ROCKHOUND NEWSLETTER
石 犬 通 訊

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MINING • ENERGY • NATURAL RESOURCES
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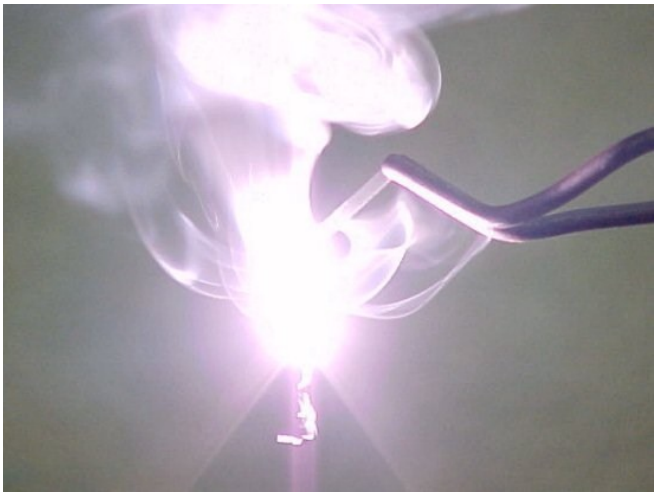
Magnesium

鎂

Magnesium is the eighth most abundant element in the Earth's crust and the third most abundant in seawater. As it is a highly reactive element, it does not occur in nature by itself but mostly as a compound. For most of us the one memory of our school chemistry lessons is the lighting up of a magnesium ribbon which gives a bright flash. As we all know because of this property magnesium has been used for flash photography.



Magnesium ribbon burning in the air
空氣中燃燒的鎂條

Weighing about two-thirds of aluminium, magnesium is the lightest of all metals (1,740kg/m^3 compared to aluminium 2,700 kg/m^3 and titanium 4,500kg/m^3). It is mainly used to make aluminium alloy; such aluminium-magnesium alloys are high-strength, corrosion-resistant materials and used as castings for machinery, tools and other consumer products, such as mag wheels for cars. Moreover, in our daily lives, aluminium beverage cans are not purely aluminium, but contain about 2.5% of magnesium. Magnesium is fast becoming one of the most versatile material choice. It enhances product functionality, improves user mobility, (e.g. LED's, lighter vehicles and long life batteries), increases energy efficiency and has many environmental benefits.

Aluminium cans, which dominate the beverage cans' market consists of about 2.5% magnesium
鋁罐主導了飲料罐的市場含有約2.5%的鎂金屬

Magnesium compounds are also very useful. For example magnesium oxides are feedstock to produce refractory material used in lining furnaces or kilns, whilst caustic calcined magnesia is widely used in the chemical industry, for animal husbandry, papermaking, production of pharmaceuticals and rubber making, as well as for a range of products in the building materials industry.

鎂這種元素十分常見，在地球地殼的藏量排行第八，海洋則排行第三。由於鎂是非常活躍的原素，因此在自然裡並不單獨存在，而是經常與其他元素合成。相信大家對鎂的認識是來自從前化學課上，燃燒鎂條時綻放出耀眼的火光留下深刻的印象。正正因為鎂的這種特點，它最廣為人知的用途是用作攝影的閃光燈。鎂的重量大約為鋁的三份二，是所有金屬中最輕(1,740kg/m^3 相對鋁的2,700 kg/m^3 和鈦的 4,500kg/m^3)。

鎂主要用作鋁合金，這種鋁與鎂合成的合金除了十分堅固之餘還抗腐蝕，用於鑄造機械外殼、工具、及其它包括鎂製車輪等的消費品。除此之外，我們日常接觸到的鋁罐其實並非百分之百由鋁製造，而是含有 2.5%的鎂。鎂成為了用途最廣泛的材料之一。它增強了產品的功能，提高用戶的流動性，（如發光二极管、更輕型的車輛和長壽命電池），提高能源效率，並有許多環境的效益。

鎂化合物也非常有用，例如鎂氧化物是製造火爐和窯耐火內壁的原料，另外煅燒氧化鎂亦廣泛應用於生化工業 包括畜牧業 造紙業 製藥業 塑膠製造業以及建材工業的一系列產品。

Geological Deposition

Seawater and lake brines are two sources of magnesium; thus, from this simplistic viewpoint resources to extract magnesium are virtually unlimited. But the major commercially mineable sources of magnesium originate from magnesite($MgCO_3$) and dolomite($CaMg(CO_3)_2$) rock :

1. Magnesite and Dolomite – these rocks are deposits formed from the replacement of calcium in limestone by magnesium which has been incorporated during the rock forming pro-

地質分佈

海水和鹹湖水是鎂的兩個主要來源，從這個簡單的角度來看，鎂是取之不盡的，然而，可供用作商業用途的鎂的主要來源卻只來自菱鎂礦石($MgCO_3$) 和白雲石($CaMg(CO_3)_2$):

1. 菱鎂礦石和白雲石 — 這些石頭其實是在白雲石化，即石頭形成的過程期間或之後鎂取代了石灰石中的鈣而形成的沉積物。

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cess – known as dolomitization.

