ROCKHOUND NEWSLETTER
石 犬 通 訊

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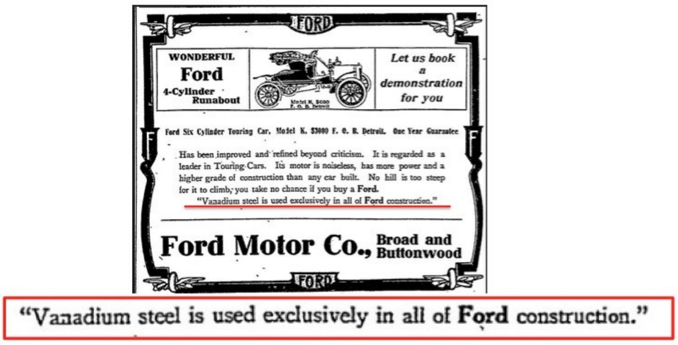
MINING・ENERGY・NATURAL RESOURCES
礦業・能源・天然資源

Vanadium

Vanadium is a transition metal which is silvery-grey and malleable. Its chemical symbol is V and atomic number 23; it is under the same group as niobium and tantalum in the periodic table. The metal is not found in its native state, but it occurs naturally in 156 different minerals according to the USGS. In 2018 nearly 90% of vanadium feedstock was from mined sources with the balance as a secondary product from fly ash, petroleum residues, alumina slag and recycling. The most important industrial vanadium compound is vanadium pentoxide (V_2O_5).



Ford's advertisement on Model K in 1907 *1907年福特的K型號廣告*

Vanadium has several unique characteristics that position it strongly in the steel, alloys, energy and chemical sectors. However, its use is dominated by its applications in steel making which was estimated to account for 93% of total consumption in 2018. Vanadium pentoxide is considered a strategic and critical mineral to the steel and energy industries.

In the production of steel alloys vanadium imparts strength, toughness and wear resistance; a few kilograms in a tonne of steel increases the strength of the steel by as much as 25%. These high-strength low-alloy steels are mainly used for auto parts, buildings, bridges, cranes, pipelines, rail cars, ships, and truck bodies, including armour plating for military vehicles. Replacement of vanadium with other minerals requires significant technical adjustments to the steel production process; thus, substitution for vanadium is not practical for short-term changes in market conditions.

Vanadium-titanium alloys have the best strength-to-weight ratio in all known material; they are commonly used in the aerospace industry in jet engines and high-speed airframes. There are no effective substitutes to this alloy in the aerospace industry.

Recent research in battery technology has also increased the demand of vanadium. Vanadium Redox Flow Batteries (VRFB) are becoming widely popular to be used for energy storage in renewable energy systems. VRFB is a leading energy storage system given its virtually unlimited storage capacity, long battery life, low maintenance requirements, adaptability and nominal environmental footprint. In 2018 this sector accounted for 3% of total consumption.

In the case of car batteries (lithium ion battery), vanadium increases the energy density and voltage of the battery. This is important for performance in electric and hybrid vehicles, as energy density equates to distance/range, while voltage equates to available torque.

釩

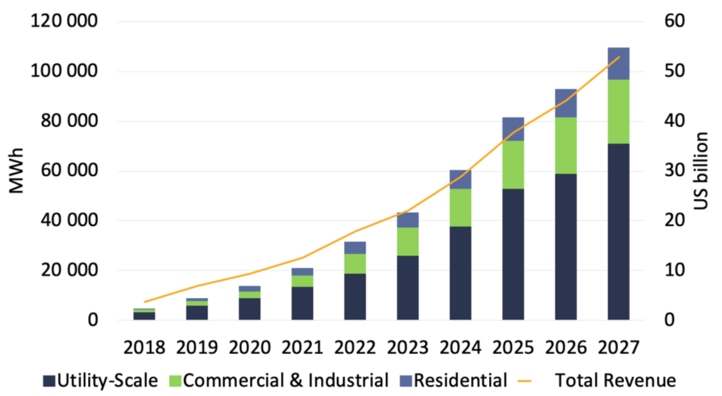
釩是一種銀灰色和可延展性的過渡金屬。它的化學符號是 V，原子序數為 23； 它與元素週期表中的鈮和鉭屬於同一族。該元素未發現於自然界中，但天然存在於 156 種不同的礦物中。2018 年近 90%的釩原料來自礦產資源，其餘為粉煤灰、石油殘留物、氧化鋁渣和回收利用的副產品。最重要的工業釩化合物是五氧化二釩（V_2O_5）。

