

Niobium

Niobium is a shiny ductile metal with a white lustre, which takes on a bluish tinge when exposed to air at room temperature. It has many similarities to tantalum (see February 2006) and both are often found in niobium minerals.

This close relationship gave the German analytical chemist Heinrich Rose the inspiration to change the element's name from columbium, the name given in 1801 by its discoverer, the English chemist Charles Hatchett, to niobium after Niobe, the daughter of Tantalus. The original name was apparently chosen because its source was a columbite mineral found in Connecticut, USA.

Of the refractory metals, niobium has the lowest melting point (2,470°C), thermal conductivity (0.523 cal/sec per sq cm°C/cm) and density (8,570 kg/m³). Niobium offers similar corrosion resistance to tantalum, yet it is formable, weldable and easier to machine.

Niobium is available in foil, sheet, wire, insulated wire, powder, rod, turnings and tube. The metal price is usually around one sixth of tantalum's, making it a lower-cost alternative solution for high-strength, low-alloy steel.

Niobium is ten times more abundant in the Earth's crust than tantalum, with an average of 20 ppm. Approximately 90% of current niobium production is obtained from the mineral pyrochlore according to the Tantalum-Niobium International Study Center (TIC).

EXTRACTION

Large pyrochlore deposits are found in Brazil and smaller reserves in Canada and the Democratic Republic of Congo (DRC). The largest, 457m tonne, deposit of pyrochlore is in Araxá, Brazil and is owned by Companhia Brasileira

de Metalurgia e Mineração (CBMM) and Companhia Mineradora de Minas Gerais (Comig). CBMM currently has a production capacity of 45,000 tpy of ferro-niobium, which it is planning to expand to 70,000 tpy.

Anglo American Brasil Mineração Catalão's open pit deposit in Brasil contains 18m tonnes at 1.34% niobium oxide. The company's production rose 14% to 4,000 tpy after completing a scalping project last year.

In Quebec, Canada's Cambior operates the world's only underground niobium mine. The Niobec mine has reserves of 24.3m tonnes at 0.66% niobium oxide and the company is investing US\$3.9m this year to maintain its 12-14% of global market share.

Other very large deposits of pyrochlore



Cambior uses a powerful exothermic reaction between niobium pentoxide concentrates, iron, aluminium powder and other agents to produce a ferro-niobium button, which is then cooled, cleaned and crushed

Cambior

exist, but their exploitation is unlikely because of the dominant market position of existing producers and their substantial spare capacity. Nevertheless, the Niocan Inc. project in Canada may come into production in the medium-term and possibly even rival Cambior's niobium output.

The US Geological Survey (USGS) estimates that Brazil has 4,300,000 tonnes of niobium reserves, Canada's reserves equal 110,000 tonnes and Australia has 29,000 tonnes.

Niobium is also extracted from columbite – providing 7.5% of total primary supply – located in Australia, Brazil, Canada, Nigeria and the DRC, when the mineral's tantalum content is processed. The metal is also found in small quantities in tantalite, tin slags, struverite and loparite.

Columbites are refined in the same way as tantalites but fluoride reduction is carried out with aluminium rather than sodium. The purified niobium-containing mixture is generally converted to niobium hydroxide by the introduction of ammonia, followed by washing, filtration, and calcining to the oxide.

The pyrochlore mineral is mainly processed to produce a HSLA-quality ferro-niobium with niobium oxide content ranging from 55% to about 66%. Niobium oxide from pyrochlore is either converted into niobium ingots through aluminothermic reduction (around 2,400°C), using no external source of energy, or by reduction in an electric arc furnace.

Double- and triple-melt ingots achieve a very high level of purification with respect to metallics and interstitial elements. Ingots are used to produce niobium alloys such as niobium-1% zirconium, niobium-titanium, C-103 and Inconels.

During 2004, global niobium raw material production was 101.7m lb (46,150 tonnes) niobium pentoxide contained according to TIC. In the first half of last year, 59.7m lb (27,092 tonnes) niobium pentoxide contained were produced.

TIC's figures show that niobium processors' shipments totalled 44.7m lb (20,317 tonnes) niobium contained in the first half of last year, while deliveries equalled 72.3m lb (32,830 tonnes) during 2004.

Estimated world mine production (tonnes)*

	Mine production in 2005
Australia	200
Brazil	29,900
Canada	3,400
Congo (Kinshasa)	52
Ethiopia	6
Mozambique	110
Namibia	1
Nigeria	170
Rwanda	63
Uganda	2
World total	33,904

*Bolivia, Burundi, China, Russia, Zambia and Zimbabwe also produce niobium, but production data are not available from these countries
Source:USGS

Little niobium is specifically recovered from products just for the niobium content. Yet as much as 20% of US apparent consumption of 7,180 tpy of niobium may come from recycled sources according to the USGS.

APPLICATIONS

Niobium is principally consumed as ferro-niobium, which is an important ingredient in high strength low alloy (HSLA) grade steels. HSLA ferro-niobium represented 89% of the total niobium HSLA steel contained shipments in 2004 by TIC member companies (see table), although HSLA steel only equates to about 10% of all steel currently produced.

