80 Zircon

Zircon ($ZrSiO_4$) is found usually as a constituent in heavy mineral sand assemblages which include ilmenite, rutile, leucoxene, monazite and garnet in varying proportions. Zirconium and hafnium are extracted (via their salts) from zircon sand and baddeleyite (an oxide-ZrO_2). Normally, all zirconium compounds contain between 1.4% and 3% hafnium. Zircon is very stable at high temperatures and has excellent thermal shock resistance, low thermal conductivity and chemical inertness. It finds use chiefly in industries like ceramic, refractory, abrasive, foundry, chemical and alloys.

RESOURCES

Zircon occurs in close association with other heavy minerals, such as ilmenite, rutile and monazite, all along the coastal tracts of the country. Its concentration in the deposits is about 0.6-18.7% of the total heavy minerals. Indian zircons analyse 63-66% ZrO_2. The AMD has carried out reconnaissance investigations in parts of Maharashtra, Andhra Pradesh, Tamil Nadu, Kerala and Orissa during 2007-08. The resources estimation in these areas is almost complete. The resources of zircon have been enhanced from 23.70 million tonnes in 2002 to 28.29 million tonnes in September 2005. The statewise break-up of the resources is given in Table-1.

Table - 1 : Resources of Zircon

(In million tonnes)

State	Resources*
Total	**28.29**
Andhra Pradesh	10.18
Bihar	0.08
Kerala	5.99
Maharashtra	0.07
Orissa	2.96
Tamil Nadu	8.62
West Bengal	0.39

Source: *Department of Atomic Energy, Mumbai.*
** Inclusive of indicated, inferred and speculative resources.*

EXPLORATION & DEVELOPMENT

Exploratory agencies comprising GSI; Directorate of Geology, Orissa; IREL and AMD carried out exploration in the beach sands deposits which contain heavy minerals, such as ilmenite, rutile, monazite, rare earths, zircon and garnet. For details, the review on 'Ilmenite and Rutile' may be referred.

PRODUCTION AND PRICES

Production of zircon increased to 35,976 tonnes in 2007-08 from 20,535 tonnes in the preceding year. Tamil Nadu was the leading producer, contributing 44% to the total production, followed by Kerala (41%) and Orissa (15%) (Table-2). The prices of zircon as furnished by IREL, KMML and Beach Minerals Co. Pvt. Ltd (BMC) are given in Table - 3.

Table - 2 : Production of Zircon, 2005-06 to 2007-08 (By States)

(In tonnes)

State	2005-06	2006-07	2007-08
India : Total	**27133**	**20535**	**35976**
Kerala	10151	5797	14569
Orissa	6671	5558	5477
Tamil Nadu	10311	9180	15930

Source: *Department of Atomic Energy, Mumbai.*

Table - 3 : Prices of Zircon, 2005-06 to 2007-08

(Rs. per tonne)

Period	Grade	Price	Remarks
IREL			
1.4.2005 to	Q & MK	30000	Ex-works, bagged
30.9.2005	OR	26000	Ex-works, bagged
1.10.2005 to	Q & MK	34000	Ex-works, bagged
23.1.2006	OR	30000	Ex-works, bagged
24.1.2006 to	Q & MK	35000	Ex-works, bagged
5.6.2006	OR	31000	Ex-works, bagged
6.6.2006 to	Q & MK	40000	Ex-works, bagged
19.11.2007	OR	36000	Ex-works, bagged
20.11.2007 to	Q & MK	34000	Ex-works, bagged
31.3.2008	OR	29000	Ex-works, bagged
KMML			
2005-06	NA	35000	-
2006-07	NA	42500	-
2007-08	NA	34252	-
V. V. Mineral			
2005-06	NA	-	-
2006-07	NA	-	-
2007-08	NA	32000	

Source : *Department of Atomic Energy, Mumbai.*
Q: Quilon; MK: Manavalakurichi; OR: Orissa

MINING AND PROCESSING

IREL, a Government of India Undertaking, KMML, a Kerala State Government Undertaking and Beach Minerals Co. Pvt. Ltd (BMC), a private sector company are engaged actively in mining and processing of beach sands in India. Zircon is recovered as a co-product of mining/dredging of heavy mineral sands which include ilmenite, rutile, leucoxene, monazite, sillimanite and garnet. Beach sand deposits containing these minerals are worked from coastal tracts of Manavalakurichi in Tamil Nadu, Chavara in Kerala and Gopalpur in Orissa. As such, no deposit is being worked exclusively for zircon alone. For details regarding mining and processing etc., review on `Ilmenite and Rutile' may be referred. Plantwise capacity and production of zircon during 2004-05 to 2006-07 are given in Table-4.