釩具有幾個獨特的特性，使其在鋼鐵、合金、能源和化學領域具有優勢地位。 但是它的用途主要是在煉鋼領域的應用，據估計佔 2018 年總消費的 93%。五氧化二釩被認為是鋼鐵和能源行業的戰略性和關鍵性礦物。

在鋼合金的生產中，釩能增加強度、韌性和耐磨性。 一噸重的鋼材添加幾公斤的釩，鋼的強度最多可提高 25%。這些高強度低合金鋼主要用於汽車零件、建築物、橋樑、起重機、管道、鐵路車輛、輪船和卡車車體，包括軍用車輛的裝甲板。用其他礦物替代釩需要對鋼鐵生產工藝進行重大技術調整；因此對於釩在市場上的短期變化而替代是不可行的。

釩鈦合金在所有已知材料中具有最佳的強度重量比； 它們通常在航空航天工業中用於噴氣發動機和高速機身。在航空航天工業中，沒有有效的替代品。

電池技術的最新研究也增加了對釩的需求。 釩氧化還原液流電池（VRFB）越來越廣泛地應用於可再生能源系統中的儲能。 VRFB 是領先的儲能系統，因為其幾乎無限的存儲容量、較長的電池壽命、較低的維護要求、適應性和環境足跡。



Note: Utility segment includes thermal storage technology
Source: Navigant Research

VRFB growth forecast *釩氧化還原液流電池的增長預測*

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Compounds of vanadium were first discovered in 1801 by Mexican Andres Manuel del Rio but these were thought to be of chromium. In 1830 Swedish scientist Nils Sefstrom proved that the element was in fact vanadium, which he named after Vanadis, the Scandinavian Goddess of beauty and fertility, on account of the wide range of colors found in vanadium compounds.

Geological Deposition

Vanadium is a trace element and widely distributed in nature – it is the 22nd most abundant element in the Earth's crust and it is an essential constituent of many minerals. Major vanadium deposits are distributed globally. Vanadium is extracted from different types of ore deposit of which the principal types are:

* Vanadiferous titanomagnetite (termed VTM):- Vanadium bearing minerals are commonly hosted within mafic to ultramafic intrusive igneous rock which are characterized by very low silica contents and high iron and magnesium contents. The host rocks are often layered intrusions formed at great depths in the earth's mantle, with the vanadiferous ores either closely packed or disseminated.
* Sandstone hosted vanadium (termed SSV):- SSVs are usually associated with uranium, which is a radioactive mineral. The USA is the only producer of vanadium from SSV deposits.
* Shale hosted vanadium:- Shale hosted vanadium typically contains high concentration of organic matter, suggesting vanadium is incorporated in this matter during burial. It is then buried to enough depth to pass the oil window; thus, some petroleum also contains high vanadium concentrations, and is recovered in the oil refinery process.
* Vanadate deposit:- Salts derived from vanadium pentoxide are found in vanadates of lead, zinc and copper ores present in oxide zones of base-metal deposits. These deposits are secondary accumulations during supergene processes in arid climates with deep oxidation. Major deposits are only found in southern Africa.

Mining and Processing

VTM deposits, as magnetite (Fe_3O_4) or titano-magnetite ($FeTiO_3$) ores, are by far the major source of global supply of vanadium. Most global vanadium supply is from VTMs, either as a primary product (18% of global supply in 2018) or, more commonly, as a co-product with iron (ie magnetite) processed for steel production (70% of global supply in 2018). VTMs, commonly only contain 0.2% - 1% V_2O_5, which explains why it is not the primary product within the ore. The major primary vanadium rich ore is carnotite.