2. Magnesite – in this case magnesite originates from serpentinite, a metamorphic rock rich in serpentine, which in turn has formed from the alteration of rocks rich in magnesium. The magnesite from this origin forms when carbon dioxide rich waters percolate through the serpentinite over geological time.

Magnesium compounds are also found in veins, as naturally formed sedimentary deposits and lacustrine type deposits (formed in a lake environment), but these types are seldom mined on a large scale.

Mining and Processing

Although seawater can also be used to extract magnesium, the process is complicated and expensive. In contrast, magnesite and dolomite are easily mined by traditional drilling and blasting techniques. The rock extracted is hauled to a plant where it is crushed, screened and washed in the first stage of processing towards magnesium production. Typically, a rock is considered an ore suitable for magnesium, where MgO > 4% in dolomite or MgO > 35% in magnesite.

Magnesia (MgO)

After the initial crushing and screening, the raw magnesite (i.e. the ore) is heated to about 700°C - 1000°C and as carbon dioxide is released caustic magnesia is produced. The process is referred to as calcination:

$$MgCO_3 + \text{heat} \rightarrow MgO + CO_2$$

Caustic magnesia is very useful in water treatment as it absorbs heavy metals and ions from liquid streams.

If the temperature is increased to 1530°C – 2300°C, "sintered magnesia" is produced, which is a refractory material.

When caustic magnesia or sintered magnesia is heated to around 3000°C in an electric arc furnace, electrofused magnesia, which is a premium refractory material, is produced.

Magnesium metal (Mg)

Magnesium metal can be produced by the electrolytic process or the silicothermic process. The electrolytic process uses the principle of electrolysis to extract magnesium from magnesite or magnesium rich seawater. In contrast, the silicothermic process uses calcined dolomite or magnesite mixed with ferrosilicon through a reduction reaction to produce magnesium:

$$2(MgO{\cdot}CaO) + Si\ (Fe) \rightarrow 2Mg + 2\ CaO{\cdot}SiO_2 + Fe$$

Both processes are energy intensive; thus, it requires low cost electricity to be viable. Other than forming an alloy with aluminium, magnesium can also be used in titanium reduction, the Kroll process (as mentioned in the Titanium issue, please see Rockhound Newsletter Issue 6).

2. 菱鎂礦石— 另一種情況是菱鎂礦石來自於蛇紋岩，一種含有豐富蛇紋石的變質岩。這種礦石是由含有豐富鎂的石頭演變而成的。在這種情況下，鎂礦石之所以形成是因為含有大量二氧化碳的水在地質年代期間不斷滲入蛇紋岩所致。

另外，鎂化合物也可於礦脈、天然形成的沉積物或湖沉積（在湖的環境中形成）中找到，但很少會作大規模開採。

The Dolomites, located in north eastern Italy, which are a mountain range primarily made up of limestone and dolomite were declared a natural heritage site by UNESCO in 2009
位於意大利東北部的 The Dolomites 主要由石灰石和白雲石組成，並於2009年被聯合國教科文組織定為自然遺產

Top 5 World Magnesite Mine Production
(Source: USGS)

Countries 國家	2009 (tonnes) (噸)
China 中國	3,170,000
Turkey 土耳其	576,000
North Korea 北韓	346,000
Russia 俄羅斯	288,000
Austria & Slovakia 奧地利 及 斯洛伐克	231,000

Top 5 World Magnesium Production
(Source: USGS)

Countries 國家	2009 (tonnes) (噸)
China 中國	501,000
Russia 俄羅斯	37,000
Israel 以色列	29,000
Kazakhstan 哈薩克斯坦	21,000
Brazil 巴西	16,000

開採與處理

雖然鎂可以從海水中提取，但工程複雜而且成本高。相反，傳統的鑽探與爆破技術已可輕易開採出菱鎂礦石與白雲石。開採出來的礦石會先被拖運到工場作製鎂前的第一階段處理，包括壓碎、篩選以及清洗。一般而言，只要白雲石和菱鎂礦石的氧化鎂含量分別不低於4%或35%，這些礦石便已適合提取鎂。

氧化鎂 (MgO)

經過頭一輪的壓碎和篩選後，天然的菱鎂礦石會被加熱至大約攝氏 700 至 1000 度 期間會釋放二氧化碳並產生苛性氧化鎂，這個過程稱為鍛燒：

$$MgCO_3 + \text{熱} \rightarrow MgO + CO_2$$

苛性氧化鎂在水處理中作用很大，因為它能吸收河流中的重金屬和離子。如果加熱的溫度增加至攝氏 1530 至 2300 度，燒結氧化鎂就會產生，那是一種很好的耐火物料。假如苛性氧化鎂或燒結氧化鎂放進電弧爐中以攝氏 3000 度加熱，就會產生優良的耐火物料— 電熔氧化鎂。

