



2012 Minerals Yearbook

ZIRCONIUM AND HAFNIUM [ADVANCE RELEASE]

ZIRCONIUM AND HAFNIUM

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World production of zirconium mineral concentrates in 2012, excluding U.S. production, was about 1.46 million metric tons (Mt), 10% less than the 1.62 Mt produced in 2011. The primary source of zirconium was the mineral zircon ($ZrSiO_4$), principally found in heavy-mineral sands. A relatively small quantity of zirconium was derived from the mineral baddeleyite, a natural form of zirconium oxide (ZrO_2) recovered from a single source in Kovdor, Russia. In 2012, the leading producers of zircon were Australia and South Africa. Zircon was also the primary source of hafnium; zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. The leading producers of zirconium and hafnium metal were France, Russia, and the United States.

U.S. production of milled zircon decreased by 17% compared with that of 2011. In 2012, the United States was a net exporter of zirconium ore and concentrates. Net exports decreased by 18% compared with those in 2011.

Production

Zircon is a coproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile. In 2012, U.S. producers of zircon were DuPont Titanium Technologies (DuPont) (a subsidiary of E.I. du Pont de Nemours and Co.) and Iluka Resources, Inc. (a wholly owned subsidiary of Australian company Iluka Resources Ltd.). DuPont produced zircon from its operation near Starke, FL, and Iluka produced zircon from its operations near Stony Creek, VA. Southern Ionics Inc. was developing heavy-mineral deposits in Brantley County and Charlton County, GA. Production of 12,000 metric tons per year (t/yr) of zircon was expected to begin in late 2013 (Southern Ionics Inc., 2013).

U.S. producers of zirconium and hafnium metal were ATI Wah Chang (an Allegheny Technologies, Inc. business unit) in Albany, OR, and Western Zirconium (a subsidiary of Westinghouse Electric Co.) in Ogden, UT.

The two domestic zircon concentrate producers responded to a voluntary survey of domestic mining operations. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of zircon concentrate in 2012 decreased compared with that of 2011.

Data for zirconium and hafnium manufactured materials were developed by the U.S. Geological Survey (USGS) from a voluntary survey of domestic operations. Of the 41 operations surveyed, 9 responded, representing 87% of milled zircon production. Data for nonrespondents were estimated on the basis of prior-year levels adjusted for the effect of economic conditions. Domestic production of milled zircon was 44,600 metric tons (t) (table 1).

Consumption

Global consumption of zircon increased in 2012 largely as a result of increased demand in developing economies in Asia and the Middle East. Globally, the leading end uses for zircon were ceramics, zirconia, zirconium-based chemicals, refractories, and foundry and casting applications. Zircon was also used as a natural gemstone and may be processed to produce cubic zirconia, a synthetic gemstone and diamond simulant.

Zirconium metal was used in corrosive environments, nuclear fuel cladding, and various specialty alloys. The principal uses of hafnium were in high-temperature ceramics, nickel-base superalloys, nozzles for plasma arc metal cutting, and nuclear control rods.

Zirconium oxide exhibits high light reflectivity and good thermal stability and was primarily used as an opacifier and pigment in glazes and colors used for pottery and other ceramic products. Yttria-stabilized zirconia (YSZ) was used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces. YSZ was also used in the manufacture of a diverse array of products, including cubic zirconia, fiber optic connector components, refractory coatings, and engineering and structural ceramics. YSZ was used in dental applications, such as bridges, crowns, and inlays, because it has two to three times the fracture resistance and 1.4 times the strength of similar alumina products.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon was used in refractory paints for coating the surfaces of molds. Refractory bricks and blocks containing zircon were used in furnaces and hearths for containing molten metals. Glass-tank furnaces use fused-cast and bonded alumina-zirconia-silica-base refractories.

Baddeleyite was used principally in the manufacture of alumina zirconia abrasives and in ceramic colors and refractories.

Ammonium- and potassium-zirconium carbonates were used as paper and board coatings or insolubilizers for high-quality print performance. Zirconium chemicals were also used in inks to promote adhesion to metals and plastics, and as crosslinkers in polymers and printing inks.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal was used as cladding for nuclear fuel rod tubes. Hafnium was used in nuclear control rods because of its high thermal neutron absorption cross section. Commercial-grade zirconium, unlike nuclear grade, contains hafnium and was used in the chemical process industries because of its excellent corrosion resistance. Hafnium metal also was used as an alloy addition in superalloys.

