



2013 Minerals Yearbook

ZIRCONIUM AND HAFNIUM [ADVANCE RELEASE]

ZIRCONIUM AND HAFNIUM

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In 2013, production of zirconium ore and concentrates in the United States decreased from that of 2012 owing to lower prices, higher stocks of unsold material, and reduced demand from consumers. World production of zirconium mineral concentrates in 2013, excluding U.S. production, was about 1.51 million metric tons (Mt), a 4% increase over the 1.45 Mt produced in 2012.

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 2013, 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 increased by 8% compared with that of 2012. In 2013, the United States was a net exporter of zirconium ore and concentrates. Exports of zirconium concentrates increased by 46% over those of 2012 owing to a sharp increase in exports to China. Imports decreased by 52% compared with those in 2012.

Production

Zircon is a coproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile. In 2013, 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 the 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 at its Mission North and Mission South Mines in Brantley County and Charlton County, GA, respectively. The Mission South Mine was officially opened in May 2014, the Offerman mineral separation plant in Pierce County was expected to become operational in late 2014, and the Mission North Mine was expected to become operational in early 2015. Production in 2014 was expected to be at a rate of 12,000 metric tons per year (t/yr) and increase to 14,700 t/yr after commissioning of the Mission North Mine (Southern Ionics Inc., 2013, 2014).

The two domestic zircon concentrate producers responded to a voluntary survey of domestic mining operations representing 100% of production. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data. Domestic production of zircon concentrate in 2013 decreased compared with that of 2012.

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 30 operations surveyed, 8 responded. 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 48,200 metric tons (t), an increase of 8% from that of 2012 (table 1).

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.

Consumption

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. In 2013, the global demand for zircon by end use, in decreasing order, was ceramics, zirconia, chemicals, refractory, foundry, and other (TZ Minerals International Pty. Ltd., 2014, p. 75).

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.

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.

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.

Zirconium metal was used in corrosive environments and various specialty alloys. Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal was used as cladding for nuclear fuel rod tubes. Commercial-grade

zirconium, unlike nuclear grade, contains hafnium and was used in the chemical process industries because of its excellent corrosion resistance.

The principal uses of hafnium were in high-temperature ceramics, nickel-base superalloys, nozzles for plasma arc metal cutting, and nuclear control rods. Hafnium metal was used in nuclear control rods because of its high thermal neutron absorption cross section.

Prices

The 2013 yearend published price range of standard-grade bulk domestic zircon concentrate was \$950 to \$1,150 per metric ton, a decrease of about 60% from the record-high 2012 yearend price range of \$2,550 to \$2,750 (table 2). According to U.S. Census Bureau data, the average unit value of imported zirconium ore and concentrates in 2013 was \$1,250 per metric ton, a 51% decrease from that of 2012 (table 4). The price decline was attributed to weaker demand and the buildup of production stocks when prices were at an alltime high in 2012.

No published prices were available for zirconium or hafnium metal. In 2013, the average duty-paid unit value of imported unwrought zirconium powder from France was \$79 per kilogram, a 19% decrease from that in 2012. The average duty-paid unit value of imported unwrought hafnium (including sponge and powder) from France was \$579 per kilogram, a 14% increase from that in 2012.

Foreign Trade

In 2013, exports of zirconium ore and concentrates increased by 46% from 2012 owing to increased exports to China, while imports of zirconium ore and concentrates decreased by 52% from those of 2012 (tables 3, 4). 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 714 t in 2013, a 26% increase from that in 2012. Imports of hafnium metal, the HTS category 8112, totaled 10 t, which was a 57% decrease from that of 2012. South Africa supplied most (91%) of the zirconium ores and concentrates imported into the United States (table 4). Imports of germanium and zirconium oxides, HTS category 2825, decreased by 30%; China (47%), France (29%), and the United Kingdom (13%) were the leading import sources of oxides. Domestic imports of ferrozirconium alloys decreased to 4 t in 2013 from 5 t in 2012.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 2013 was about 1.51 Mt, a 4% increase compared with revised 2012 data (table 5). Australia and South Africa supplied about 68% of all production outside the United States.