Table - 4 : Plantwise Capacity and Production of Zircon, 2005-06 to 2007-08

(In tonnes)

Company	Location	Specification	Installed capacity (tpy)	Production		
				2005-06	2006-07	2007-08
Total			**27500***	**27133**	**20535**	**35976**
Indian Rare Earths Ltd	Manavalakurichi, Kanyakumari dist., Tamil Nadu	65% ZrO_2 32% SiO_2 0.6% TiO_2	10000	10311	9180	8404
	Chavara, Kollam dist., Kerala	65% ZrO_2+HfO_2(min) 33% SiO_2	12000	8287	4033	12394
	Orissa Sand Complex, Ganjam dist., Orissa	64.25% ZrO_2+HfO_2(min) 32% SiO_2	2000	6671	5558	5477
Kerala Minerals & Metals Ltd	Chavara, Kollam dist., Kerala	65% ZrO_2	1500	1864	1764	2175
V. V. Mineral	Keeraikaranthattu, Tirunelveli dist., Tamil Nadu	NA	NAS	Nil	Nil	7526
Beach Mineral Co. Pvt. Ltd	Tamil Nadu	Zircon	2000	Nil	Nil	Nil

**Excluding V. V. Minerals.*
Source: *Department of Atomic Energy, Mumbai.*

INDUSTRY

IREL has set up a dry grinding mill at Chavara, Kerala to produce zirflour for its application in the ceramic industry. A wet grinding mill was also set up at Chavara to produce micro-zir for its specialised application as opacifier. In addition, a small chemical plant was set up at Manavalakurichi, Tamil Nadu, to produce zircon frit, zirconium chloride, etc. primarily for making supply of zircon frit to Nuclear Fuel Complex (NFC), Hyderabad. A pilot plant (capacity - 3.5 tpy) was set up at Orissa Sand Complex (OSCOM) to produce a whole range of zirconia stabilised with CaO, MgO and rare earths.

The NFC, Hyderabad has different types of production facilities which include the zirconium oxide plant for processing of zircon to pure zirconium oxide; and zirconium sponge plant for conversion of zirconium oxide to pure sponge metal; facilities for reclamation of zircaloy mill-scrap; the Zircaloy Fabrication Plant for producing various zirconium alloy tubings and also sheet, rod and wire products. Zircon sand is processed through caustic fusion, dissolution, solvent extraction (to remove hafnium), precipitation and calcination to obtain zirconium oxide. The pure oxide is subjected to high temperature chlorination, reactive metal reduction and vaccum distillation to obtain homogeneous zirconium sponge. The sponge is briquetted with alloying ingredients and melted in vacuum arc to produce zircaloy ingots. The alloy ingots are extruded to convert into seamless tubes, sheets and bars. The total installed capacity and production of zirconium oxide and zirconium sponge plants of NFC is furnished in Table - 5.

Table - 5 : Production of Zirconium Oxide and Sponge by NFC, 2005-06 to 2007-08

	Installed capacity (tpy)	Production		
		2005-06	2006-07	2007-08
Zirconium Oxide Plant	500*	322.327	320.29	437.105
Zirconium Sponge Plant	250	282.66	302.31	325.80

** New Zirconium oxide plant capacity from March 2007 onwards.*
***Source**: Department of Atomic Energy, Mumbai.*

Besides, Bhalla Chemical Works Pvt Ltd operates two plants located at Gurgaon, Haryana to manufacture zirconium derivatives (capacity 10,000 tpy) and zirconium silicate opacifiers (capacity 5,000 tpy). One plant of the company in Rajasthan manufactures zirconium oxychloride crystals and special zirconias (capacity 10,000 tpy).

USES & CONSUMPTION

Zircon's exceptional qualities of hardness and durability makes it a must-use for the manufacture of ceramics and refractory tiles and also for a range of other high-tech applications such as armour plating on military aircraft, heat shield in space shuttles and potentially as solid oxide fuel cells in hydrogen powered vehicles in many industrial and chemical applications. Owing to its chemical inertness, very low heat conductivity, high specific gravity, low expansion, good resistance to abrasion, high melting point and no shrinkage on being heated up to 1750^{0}C, zircon is found to be an outstanding refractory material.