Prices

After a sharp increase in 2011, the 2012 yearend published price range of standard-grade bulk domestic zircon concentrate remained unchanged from that in 2011 at \$2,550 to \$2,750 per metric ton (table 2). According to U.S. Census Bureau data, the average unit value of imported zirconium ore and concentrates was \$2,580 per ton at yearend 2012, a 19% increase from that at yearend 2011.

No published prices were available for zirconium metal. In 2012, the average unit value of imported unwrought powder from France was \$92 per kilogram, a 44% increase from that in 2011. The average duty-paid unit value of imported unwrought hafnium (including sponge and powder) from France was \$507 per kilogram, a 7% decrease from that in 2011.

Foreign Trade

In 2012, exports of zirconium ore and concentrates decreased by 18% (table 3). Most zirconium metal was exported in wrought products classified as "Other zirconium" in the Harmonized Tariff Schedule (HTS) category 8109.90.0000.

Imports of zirconium metal, the HTS category 8109, totaled 567 t in 2012, a 35% decrease from that in 2011. Imports of hafnium metal, the HTS category 8112, totaled 23 t, which was 130% more than that of 2011. South Africa supplied most (96%) of the zirconium ores and concentrates imported into the United States (table 4). Imports of germanium and zirconium oxides increased by 51%; China (43%), France (31%), and the United Kingdom (23%) were the leading import sources of oxides. Domestic imports of ferrozirconium alloys decreased to 5 t in 2012 from 88 t in 2011.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 2012 was about 1.46 Mt, a 10% decrease compared with revised 2011 data (table 5). Australia and South Africa supplied about 67% of all production outside the United States. The leading global zircon producing companies were Iluka, Richards Bay Minerals, and Tronox Ltd.

Australia.—In June, Tronox Inc. (Stamford, CT) completed the acquisition of Exxaro Resources Ltd.'s mineral sand operations in Western Australia and South Africa in exchange for a 38.5% equity stake in Tronox. The acquisition included Exxaro's 50% interest in the Tiwest Joint Venture in Western Australia that was jointly owned with Tronox (Tronox Inc., 2012).

Iluka Resources Ltd. produced 294,000 t of zircon from its operations in Australia, a decrease of 46% compared with that of 2011. Production included 158,000 t from its operations in the Eucla Basin, South Australia, and Perth Basin, Western Australia. Production from Iluka's operations in the Murray Basin, Victoria, totaled 136,000 t (Iluka Resources Ltd., 2013, p. 54–56).

Murray Zircon Pty. Ltd. restarted mining operations at its Mindarie Mineral Sands, South Australia project in October. Murray Zircon's majority owner was Guangdong Orient Zircon Industry Science and Technology Co. Ltd. of Guangdong, China, which intended to purchase the zircon for

use at its manufacturing facilities in China. Murray Zircon expected to produce 10,000 tons per month of heavy-mineral concentrate for shipment to China for further processing into zircon and titanium minerals (Murray Zircon Pty. Ltd., 2012, 2013).

Production at the Gunson Resources Ltd. Coburn project in Western Australia was expected to be 49,500 t/yr of zircon, 109,000 t/yr of ilmenite, and 23,500 t/yr of a mixture of rutile and leucoxene containing 90% TiO₂. At these rates, mine life was expected to be 19 years. No schedule was given for commencement of production (Gunson Resources Ltd., 2014).

MZI Resources Ltd. continued to develop the Keysbrook deposit, 70 kilometers south of Perth. MZI planned to begin mine construction in the second quarter 2013 and to begin mining in early 2014. The Keysbrook project was expected to operate for 7 years with a potential expansion to 15 or more years with additional approvals and land access arrangements. Average production during the 7 years was expected to be 62,200 t/yr of leucoxene and 28,700 t/yr of zircon (MZI Resources Ltd., 2013, p. 3). Mining at the company's Lethbridge South project in the Tiwi Islands commenced in late 2011, and the wet concentrator started up in January 2012 (MZI Resources Ltd., 2012, p. 21). Extensions to the ore body were identified that enabled mining activities to extend to January 14, 2013, and a total of 21,100 t of heavy-mineral concentrates were produced before the operation shut down (MZI Resources Ltd., 2013, p. 2).

