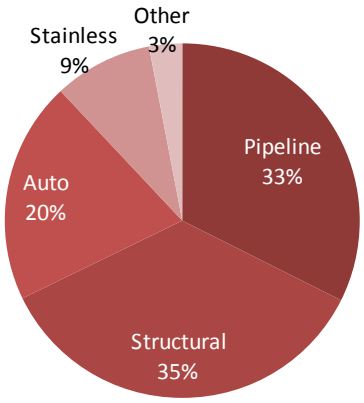
In the three largest mining operations listed above, the pyrochlore mineral is processed primarily by physical processing technology to give a concentrate ranging from 55 to 60% niobium oxide. These three deposits provide about 85% of the world's demand for niobium products, with most of that output in the form of ferroniobium (FeNb) comprised of around 60-65% niobium oxide. Its use, as described, below, is mainly for making "high-strength, low-alloy" (HSLA) steel.

What is Niobium Used For?

Niobium's main use is in the steel industry. A small amount of niobium can increase the quality of the steel considerably.

Niobium is most used in HSLA steel, and the largest end market for HSLA steel is for large pipelines for the transmission of oil and natural gas. As Figure 2 shows, about a third of niobium is used for pipeline steels, representing the largest application of ferroniobium. Although alloys used in HSLA contain only a maximum of 0.1%, that small percentage of niobium greatly improves the strength of the steel.

Figure 2: Applications of Ferroniobium (FeNb) in China (2009)



Source: CBMM.

In structural steels the addition of niobium imparts strength, hence the name high-strength low-alloy (HSLA) steels. Mainly used in the automotive industry, HLSA steel's increased strength allows for thinner and lighter structural designs, thus improving energy efficiency. Because niobium is also corrosion resistance, it is also very important in tubular steels for gas pipelines on land or sea.

Super-alloys such as nickel-based "Inconel alloys" are widely used in aircraft engines, where the use of niobium is assured for the foreseeable future as they cannot easily be substituted once they are engineered and tested. Alloys of up to

13% Nb are also used for bone replacements in medicine, while U-Nb alloys of 2-8% Nb exhibit shape-memory effects.

Niobium is also used as high-purity and optical-grade oxides. These oxides are destined for high refractive-index lenses and electronic capacitors, providing a compact form and inherent thermal stability, as well as for making lithium niobate for surface acoustic wave (SAW) filters. Pure niobium metal is used in super-conducting Nb-Ti wire for applications such as magnetic resonance imaging and particle accelerators.

Niobium complexes are used as catalysts for producing bio-fuels from vegetable crops, whereas carbides are used to produce cutting tools. Overall, as Figure 3 illustrates, there is a wealth of uses for this metal.

