

## An overview of the mineral sands industry

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The mineral sands industry is one in which Australia plays an important role as a key supplier of the feedstock minerals for TiO<sub>2</sub> (ilmenite and rutile) and close to 40% of the world's zircon. These are global businesses with a handful of heavyweight producers involved including Iluka, Rio Tinto, BHP, DuPont and Cristal just to name a few.

The TiO<sub>2</sub> business is worth more than US\$ 10 billion per year and zircon accounts for another US\$ 1.3 billion.

### Formation of deposits

Although heavy minerals form as accessory minerals in many igneous and metamorphic rocks, nearly all major economic deposits of these minerals, principally rutile, zircon and ilmenite occur in detrital accumulations in young (Pliocene or younger) shoreline or beach placer deposits. Mineral sands are sand sized occurrences of detrital minerals of high specific gravity (heavy minerals), including rutile, zircon, ilmenite, magnetite, kyanite, silimanite, monazite, xenotime, chromite, tourmaline, garnet and staurolite. These granular minerals eroded from the original rock formations and gradually washed towards the sea where sorting by natural waves and current occurs. The heavy minerals were then carried back up onto the beach by waves. As the waves washed up and down on the beach, they carried the lighter quartz grains with them back into the sea, leaving the grains of the heavy minerals rutile, ilmenite, zircon and monazite behind on the beach in what which we now see as strandlines. Wind also helped to concentrate the heavy minerals by blowing away the lighter quartz sand. These processes were repeated many times over millions of years, eventually creating a large deposit of mineral sands on the beach. As the sea level rose and fell over geological time, the shoreline moved further inland and then back again. As this happened, the deposits

of mineral sand were covered by more sand and built up or eroded and re-deposited elsewhere. This is why we sometimes find mineral sand deposits many kilometres inland and maybe as much as 50 m below the current land surface.

In these deposits the main minerals of economic interest are ilmenite (FeTiO<sub>3</sub>), rutile (TiO<sub>2</sub>), leucoxene (a mineral derived from the weathering of ilmenite), and zircon (ZrSiO<sub>4</sub>), by far the most common zirconium mineral.

### Commercially important heavy minerals

Mineral	Theoretical formula	TiO <sub>2</sub> Content (%)
Rutile	TiO <sub>2</sub>	>95
Ilmenite	FeOTiO <sub>2</sub>	<70
Leucoxene	FeO.TiO <sub>2</sub>	>70
Zircon	ZrO <sub>2</sub> .SiO <sub>2</sub>	Nil
Monazite	(Ce,La,Nd,Th) PO <sub>4</sub>	Nil
Xenotime	YPO <sub>4</sub>	Nil

These heavy minerals typically have a specific gravity around 2.9 - 5.5 (quartz ~ 2.65), are chemically stable, resistant to abrasion and with the exception of ilmenite, able to withstand diagenic alteration. The difference in specific gravity and the relative degree of magnetic sensitivity are the main characteristics allowing separation from silica sand and one another.

### Titanium Feedstocks

These ores are the principal raw materials used in the manufacture of titanium dioxide pigment. The first step is to purify the ore, and is basically a refinement step. Either the sulphate process, which uses sulphuric acid as an extraction agent or the chloride process, which uses chlorine, may achieve this. After purification the powders may be treated (coated) to enhance their

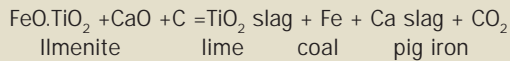
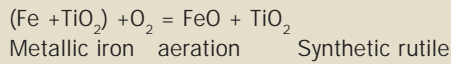
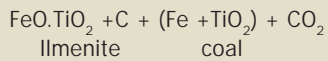
performance as pigments.

Because naturally occurring titanium minerals with a high TiO<sub>2</sub> content, such as rutile, are in limited supply, the heavy mineral sands industry has developed two types of beneficiated products that can be used as substitutes for, or in conjunction with natural rutile. Both are produced from ilmenite and are known as synthetic rutile and titanium slag. Ilmenite accounts for nearly 90% of titanium minerals production. As a group, the naturally occurring titanium minerals and these beneficiated products are referred to as 'titanium feedstocks.'

The need for higher grade titanium has encouraged the upgrading of ilmenite, by removing iron oxides and other impurities. It enriches the TiO<sub>2</sub> content to form synthetic rutile or synrutile. There are several ways of commercially producing synthetic rutile: by smelting to produce a high-titania slag and a low manganese iron by-product, roasting to a synthetic rutile via the Becher process; or roasting and acid leaching to synthetic rutile such as the Benelite process.