China.—In September, China's State Nuclear WEC Zirconium Hafnium Co. Ltd. produced 1.1 t of nuclear-grade zirconium sponge. This was the first time China had produced nuclear-grade sponge and underscored the country's desire to lessen dependence upon imported products for its expanding nuclear power industry (Mineral Sands Report, 2012a).

Kazakhstan.—TOO Tioline was developing a zircon and titanium mineral deposit. Set to reach full production capacity in 2014, the company expected to produce 50,000 t/yr of zircon, 50,000 t/yr of ilmenite, and 12,000 t/yr of rutile (Watts, 2012).

Kenya.—Base Resources Ltd. expected to begin mining operations at its Kwale prospect in July, 2013. During the first 7 years of operation, production was expected to be 330,000 t/yr of ilmenite, 79,000 t/yr of rutile, and 30,000 t/yr of zircon (Base Resources Ltd., 2012, p. 7).

Madagascar.—World Titanium Resources Ltd. (WTR) planned to begin production at its Ranobe Mine in the Toliara Sands Project in southwest Madagascar in the second half of 2014. WTR expected to produce 326,000 t/yr of saleable ilmenite and 44,000 t/yr of rutile and zircon concentrate over a 20-year period (Ollett, 2012).

Mozambique.—Kenmare Resources plc's production of heavy-mineral concentrates was 772,000 t, a decrease of 10% compared with that of 2011 owing to electric supply disruptions and geotechnical challenges associated with elevating the dredge pond and moving the concentrator plant and dredges up the side of a hill. In 2012, zircon production was 46,900 t, an increase of 8% compared with that of 2011 (Kenmare Resources plc, 2013, p. 20).

Senegal.—Astron Ltd. reported an ore reserve estimate for its Niafarang mineral sands project, south of Dakar. Probable

ore reserves were 4.65 Mt containing 11% heavy minerals. The heavy mineral assemblage contained 75% ilmenite, 13% zircon, and 2% rutile (Astron Ltd., 2012, p. 10).

Mineral Deposits Ltd. continued to develop and construct the mine and separation plants at its Grande Cote heavy-minerals deposit, and initial production was scheduled for 2013. Mineral Deposits entered into a joint-venture agreement with ERAMET SA (Paris, France), whereby Mineral Deposits 90% stake in the Grande Cote deposit was combined with ERAMET's 100% stake in the Tyssedal ilmenite upgrading plant in Norway to form a new entity, TiZir Ltd. Once the Grande Cote mine and separation plants were fully commissioned, TiZir expected to produce an average of 575,000 t/yr of ilmenite, 85,000 t/yr of zircon, and small amounts of rutile and leucosene during a mine life of 20 years (Mineral Deposits Ltd., 2012, p. 11).

Sierra Leone.—Sierra Rutile Ltd. (SRL) reported sales of 28,232 t of zircon and other mineral concentrates in 2012. In October, SRL announced plans to develop its Gangama dry mining project. Production was forecast to be 83,400 t/yr of rutile, 46,000 t/yr of ilmenite, and 9,500 t/yr of zircon and other concentrates over a mine life of 6 years. A feasibility study on the project was scheduled for completion in the second quarter 2013 (Sierra Rutile Ltd., 2012, p. 11, 13).

South Africa.—In June, Tronox (Stamford, CT) completed the acquisition of Exxaro Resources Ltd.'s mineral-sand operations in Western Australia and South Africa in exchange for 38.5% of Tronox's equity. The acquisition included Exxaro's 74% of Exxaro's KwaZulu-Natal (KZN) Sands and Namakawa Sands operations in South Africa (Tronox Inc., 2012).

In October, Rio Tinto plc acquired BHP Billiton's entire holdings in Richards Bay Minerals (RBM) and raised Rio Tinto's holdings in RBM to 74% (Rio Tinto plc, 2013, p. 26).

Vietnam.—The Binh Thuan Provincial Industrial Zones Management Authority planned to develop two industrial parks in the Bac Binh and Ham Tan districts for processing of zirconium and titanium minerals. The provincial government was preparing for infrastructure development and calling for private investment in plant construction, with production expected to begin in 2015 (Vietnam National Coal-Mineral Industries Holding Corp. Ltd., 2012).