Figure 3: Applications for Niobium

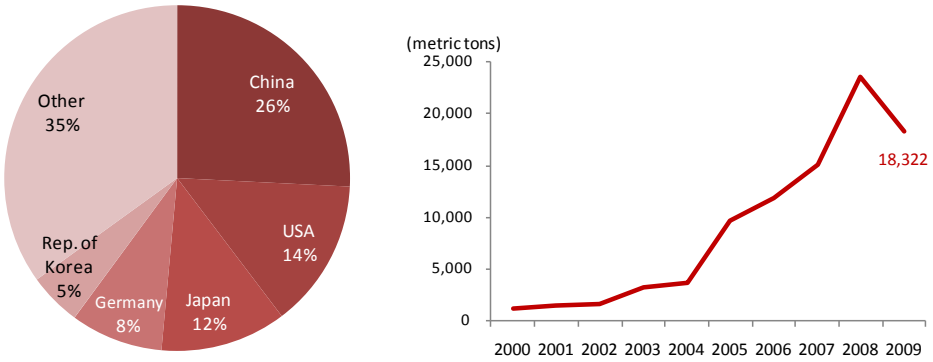
Niobium oxide	Lithium niobate for surface acoustic wave filters. - Camera lenses. - Glass coating on computers. - Ceramic capacitors.	- High index of refraction - High dielectric constant. - Increase light transmittance.
Niobium carbide	Cutting tool compositions.	High temperature deformation, controls grain growth.
Niobium powder	Niobium capacitors for electronic circuits.	High dielectric constant, stability of oxide dielectric.
Niobium metal plates, sheets, wire, rod, tubing	- Chemical processing equipment. - Sputtering targets. - Cathode protection systems for large steel structures.	Corrosion resistance, formation of oxide and nitride films. Increase in high temperature resistance and corrosion resistance, oxidation resistance, improved creep resistance, reduced erosion at high temperatures.
Niobium-titanium alloy Niobium-tin alloy	Superconducting magnetic coils in magnetic resonance imagery (MRI) equipment, magnetoencephalography, magnetic levitation transport systems, particle physics experiments.	Electrical resistance of alloy wire drops to virtually zero at or below temperature of liquid helium (-268.8°C).
Niobium-1% zirconium alloy	- Sodium vapor lamps - Chemical processing equipment	Corrosion resistance, fixation of oxygen, resistance to embrittlement.
Vacuum-grade ferro-niobium and nickel-niobium	Superalloy additions for turbine blade applications in jet engines and land-based turbines. Inconel family of alloys, superalloys.	Increase in high temperature resistance and corrosion resistance, oxidation resistance, improved creep resistance, reduced erosion at high temperatures.

Source: Tantalum-Niobium International Study Center.

Niobium and China

China has played a crucial role in the growth of niobium applications, particularly in the steel industry. Today China is the single strongest market for niobium in the world. At present, while China consumes around 25% of all ferroniobium produced, a negligible amount is produced domestically. As such, China has been a top importer of FeNb in recent years, and its imports have increased over the last decade. (See Figure 4).

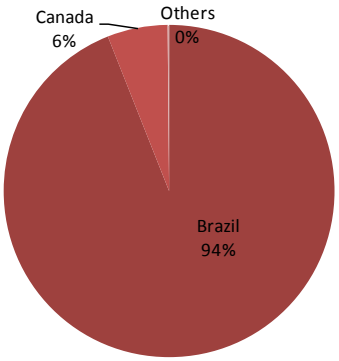
Figure 4: Top FeNb Importers (2009) and China Imports of FeNb (2000-2009)



Source: UN Comtrade.

As mentioned, China is the strongest FeNb market. As Figure 5 shows, China imports almost all of its niobium from Brazil, mainly from the top producer CBMM.

Figure 5: China FeNb Imports by Country (2009)



Source: UN Comtrade.

Niobium is a Brazil – China story. China is the world's single largest consumer. Brazil is the largest producer.

Conclusion

The story of niobium is one of a direct link between China and Latin America. In this case, China is the largest consumer of niobium and Brazil is the largest producer. We believe the growth of Chinese niobium consumption from Brazil parallels the growth in Chinese steel and superalloy production. Keep in mind that it isn't just the growth in absolute volume of steel that will drive growth in niobium. It is important to look deeper. Today, there is a sharp rise in FeNb consumption in China, expressed in grams of FeNb consumed per ton of crude steel produced. China has more than tripled its specific FeNb consumption from 11g/t in 2004 to 35g/t in 2008, implying that steel mills are not just producing more product, but also that the product's quality (expressed in the increased use of niobium) is also increasing.

Partners
Jorge J. Barreda
Erik Bethel
Luis Gómez
Mei Lu
Rafael Valdez

Professional Staff
J. Gregory Arthur
Felipe Canales
Sean Chang
Nina Chen
Maria de la Rocha
Angela Ku
Simon Wu
Betty Yang
Tony Yang

SinoLatin Capital
info@sinolatincapital.com
www.sinolatincapital.com

Min Sheng Lu #1518-A
Suite 703A, 200135
Shanghai, China
Tel: +86 (21) 6109-9668
Fax: +86 (21) 6109-9570

100 Park Av.
Suite 1600
New York, NY 10017
Tel: +1 (212) 984 – 1016
Fax: +1 (212) 880 - 6499