According to the USGS, the end-uses for niobium are in carbon steel (30%), HSLA steel (22%), superalloys (20%), alloy steel (14%), and in stainless and heat-resisting steels (13%).

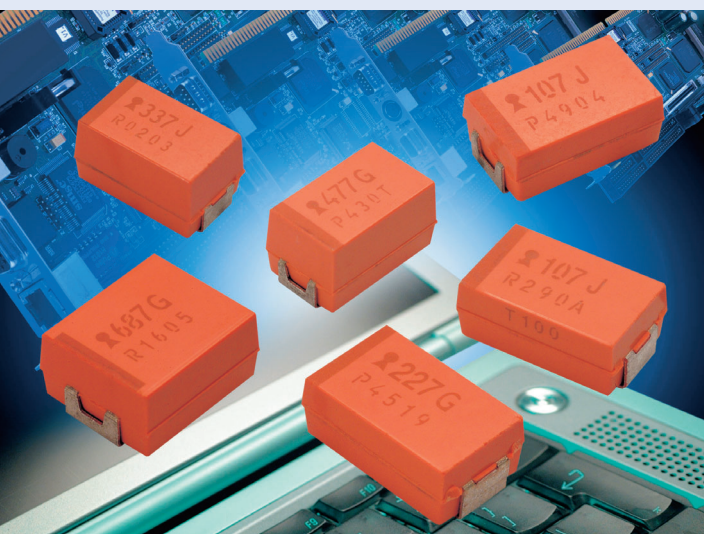
Niobium acts as a grain refiner and hardener in HSLA steel used for off-shore oil pipelines, construction and automobiles. It is also added to stainless steel to stop embrittlement after welding.

Significant growth potential for niobium use is expected to come from future increases in HSLA steel production, especially in China and Russia, where niobium consumption is estimated to be below the average of other major industrialised economies.

Niobium's high-temperature and corrosion resistance make it a fundamental ingredient in the manufacture of superalloy jet engine components, rocket sub-assemblies and combustion equipment. It also has the low thermal-neutron capture cross-section required for nuclear engineering applications when alloyed with zirconium.

Niobium carbide is used in cemented carbides to impart toughness and shock resistance to the cobalt-bonded, tungsten-carbide-base material for cutting tools. Niobium-titanium or -tin alloy lower the electrical resistance of alloy wire when cooled to temperatures approaching absolute zero in superconducting magnetic coils used in nuclear magnetic resonance imagery for medical diagnostics or in particle accelerators.

AVX predicts that the market for niobium oxide capacitors is likely to be 50% greater in 15 years' time compared with 10-14% greater for tantalum capacitors



Niobium applications

Product	Niobium content (lb)
HSLA ferro-niobium	64,455,630
Chemicals – oxide and chloride	3,376,085
Vacuum grade ferro-niobium and nickel-niobium	2,871, 817
Pure metal in mill products, ingot, powder and scrap	1,001,341
Alloys – niobium-titanium, niobium-zirconium in mill products, powder and scrap	672,585
Total	72,377,458

Data for 2004

Source:TIC

Niobium oxide improves the refractive index of optical glass, allowing thinner and lighter lenses. It is also used to manufacture capacitors and this emerging market is viewed by London-based analysts Roskill as a future rival to superalloys in terms of production share.

Niobium metal was initially used for capacitors 50 years ago by the former USSR because of the lack of availability of tantalum within the country. It was only in 2000, when tantalum supplies were thought to be decreasing, that international capacitor manufacturing companies like AVX launched niobium metal capacitors as an alternative product.

But AVX's Tantalum Division Technical and Quality Director William Millman says that, within the capacitor market, niobium metal has long been seen as the poor cousin to tantalum because of its instability, poor reliability and high leakage level. These problems have been overcome by the use of robust, cost-competitive niobium oxide capacitors that can be used effectively in applications where a tantalum capacitor would not be possible.

Niobium oxide is replacing aluminium and ceramic-multi-layer capacitors in some automotive, notebook and LCD/plasma screen applications because of its high-resistance characteristics and smaller product size.

Millman told MBM that niobium capacitors are complementary to tantalum and will only become a substitute if there is a future tantalum shortage. He forecasts that the market for niobium oxide capacitors is likely to be 50% greater in 15 years' time compared with 10-14% greater for tantalum capacitors.

AVX's niobium oxide 'OxiCap' capacitor represents 10% of the company's current US\$262.9m tantalum component sales. The company's supply of niobium oxide is sourced from outside the tantalum supply chain, which means it is very stable in terms of both availability and price.

The USGS says the typical price for standard-grade ferro-niobium is between US\$6.45 and \$6.70 per lb of niobium content. Roskill says that the leading role of a small number of producers has kept ferro-niobium's price stable but in real terms the price is falling.

At the risk of lower performance and cost-effectiveness, niobium may be replaced by molybdenum or vanadium as an alloying element in HSLA steel, and by tantalum or titanium in stainless steel and high-temperature applications, according to the USGS.