In foundry industry, zircon is used as facing for foundry moulds as it increases the resistance to metal penetration and affords a uniform finish to castings. Zircon sand is preferred to silica sand because of its uniform size, higher melting point, low thermal expansion and resistance to molten metal, acidic chemicals, slag, etc. Zircon containing 64% ZrO_2 is used generally for foundry applications.

In ceramic industry, finely ground high-grade zircon and zirconium dioxide are used as opacifier in melts for vitreous enamelling and in ceramic glazes. Zirconium oxide is considered as a potential ceramic material for high temperature applications like engine components. Usually, zircon containing 65% ZrO_2 is preferred in ceramics. The toughened zirconia finds its use in ceramic coatings in jet aircraft engines and in other applications where strength and high temperature oxidation resistance are important. Zirconia ceramics are also used in automobiles in sensors for the microprocessor controls of engines.

In chemical industry, its property of high resistance to corrosion is used where dry chlorine, hydrochloric acid and caustic alkalies are involved. Abrasive and grinding wheels made from zircon sands are used for polishing optical glasses.

Zirconium and zirconium powders are used in ammunition, primers, detonation caps, flashlight mixtures, radio tubes and in various heating elements. It is also used as cladding material in atomic reactors due to its low absorption cross section for thermal neutron.

Consumption of zircon/zirflor decreased to 19,925 tonnes in 2007-08 from 22,701 tonnes in 2006-07. Consumption of zircon/Zirflor during 2005-06 to 2007-08 is furnished in Table - 6.

Table - 6 : Consumption of Zircon/Zirflor 2005-06 to 2007-08 (By Industries)

(In tonnes)

Industry	2005-06	2006-07	2007-08
All Industries	**24558**	**22701**	**19925**
Ceramic	16999	15718	12339
Foundry	3750	3485	3997
Refractory	1827	1542	1048
Chemical	917	1305	1403
TV face plates/glass	753	567	601
Others*	311	84	537

Consumption relates to sales figures of IREL.
** Include electrode, abrasive and other industries.*
***Source**: Department of Atomic Energy, Mumbai.*

POLICY

Zircon was classified as a 'prescribed substance' as per notifications issued under Atomic Energy Act, 1962. From the revised list notified vide S. O. No. 61(E), dated 20.1.2006, zircon has been deleted, subject to the condition that the mineral shall remain a prescribed substance till the policy on exploration of beach sand minerals notified on 6.10.1998, is adopted/revised/modified by Ministry of Mines or till 1.1.2007, whichever occurs earlier and shall cease to be so thereafter.

As per the Foreign Trade Policy 2004-2009 and the policy on export and import effective from 1.4.2008, zirconium ores and concentrates under heading 2615 can be imported/exported freely.

WORLD REVIEW

The world reserve base of zirconium and hafnium is placed at 72 million tonnes and 1.1 million tonnes of ZrO_2 and HfO_2, respectively. Australian mineral sands deposits hold the world's largest reserve base of the zirconium and hafnium. The world production of zirconium minerals was estimated at 1.5 million tonnes in 2007. Australia and South Africa are the principal producers of zirconium minerals. Besides, USA, China, Vietnam and Ukraine are also the important producers (Tables - 7 and 8).

Table - 7 : World Resources of Zirconium and Hafnium (By Principal Countries)

(In '000 tonnes of ZrO_2)
(In '000 tonnes of HfO_2)

Country	Reserve base	
	Zirconium	Hafnium
World : Total	72000	1100
Australia	30000	600
Brazil	4600	91
China	3700	NA
India	3800	46
South Africa	14000	290
Ukraine	6000	NA
USA	5700	97
Other countries	4100	NA

Source: *Mineral Commodity Summaries, 2008.*

Table - 8 : World Production of Zirconium Minerals (By Principal Countries)

(In '000 tonnes)

Country	2005	2006	2007
World Total	**1237**	**1410**	**1524**
Australia	426	491	600
Brazil #	26	25	27
China[(e)]	160	170	180
India	27	22[(e)]	24[(e)]
South Africa	314	414	389
Ukraine[(e)]	35	35	35
USA	164	143	120
Vietnam[(e)]	35	27	22
Other countries	50	83	127

Source: *World Mineral Production, 2003-2007.*
 # Including caldasite rock containing zircon and baddeleyite.