Outlook

Recovery from the downturn in zirconium mineral concentrate consumption in 2012 was not expected to occur as quickly as that of titanium minerals and pigments, but demand was expected to increase with better economic conditions. Several Chinese companies were attempting to acquire mining and access rights outside of China in order to secure a dependable supply. Iluka registered an independent trading company in Shanghai in October 2012 to facilitate trade (Mineral Sands Report, 2012b). As of September 2011, approximately 46% of Iluka's zircon sales were to China (Iluka Resources Ltd., 2011, p. 4).

Construction and operation of new nuclear powerplants, principally in China, were expected to increase future demand for zirconium and hafnium metal. China's medium-term to long-term nuclear power development program called for an increase in its nuclear power capacity from the current level of 9 million

kilowatts (kW) to 86 million kW. About 30 t of zirconium would be required for each million kW and one-third of the zirconium would need to be replaced annually. China expected the demand for zirconium by its nuclear power industry to exceed 8,000 t/yr during the next decade (Mineral Sands Report, 2011a).

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TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS¹

(Metric tons)

	2008	2009	2010	2011	2012
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon	61,500	38,400	46,900	53,600	44,600
Exports	42,100	39,600	47,400	24,300	20,000
Imports for consumption ²	34,400	14,400	22,900	26,500	25,800
Consumption, apparent ³	W	W	W	W	W
Stocks, December 31, dealers and consumers ⁴	26,600	NA	NA	NA	NA
Zirconium oxide:					
Production ⁵	18,100	NA	NA	NA	NA
Exports ⁶	2,970	3,050	5,630	6,710	6,230
Imports for consumption ⁶	5,060	2,810	2,920	3,020	4,560
Consumption, apparent ³	20,400	NA	NA	NA	NA
Stocks, December 31, dealers and consumers ⁴	1,670	NA	NA	NA	NA
Zirconium, unwrought, waste and scrap, other:					
Exports	2,670	2,300	2,060	2,000 ^r	1,800
Imports	1,030	977	1,160	875 ^r	567
Ferrozirconium:					
Exports	316	566	569	2,680	2,560
Imports	129	(7)	45	88	5
Hafnium, unwrought, waste and scrap, other, imports	12	5	8	10	23

^rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data.

¹Data are rounded to no more than three significant digits.

²Includes insignificant amounts of baddeleyite.

³Defined as production plus imports for consumption minus exports plus or minus Government shipments.

⁴Excludes foundries.

⁵Excludes intermediate oxides associated with metal production.

⁶Includes germanium oxides and zirconium dioxides.

⁷Less than ½ unit.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM MATERIALS

(Dollars per metric ton)

Material	2011	2012
Zircon:		
Domestic, standard-grade, bulk	2,550–2,750	2,550–2,750
Australian, standard-grade, free on board, bulk	2,400–2,600	2,000–2,150
Zirconia, fused, monoclinic, refractory/abrasive	6,500–7,800	6,500–7,800

Source: Industrial Minerals.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY¹

Class and country	HTS ²	2011		2012	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates:	2615.10.0000				
Belgium		690	\$1,740	1,260	\$2,580
Brazil		1,860	3,390	7	33
Canada		1,310	2,680	4,950	2,430
China		2,750	3,580	2,280	3,140
Colombia		1,270	2,700	--	--
Germany		496	1,480	924	1,270
Hong Kong		1,160	2,130	--	--
Italy		1,010	2,100	1,130	3,830
Japan		1,240	1,850	1,080	1,990
Korea, Republic of		1,040	1,420	621	2,180
Mexico		3,570	6,790	2,710	7,640
Netherlands		2,420	5,030	1,130	1,030
Spain		2,040	3,770	245	120
United Kingdom		1,130	2,110	1,380	3,050
Other		2,290 ^r	6,180 ^r	2,290	5,570
Total		24,300	46,900 ^r	20,000	34,900
Ferrozirconium:	7202.99.1000				
Mexico		2,380	6,000	2,400	5,990
Other		304 ^r	719 ^r	156	426
Total		2,680	6,720	2,560	6,420
Unwrought zirconium, including powder:	8109.20.0000				
China		37	1,850	99	5,480
France		231	14,800	50	3,160
Germany		16	1,100	19	1,420
Mexico		32	1,140	4	118
Russia		17	780	16	1,040
Sweden		35	1,790	140	8,390
United Kingdom		102	3,520	118	4,410
Other		50 ^r	1,950 ^r	31	1,320
Total		528	26,900	477	25,300
Zirconium waste and scrap:	8109.30.0000				
Belgium		34	551	22	307
Canada		33	2,150	30	1,920
Hong Kong		18	621	--	--
Italy		19	455	12	273
Japan		25	556	--	--
Spain		5	469	7	640
Other		13	203 ^r	5	108
Total		149	5,010 ^r	76	3,250
Other zirconium:	8109.90.0000				
Canada		316	26,900	386	34,500
China		150	12,800	141	14,100
France		92	8,100	29	2,740
Japan		89	7,980	134	13,500
Korea, Republic of		349	32,600	269	20,500
Spain		93	16,300	33	5,970
Sweden		131	13,000	114	12,800
Other		107 ^r	9,890	139	13,600
Total		1,330	127,000	1,250	118,000