Approximately 94% of titanium feedstocks produced worldwide, amounting to over four million tonnes in 2007, are used for the production of very fine white titanium dioxide (TiO<sub>2</sub>) pigment, which is utilised in the paints, plastics and paper industries. The manufacturers of TiO<sub>2</sub> pigment require different types of feedstock depending on the production processes they use. There are two major production processes, known as the sulfate and the now dominant chloride process.

Overall titanium feedstock production was 5.8 million TiO<sub>2</sub> units in 2007. This tonnage is dominated by the production of ilmenite, which accounted for over 42% of the total. Titanium feedstocks are not commodities with a clearly defined price structure. Their final

**Production of TiO<sub>2</sub> slag****Production of TiO<sub>2</sub> slag**

prices are largely a reflection of a product's marketability, which in turn is controlled by its quality. Individual products are sold according to specific quality parameters that vary depending on the end use application and the customer.

Variations in quality of titanium mineral products arise from differences in the nature of the mineral deposit and the manner in which the valuable mineral is extracted from the ore. Depending on the product quality, prices for ilmenite in particular can vary markedly. The marketability of any particular product can only be determined by a detailed assessment of its quality and likely performance in a particular application.

The market for titanium feedstocks is expected to grow at a long-term average rate of around 3.0% per annum stimulated by Chinese demand. On a short term basis, growth is expected to fluctuate around this average in response to specific economic factors in end-use markets. It is anticipated that a significant portion of this annual growth will occur for chloride grade feedstocks, and that the demand for sulfate grade feedstocks will be boosted by the rapidly expanding Chinese TiO<sub>2</sub> pigment industry.

**Major uses for rutile - ilmenite:**

Applications for sintered titania are limited by its relatively poor mechanical properties. It does however find a number of electrical uses in sensors and electro-catalysis. By far its most widely used application is as a pigment, where it is used in powder form, exploiting its optical properties.

**Pigments**

The most important function of titanium dioxide however is in powder form as a pigment for providing whiteness and opacity to such products such as paints and coatings (including glazes and enamels), plastics, paper, inks, fibres and food and cosmetics.

Titanium dioxide is by far the most widely used white pigment. Titania is very white and has a very high refractive index – surpassed only by diamond. The refractive index determines the opacity that the material confers to the matrix in which the pigment is housed. Hence, with its

high refractive index, relatively low levels of titania pigment are required to achieve a white opaque coating.

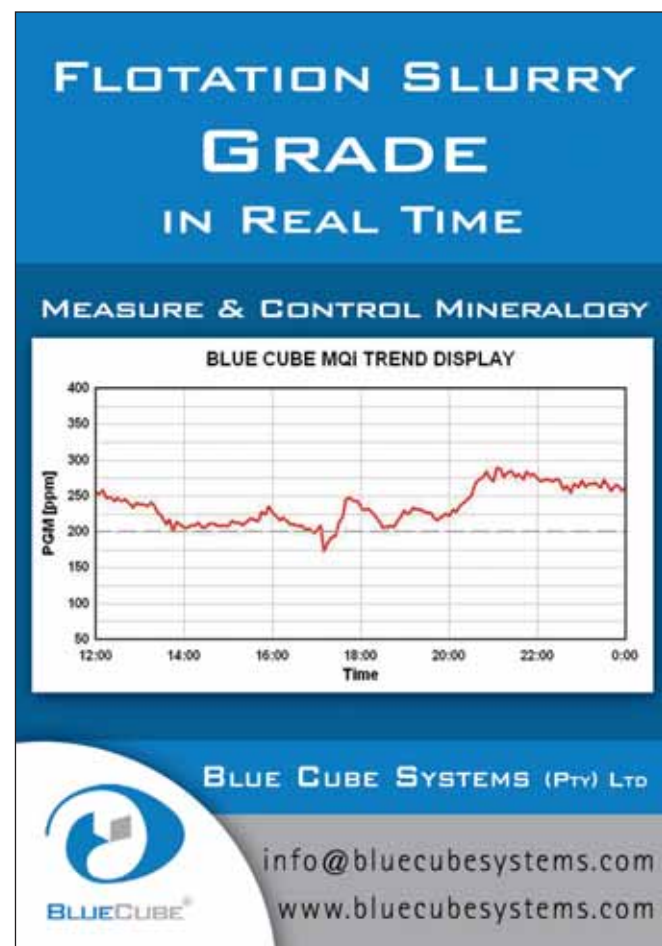
The high refractive index and bright white colour of titanium dioxide make it an effective opacifier for pigments. The material is used as an opacifier in glass and porcelain enamels, cosmetics, sunscreens, paper, and paints. One of the major advantages of the material for exposed applications is its resistance to discoloration under UV light.