Commercial extraction of the VTM at the mine site is usually carried out as an underground operation, using standard mining procedure. The ore is then crushed and concentrated to remove waste before going through further physical and chemical metallurgical processes. Since vanadium is essentially mined as a byproduct of magnetite the mining methods and processing suitable to magnetite ores tend to prevail.

The main traded vanadium products are vanadium pentoxide (V_2O_5) and ferrovanadium (FeV), with vanadium powder to a lesser extent .

To produce these most of the vanadium bearing ores or slags are crushed, ground, screened, smelted, leached with sulphuric acid and roasted to produce a higher purity pentoxide, which is then reduced to ferrovanadium or vanadium powder. The process varies slightly depending on whether the raw material is titaniferous magnetite or primary vanadium ore. The higher the titanium the harder it is to extract the vanadium. In steel production titanium is separated out as an impurity during processing.

2018 年，該應用範疇佔總消費的 3%。

對於汽車電池（鋰離子電池），釩會增加電池的能量密度和電壓。這對於電動和混合動力車輛的性能非常重要，因為能量密度等於續航距離，而電壓等於可用扭力。

釩的化合物由墨西哥人 Andres Manuel del Rio 於 1801 年首次發現，但當時認為是鉻。1830 年瑞典科學家 Nils Sefstrom 證明了這種元素實際上是釩，由於釩化合物中發現的顏色範圍很廣，他以北歐的美麗女神 Vanadis 命名。

地理分佈

釩是一種微量元素，在自然界中分佈廣泛 — 它是地殼中第 22 個最豐富的元素，並且是許多礦物質的必需成分。主要的釩礦床散佈於全球。釩從不同類型的礦床中提取，其主要類型為：

* 釩鈦磁鐵礦（稱為VTM）：含釩礦物通常存在於鐵鎂質至超鎂鐵質侵入性火成岩中，其特徵是二氧化矽含量低，鐵和鎂含量高。主體岩石通常是在地幔深處形成的分層侵入體，而釩鐵礦脈是密堆積或散佈的。
* 砂岩釩礦（稱為SSV）：SSV通常與鈾（一種放射性礦物）有關。美國是唯一開採SSV礦床的國家。
* 頁岩釩礦：頁岩釩礦通常含有高濃度的有機物，這表明在埋葬前釩已存在於該有機物質中。然後將其埋入足夠的深度以通過油窗。因此一些石油也含有高濃度的釩，並在煉油的過程中被回收。
* 釩酸鹽礦床：在基本金屬礦床的鉛、鋅和銅礦石氧化層中發現了五氧化二釩衍生的釩酸鹽。這些沉積物是乾旱氣候中深氧化作用下表生成礦過程中的二次堆積。主要礦床僅在南部非洲發現。

開採與加工

迄今為止，VTM 礦床是磁鐵礦（Fe_3O_4）或鈦磁鐵礦（$FeTiO_3$），是全球釩供應的主要來源。 全球釩供應量的 80%以上來自 VTM，作為 VTM 的一種主要產品（佔 2018 年釩全球供應量的 18%），或更常見的是作為磁鐵礦的副產品（佔 2018 年釩全球供應量的 70%）。VTM 通常僅包含 0.2%-1%V_2O_5，這解釋了為什麼它不是礦山中的主要產品。 主要含釩富的原礦是鈣鐵礦。

VTM 的礦山通常是地下開採，採用常規的開採程序。 然後將礦石壓碎並濃縮以除去雜質，然後再進行物理和化學冶金工藝。由於釩基本上是作為磁鐵礦的副產品開採的，因此傾向於採用適合磁鐵礦的選礦方法和工藝。