^rRevised. -- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY¹

Class and country	HTS ²	2011		2012	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Zirconium ore and concentrates:	2615.10.0000				
Australia		13,900	\$30,800	136	\$351
South Africa		11,300	22,800	24,700	62,500
Other		1,240	3,940	968	3,590
Total		26,500	57,600	25,800	66,400
Ferrozirconium:	7202.99.1000				
China		71	391	(3)	3
Indonesia		17	12	--	--
Other		(3)	3	5	69
Total		88	406	5	72
Unwrought zirconium, including powder:	8109.20.0000				
Germany		41	2,870	25	3,170
Japan		6	105	81	715
Other		5	304	10	327
Total		52	3,280	116	4,210
Zirconium waste and scrap:	8109.30.0000				
Australia		191	357	154	402
United Kingdom		216	451	1	14
Other		26 [†]	713 [†]	8	215
Total		433 [†]	1,520	163	631
Other zirconium:	8109.90.0000				
Belgium		23	537	5	150
Canada		27	3,200	23	3,460
France		301	46,700	229	49,600
Other		39 [†]	4,770 [†]	31	5,070
Total		390 [†]	55,200	288	58,300
Unwrought hafnium, including powder:	8112.92.2000				
Australia		--	--	11	258
France		8	4,580	7	3,720
Germany		(3)	4	5	2,280
Other		2	180 [†]	(3)	189
Total		10	4,760	23	6,440

[†]Revised. -- Zero.

¹Data are rounded to no more than three significant digits; may not add to totals shown.

²Harmonized Tariff Schedule of the United States.

³Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
ZIRCONIUM: WORLD PRODUCTION, BY COUNTRY ^{1,2}

(Metric tons)

Country ³	2008	2009	2010	2011	2012 ^e
Australia	550,000	400,000 ^r	518,000 ^r	762,000	605,000 ⁴
Brazil	25,346 ^r	34,248 ^r	23,235 ^r	23,283 ^r	23,500 ^p
China ^e	140,000	130,000	140,000	150,000	140,000
India ^e	30,000	37,000	38,000	39,000	40,000
Indonesia ^e	65,000	63,000	50,000	130,000	120,000
Malaysia	984 ^r	1,145	1,267 ^r	1,685 ^r	1,500
Mozambique	32,985	21,100 ^r	37,100	43,600	46,900 ⁴
Russia ⁵	7,000	5,000	6,000 ^r	6,000 ^{r, e}	6,500
Sierra Leone	--	5,560	7,092	8,496	10,200
South Africa ^e	405,000	390,000	381,000	383,000	380,000
Sri Lanka	41,000	9,000	11,000	30,000	35,000
Ukraine ^e	36,000	31,000	30,000	26,000 ^r	38,000
United States	W	W	W	W	W
Vietnam ^{e, 6}	22,000 ^r	6,800	6,900	14,000	14,100
Total	1,360,000	1,130,000 ^r	1,250,000 ^r	1,620,000	1,460,000

^eEstimated. ^pPreliminary. ^rRevised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through February 20, 2014.

³Small amounts of zirconium mineral concentrates were produced in other countries; however, information is not sufficient to estimate output.

⁴Reported figure.

⁵Production of baddeleyite concentrate averaging 98% ZrO₂.

⁶Estimated figures based on Vietnam inferred exports of zirconium ore to China.