**Photocatalysis**

Titania acts as a photosensitiser for photovoltaic cells, and when used as an electrode coating in photoelectrolysis cells can enhance the efficiency of electrolytic splitting of water into hydrogen and oxygen.

**Oxygen sensors**

Even in mildly reducing atmospheres titania tends to lose oxygen and become sub stoichiometric. In this form the material becomes a semiconductor and the electrical resistivity of the material can be correlated to the oxygen content of the atmosphere to which it is exposed. Hence titania can be used to sense the amount of oxygen (or reducing species) present in an atmosphere.



**Antimicrobial coatings**

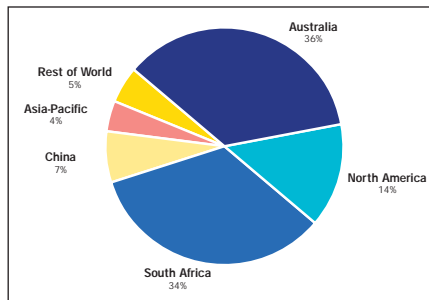
The photocatalytic activity of titania results in thin coatings of the material exhibiting self cleaning and disinfecting properties under exposure to UV radiation. These properties make the material a candidate for applications such as medical devices, food preparation surfaces, air conditioning filters, and sanitaryware surfaces.

**Zircon**

Australia has historically been the world's largest producer of zircon, with the global production of zircon being concentrated in a limited number of countries, totaling around 1.3 million tonnes in 2007. South Africa, USA (mainly Florida), Vietnam are also suppliers of zircon.

**Major uses for zircon:**

- In ceramic glazes - ceramic tiles, sanitary ware, tableware etc;



Zircon production by geographical region 2007

- In the foundry and refractory industries resisting extreme heat;
- Zirconium chemicals such as zirconium oxychloride and zirconium sulphate; and
- TV glass – mainly cathode ray tubes, now in decline.

Zirconium metal – because of zirconium's excellent resistance to corrosion, it is often used as an alloying agent in materials that are exposed to corrosive agents, such as surgical appliances, explosive primers, vacuum tube getters and filaments. zirconium dioxide (ZrO<sub>2</sub>)

is used in laboratory crucibles, metallurgical furnaces, and as a refractory material. zircon (ZrSiO<sub>4</sub>) is cut into gemstones for use in jewelry. Zirconium is also used in nuclear reactors because it does not easily absorb neutrons.

**Demand**

The largest end use market for zircon is as an opacifier in ceramic glazes, which accounted for 54% of estimated global zircon consumption in 2007. Zircon was also used in foundry (14%), refractory (13%), zirconia and zirconium chemicals (12%), and TV glass (4%) industries.

Zircon consumption globally is around 1.3 million tonnes and the construction growth in China during recent years has seen strong demand growth. Due to shortages from traditional sources of supply, artisan miners in Kalimantan, Indonesia have increased output of concentrates all of which has gone to China. This currently has



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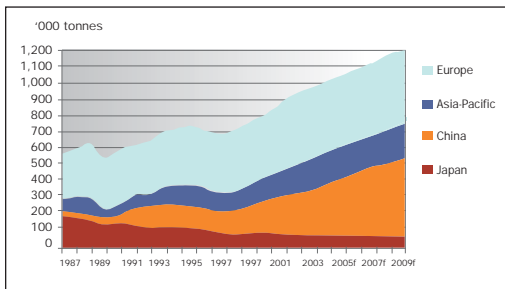
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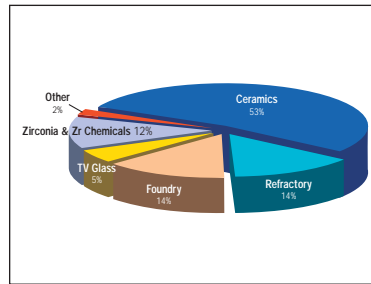


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The changing zircon balance between Europe and Asia: 1987-2010



dampened prices somewhat but this may be short-lived.

In fact there has been substantial growth in Chinese demand since 2000, which is forecast to continue to 2010.