主要交易的釩產品是五氧化二釩（V_2O_5）和釩鐵（FeV），以及規模較小的釩粉。

生產這些釩產品，通常是先將礦石或礦渣粉碎、磨碎、過篩、冶煉、用硫酸浸出並焙燒以產生更高純度的五氧化二釩，最後將其還原為釩鐵或釩粉。根據原材料是鈦磁鐵礦還是原生釩礦石，該過程會略有不同。鈦越高，提取釩的難度就越大。在鋼鐵生產中，鈦在加工過程中作為雜質被分離出來。

下游工藝的目的是生產工業級五氧化二釩，其純度至少為 86%。進一步提純可以產生品位高於 99.8%的產品。釩鐵通常包含有 35%至 80%的釩，由廢鐵、五氧化二釩、鋁和助熔劑（氟化鈣或氧化鈣）在電弧爐中加熱製成的混合物。

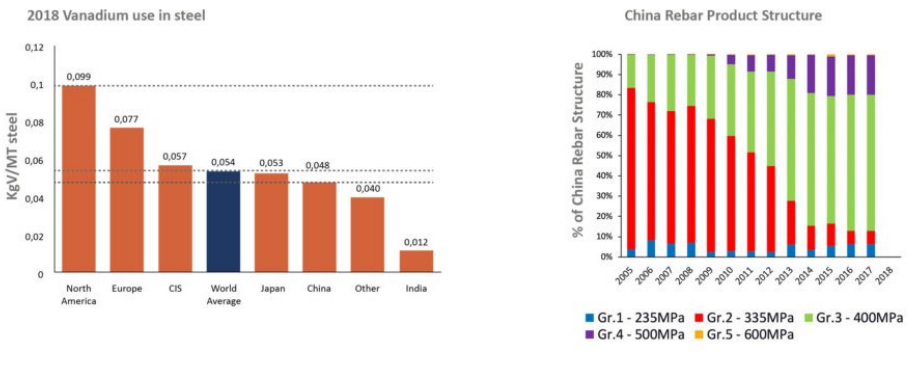
ROCKHOUND NEWSLETTER

Special Ed. 4 Vanadium 釩礦 April 2020

The intention in the downstream process is to produce technical grade vanadium pentoxide which is at least 86% purity. Further purification can produce products of greater than 99.8%. Ferrovanadium typically contains 35% to 80% vanadium and is produced from a mixture of scrap iron, vanadium pentoxide, aluminum and flux (either calcium fluoride or calcium oxide) heated in an electric arc furnace.

Market

China (54%), Russia (25%), South Africa (11%) and Brazil (10%) account for most world mine production. Total production for 2019 was estimated at 73,000t up slightly from 71,200t in 2018. Reserves are reported by USGS (2017) as 22Mt and resources at 63Mt. It should be noted that head grades in operating mines are low from a percentage viewpoint - between 0.3% (Panzhihua, Sichuan Province, China) and 1.5% (Mapochs Mine, Bushveld, South Africa). Therefore, large quantities of ore need to be mined to extract one tonne of vanadium pentoxide.



2018 Vanadium Use in Steel & China Rebar Product Structure *2018年鋼才的釩用量 及 中國鋼筋產品結構*

Source: Bushveld Minerals

Vanadium use is dominated by its applications in steel making, which was estimated to account for 93% of total consumption in 2018. VRFBs accounted for 3% with the non-ferrous alloys and chemicals sector accounting for the rest.

Over the period up to 2017 the steel market continued supporting robust vanadium demand due to structural changes in the sector, influencing both demand and supply. This is primarily in response to the implementation of new high strength rebar standards, which was expected to increase consumption in China by approximately 10,000t per annum from 2019. Demand in steel is expected to grow at a CAGR of 2.5% through to 2027.

However, the growing demand of VRFBs for use in power storage applications is expected to significantly contribute to increased demand with forecasts estimating an increase from 2.5% CAGR now to 8.4% CAGR by 2027. The importance of VRFBs cannot be understated. Electricity's share of global energy consumption has been, and will continue to grow at a rapid pace, already doubling from 10% in 1980 to 20% today. In the next 30 years it is expected to account for 45% of all energy consumption which has huge implications not only for global energy consumption, but also for all minerals in the electricity value chain.