鎂金屬 (Mg)

鎂金屬可透過電解過程或硅熱法獲得。電解過程利用電解原理從菱鎂礦石或蘊含豐富鎂的海水提取鎂；而硅熱法則是透過燒結白雲石或菱鎂礦石與鐵矽齊混合的還原反應而製造鎂：

$$2(MgO{\cdot}CaO) + Si\ (Fe) \rightarrow 2Mg + 2\ CaO{\cdot}SiO_2 + Fe$$

以上兩種過程都非常耗電，因此電費必須要便宜才能符合成本效益。除了可以與鋁合成為合金以外，鎂還可以用於鈦還原及克羅爾法 (請見石犬通訊第六期有關鈦的內容)。

ROCKHOUND NEWSLETTER

Issue No.: 7 MAGNESIUM 鎂 January 2012

Mining
開採

Raw Ore
天然礦石

Crushing, screening and washing
壓碎, 篩選, 清洗

Dolomite
白雲石

Furnace (700˚C – 1000˚C)
熔爐 (攝氏700 – 1000度)

Caustic Magnesia
苛性氧化鎂

Furnace (1530˚C – 2300˚C)
熔爐 (攝氏1530 – 2300度)

Sintered Magnesia
燒結氧化鎂

Calcination
鍛燒

Reduction
還原反應

Electric Arc Furnace (~3000˚C)
電弧爐 (攝氏~3000度)

Electrofused Magnesia
電熔氧化鎂

Magnesium Metal
金屬鎂

General Process Flow Chart
一般工序流程

The Canadian Institute of Mining, Metallurgy and Petroleum

by the authority of the Council has elected

Rockhound Ltd.

a Member of the Institute with all Privileges of such affiliation

Attested to at the Head Office of the Institute by the signature affixed

July 1, 2011
Date elected

Executive Director

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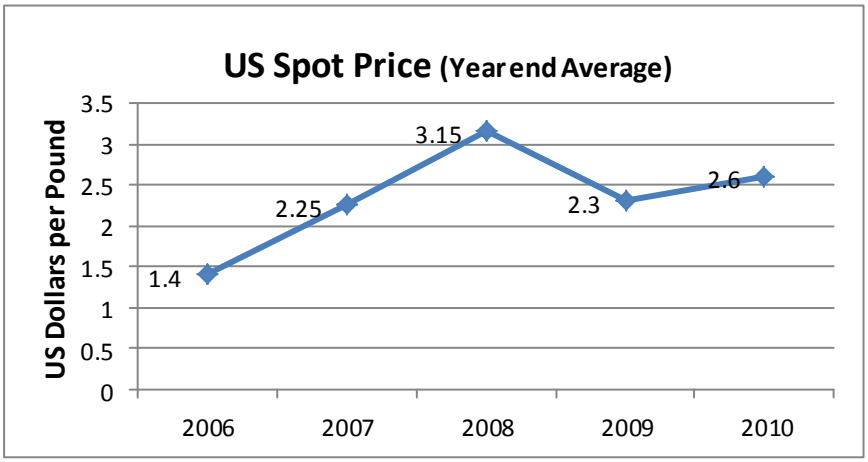
ROCKHOUND NEWSLETTER

Issue No.: 7 TOP INDUSTRIAL NEWS 鎂相關新聞 January 2012

CVM Minerals (0705.HK)

Source: CVM Minerals & The Hong Kong Stock Exchange

CVM Minerals listed on the Hong Kong Stock Exchange through an IPO in late 2008. The company acquired a 20 years mining right to extract dolomite from Dolomite Hills, Perak, Malaysia.. Since then, the company has set up a smelter to process the dolomite into magnesium ingots.



TOP: Magnesium ingots
LEFT: Historical price of magnesium in US *(Source: USGS)*
BOTTOM: Historical price of magnesium in China *(Source: USGS)*
上: 鎂錠
左: 美國的鎂金屬價格 *(資料來源: USGS)*
下: 中國的鎂金屬價格 *(資料來源: USGS)*

Dolomite Hills has a dolomite reserve of about 20 million tonnes. Its smelter is planned to have a production capacity of 30,000 tonnes per year with two production lines.

The first production line was expected to be ready by April 2009, but it was completed by June 2010. The plant adopts the silicothermic process. According to the company's information, every 11.5t of dolomite will produce 1t of magnesium ingot.

Other than operating the dolomite mine and the magnesium smelter, the company is also involved in iron, coal and manganese exploration.

In addition to its mining and exploration business, the company has signed a Memorandum of Understanding as it is considering to acquire a manufacturing and distribution plant for bottled natural mineral water in the PRC.

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.