FOREIGN TRADE

Exports

Exports of zirconium ores and concentrates increased to 123 tonnes in 2007-08 from 33 tonnes in the previous year. Exports were mostly to UAE in 2007-08. Exports of zirconium and scrap were negligible in 2007-08 as against 24 tonnes in 2006-07 (Tables - 9 and 10).

Imports

Imports of zirconium ores and concentrates increased to 28,592 tonnes in 2007-08 from 27,578 tonnes in the previous year. Main suppliers were Australia, South Africa, Nigeria and Vietnam in 2007-08. Imports of zirconium and scrap decreased to 9 tonnes in 2007-08 from 22 tonnes in the previous year. Imports were mainly from China (Tables - 11 and 12).

Table - 9 : Exports of Zirconium Ores & Conc. (By Countries)

Country	2006-07		2007-08	
	Qty (t)	Value (Rs.'000)	Qty (t)	Value (Rs.'000)
All Countries	**33**	**1933**	**123**	**1275**
UAE	1	57	120	1182
Thailand	-	-	3	93
Germany	1	23	-	-
Nigeria	2	264	-	-
Singapore	0	63	-	-
Spain	1	214	-	-
Turkey	1	166	-	-
USA	27	1146	-	-

Source: *DGCI&S, Kolkata.*

Table - 10 : Exports of Zirconium & Scrap (By Countries)

Country	2006-07		2007-08	
	Qty (t)	Value (Rs.'000)	Qty (t)	Value (Rs.'000)
All Countries	**24**	**8510**	**++**	**1807**
China	-	-	++	1598
Italy	++	1443	++	32
USA	++	283	++	1
Bahrain	2	127	-	-
Germany	++	2284	-	-
Hong Kong	++	957	-	-
Lebanon	++	784	-	-
Romania	18	1905	-	-
South Africa	++	198	-	-
UAE	3	316	-	-
Other countries	1	213	++	176

Source: *DGCI&S, Kolkata.*

Table - 11 : Imports of Zirconium Ores & Conc. (By Countries)

Country	2006-07		2007-08	
	Qty (t)	Value (Rs.'000)	Qty (t)	Value (Rs.'000)
All Countries	**27578**	**1045096**	**28592**	**1029484**
Australia	18919	791844	17526	668918
South Africa	3324	135104	6734	241835
Vietnam	110	4848	840	31177
Malaysia	633	21152	581	22436
Sri Lanka	124	4518	710	19958
Nigeria	2168	24307	1568	18103
Italy	123	7580	146	6646
China	180	9069	60	3963
Thailand	945	25374	100	3031
UAE	787	12082	-	-
Other countries	265	9218	327	13417

Source*: DGCI&S, Kolkata.*

Table - 12 : Imports of Zirconium & Scrap (By Countries)

Country	2006-07		2007-08	
	Qty (t)	Value (Rs.'000)	Qty (t)	Value (Rs.'000)
All Countries	**22**	**7465**	**9**	**12195**
China	20	1839	6	4027
Italy	1	2498	2	3191
Germany	++	936	1	1636
USA	1	1351	++	1438
Korea, Rep. of	-	-	++	867
France	-	-	++	787
Japan	++	87	++	160
UK	++	177	++	43
Liechtenstein	++	152	-	-
Switzerland	++	145	-	-
Other countries	++	280	++	46

Source*: DGCI&S, Kolkata.*

FUTURE OUTLOOK

Under-supply of zircon sand resulted in steady rise in zircon prices and causing major uncertainties in long-term strategies. Though zircon markets continued to grow, the continuing rapid expansion of the ceramic market in China led to shortfall in supply. Other problem of zircon is its being inextricably linked to titanium minerals. The heavy mineral sands mining has always centred more on titanium ore recovery than zircon, the later being considered as by-product.

Against shortfall in supply, the total demand estimated more than one million tonnes. Ceramics accounted for 52% consumption of total output. Of the total zircon production, China consumes more than one lakh tonnes and produces around 36% of world ceramic tiles. On the contrary, demand for zircon in refractory is decreasing, because the refractory consumption in steel mills has come down, as the steel industry is now stressing for increased performance. The demand in foundry has remained static. In chemical/zirconia sector, the demand is on the rise. About 70% refractories produced worldwide are used in steel industry and 4-6% each in cement, chemical, ceramics, glass and others.