At the same time the contribution of renewable energy continues to grow. Energy storage, a process in which energy generated at one point in time is preserved for use at another time plays a critical role in this transition to more 'green' electrical energy. It is here that vanadium plays a pivotal role in energy storage and VRFBs are well positioned to take a significant share of the stationary energy storage market.

市場

中國（54%）、俄羅斯（25%）、南非（11%）和巴西（10%）佔世界釩產量的大部分。 據估計 2019 年的總產量為 73,000 噸，比 2018 年的 71,200 噸略有增加。USGS（2017）報告的儲量為 2200 萬噸，資源量為 6300 萬噸。 特別注意的是，運營中的礦山品位都較低 — 在 0.3%（中國四川省攀枝花）和 1.5%（南非布什維爾德的 Mapochs 礦山）之間。因此需要開採大量礦石才能提取一噸的五氧化二釩。

釩的應用煉鋼為主，據估計，其在 2018 年佔總消費量的 93%。VRFBs 佔 3%，其餘部分由有色合金和化學製品業佔據。

截至 2017 年，由於鋼鐵行業的結構性變化支持着釩的旺盛需求，從而影響了需求和供應。這主要是對實施新高強度鋼筋標準的回應 該標準有望從 2019 年開始每年在中國增加約 10,000 噸的釩消費量。到 2027 年，鋼鐵需求預計將以 2.5%的複合年增長率增長。

但是儲能應用的 VRFBs 需求的增長預計將極大地推動釩的需求增長，據預測到 2027 年複合年增長率將從現在的 2.5%複合年均增長率提高到 8.4%。VRFB 的重要性不可低估。電力在全球能源消耗中所佔的份額一直並且將繼續以迅猛的速度增長，從 1980 年的 10%已經增長到如今的 20%。在未來的 30 年中，預計將佔所有能源消耗的 45%，這不僅對全球能源消耗，而且對電能價值鏈中的所有礦產品都有巨大影響。

同時可再生能源持續增長。能量存儲是一個過程，將其中一個時間點產生的能量保存以供其餘的時間使用，這是邁向更“綠色”電能的過程中起著至關重要的作用。釩在 VRFBs 的儲能系統中起著舉足輕重的作用，有極大優勢，可以在固定式儲能系統市場中佔據很大的份額。

Rockhound is a HK based company set up to serve the minerals industry in the Region. The company offers technical valuations and services in the natural resources sector.

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FGS – Fellow of the Geological Society (UK)
FIQ- Fellow of the Institute of Quarrying (UK)
MCIC – Member of the Chemical Institute of Canada
MIMMM – Member of the Institute of Materials, Minerals and Mining (UK)
MHKIE – Member of the Hong Kong Institute of Engineers
MCIM – Member of the Canadian Institute of Mining and Petroleum

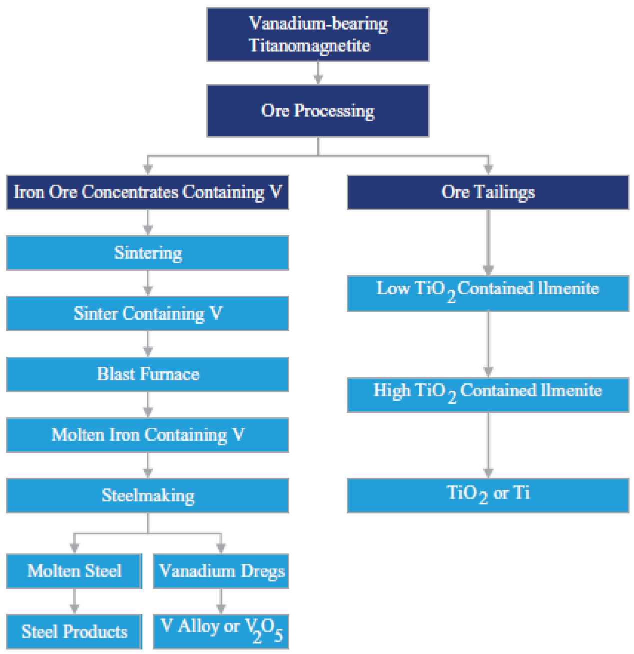
ROCKHOUND NEWSLETTER
Special Ed. 4 TOP INDUSTRIAL NEWS 釩礦相關新聞 April 2020