Asia-Pacific and Europe are the dominant zircon consuming regions, respectively accounting for 45% and 34% of total demand in 2007. Western Europe remains the major importing region for zircon sand, but China is now the single largest consuming country of zircon and seems likely to surpass Europe by the end of this decade.

In the longer term, zircon demand is forecast to grow at an average rate of 3.0% pa from 1.30 million tonnes in 2007 to a level of 1.42 million tonnes in 2010, provided there is sufficient supply available.

In 2007, zircon production increased by 1.9 % due to higher production from traditional suppliers and increased sales of concentrates mainly from Kalimantan to China, stimulated by higher prices, which have increased in real terms every year since 2000.

Zircon consumption has grown at an average 2.7% per annum rate since 1980 and is largely dependent on demand from ceramic opacifier manufacturers, which themselves are influenced by expanding diverse conditions in the ceramic tile industries, in particular China, Spain, Italy and Brazil.

In the shorter term it is forecast that zircon consumption may be

constrained by available supply, which would ensure that there would be demand for new sources of zircon.

**Prices**

Zircon FOB prices in the past have been quite volatile, because of its overall status as a co-product of titanium mineral production.

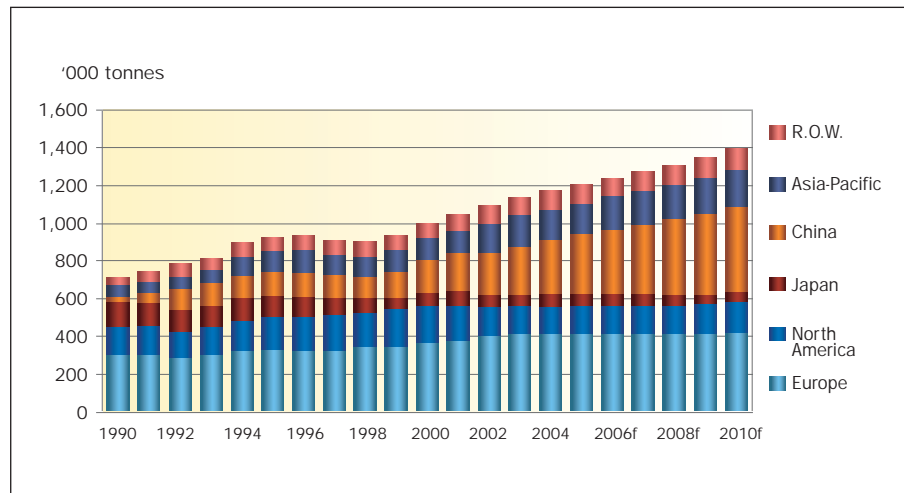
The long term historical nominal price trend of 6.1% per annum has been influenced by severe swings in prices. However, because of the changing

patterns of demand for zircon, and the possibility of partial substitution above certain price levels, real prices are now forecast to return to the highs of the late 1980s, as shown in Figure 9, while prices are forecast to increase further in the short term, they are expected to stabilise in a real 2005 range of US\$650-700 per tonne over the longer term, which is converted to nominal terms by applying a 2.5% pa growth factor.

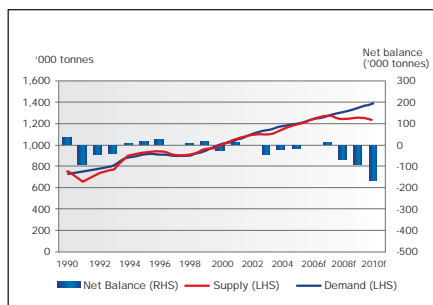
The future of mineral sand industry is bright. A number of new producers have spent years organizing their deposits and processing procedures. Rationalisation has occurred in the industry and the markets continue to grow. Australia will remain at the forefront along with South Africa with emerging producers in western African states also.

**References**

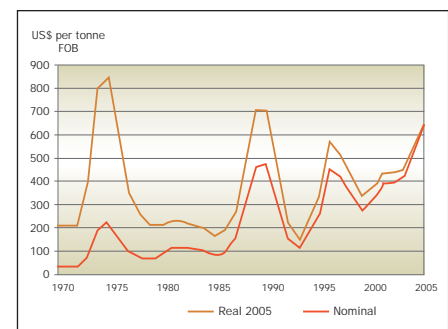
TZMI, NSW Dept of Primary Industries. ■



Zircon consumption by geographical region: 1990-2010



Zircon supply/demand balances excluding unapproved projects: 1990-2010



Long term FOB zircon prices