China Vanadium Titano-Magnetite Mining Company Limited 中國釩鈦磁鐵礦業有限公司(893.HK)

The Company has been listed on the mainboard of the Hong Kong Stock Exchange since 8 October 2009. During the year ended 31 December 2018, the Group was principally engaged in mining and ore processing, sale of self-produced products, trading of coals and steels, management of strategic investments and rendering of specialized mining services. As at 31 December 2018, the Group owned five vanadium-bearing titano magnetite mines, one ordinary iron ore mine, one gypsum mine, five processing plants and one iron pelletising plant. All mines are located in Sichuan, a region with the most abundant vanadium-bearing titano-magnetite resources in China.

The processing routes described in the prospectus is as follow:

Process Routes and Utilization of Vanadium-bearing Titanomagnetite



Source: Hatch

The Company has identified niobium and tantalum ore resources at the Baicao Mine in 2013. However , after further exploration, it was concluded that the ore resources cannot be economically recovered from the ore.

TNG Mount Peake progress may be affected by COVID-19 (excerpt)

31 Mar 2020 <Australian Mining>

TNG Limited (ASX: TNG) has provided an update on the progress of pre-development planning for its Mount Peake project in Northern Territory, taking into consideration the impact of COVID-19 pandemic on the timing of the project.

TNG is currently at an advanced stage of pre-development planning for the vanadium-titanium-iron Mount Peake mine, located approximately 230 km north of Alice Springs.

TNG is continuing a Front-End Engineering and Design (FEED) study for the project in conjunction with the German-based metallurgical engineering firm, SMS group, with limited disruptions so far to key streams of the study.

However, TNG expects the timing of the FEED study to be impacted by the temporary shutdown of business units that support the FEED work streams.

TNG has also not yet received comments from the Northern Territory Environmental Protection Authority in relation to the Environmental Impact Statement (EIS) for its TIVAN processing facility in Darwin, which will be connected to Mount Peake Mine.

TNG will treat magnetite concentrate from the Mount Peake mine site using its patented TIVAN process, which will enable the extraction and production of three high-value strategic elements – titanium dioxide, vanadium pentoxide and iron oxide – for export from Darwin.

TNG said the delay in receiving the EIS may further impact the approval timeline for meeting additional requirements for the TIVAN facility, which may be impacted by the COVID-19 situation.

Bushveld Minerals to hold 8.71% of Newly Created Invinity Energy Systems plc (excerpt)

01 Apr 2020 <Director's Talk Interview>

Bushveld Minerals Ltd (LON:BMN), the AIM quoted, integrated primary vanadium producer, which owns high-grade vanadium assets in South Africa, noted that redT energy plc has today received shareholder approval for its proposed merger with Avalon Battery Corporation. The merged entity will be named Invinity Energy Systems plc. Bushveld entered into a Joint Venture agreement with redT on 9 March 2020 to form a Vanadium Financing Partnership to supply vanadium electrolyte to be used in third party-owned Vanadium Redox Flow Batteries projects developed by redT. The Joint Venture agreement will be transferred to Invinity.

The Merger will create a leading player in the growing energy storage market with a presence in North America, Europe, sub-Saharan Africa and Asia.

Invinity is expected to have strong competitive advantages, gain financial stability and form a base for rapid future growth.

Invinity will be able to offer a VRFB that competes effectively against other energy storage technologies.