Australia.—Iluka produced 246,000 t of zircon from its operations in Australia, a decrease of 20% compared with that of 2012. Production included 186,000 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 60,000 t (Iluka Resources Ltd., 2014, p. 19).

Feasibility studies were conducted by Image Resources for its Atlas and Boonanarring deposits in the Perth Basin, Western Australia. The study called for the production of 35,000 t/yr of zircon and 110,000 t/yr of ilmenite during 10 years. Image Resources was seeking funding and offtake partners in order to begin mining operations in 2015 (Image Resources, 2014, p. 14, 17).

China.—In May, China's State Nuclear WEC Zirconium Hafnium Co. Ltd. delivered 9.6 t of nuclear grade zirconium sponge to a zirconium metal manufacturer (Mineral Sands Report, 2013b). In September, Longnan Xinneng Zircon Co., Ltd., commissioned its zirconium sponge production and produced more than 300 kilograms of sponge by yearend. Longnan expected to produce 1,000 t/yr of zirconium sponge, 20 t/yr of hafnium sponge, and 2,000 t/yr of zirconium and hafnium alloys by the end of 2014 (Mineral Sands Report, 2013c).

Kenya.—In December, Base Resources Ltd. began production of heavy mineral concentrates at its Kwale operation and its first production of zircon began in April 2014. Production at Kwale was expected to be 30,000 t/yr of zircon during the first 7 years of operation (Base Resources Ltd., 2014, p. 7, 8).

Madagascar.—World Titanium Resources Ltd. (WTR) estimated ore reserves at its Ranobe deposit in the Toliara Sands Project in southwest Madagascar to be 161,000 Mt with 8.2% heavy minerals. WTR expected to produce 407,000 t/yr of ilmenite and 44,000 t/yr of zircon/rutile concentrate over a mine life of 21 years. Production was scheduled to begin in the third quarter of 2015 (World Titanium Resources, 2014, p. 8, 17; Mineral Sands Report, 2013a).

Mozambique.—Kenmare Resources plc's production of zircon at its Moma Mine in 2013 was 31,400 t, a decrease of 33% from 2012 because of plant expansion activities and power outages in November and December (Kenmare Resources plc, 2014, p. 3, 5, 23).

South Africa.—In September, Tronox Ltd. received permits for its water use license in order to develop the Fairbreeze Mine in KwaZulu-Natal. The water use license cleared the way for mine construction at Fairbreeze. Fairbreeze was to replace the Hillendale Mine, which ceased operations in December, and was expected to be completed in the second half of 2015. Over a 12-year mine life the Fairbreeze Mine was expected to produce 60,000 t/yr of zircon (Casey, 2013, p. 8; Tronox Ltd., 2013).

In July, Mineral Commodities Ltd (MRC) signed a 3-year offtake agreement with Wogen Pacific Ltd. for the zircon-bearing nonmagnetic concentrate produced at Mineral Commodities' Tormin project for export to China. The Tormin project, located on the west coast of South Africa, was expected to produce 45,000 to 50,000 t of zircon/rutile concentrate grading up to 80% zircon and 10% rutile over an initial 5-year mine life. At yearend, the project was ready to begin production (Mineral Commodities Ltd, 2013; 2014)

Outlook

Despite decreased demand that continued throughout 2013, the long-term outlook for zircon is expected to increase.

Multiple development projects in Africa, Australia, and the United States are scheduled to begin production by 2015. Chinese companies are expected to continue acquiring mining and access rights outside of China in order to secure dependable supplies of zircon. Construction of new nuclear powerplants, principally in China, are anticipated to increase future demand for zirconium and hafnium metal.

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TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS¹

(Metric tons)

	2009	2010	2011	2012	2013
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon	38,400	46,900	53,600	44,600	48,200
Exports	39,600	47,400	24,300	20,000	29,200
Imports for consumption ²	14,400	22,900	26,500	25,800	12,400
Consumption, apparent ³	W	W	W	W	W
Zirconium oxide:					
Exports ⁴	3,050	5,630	6,710	6,230	7,000
Imports for consumption ⁴	2,810	2,920	3,020	4,560	3,190
Zirconium, unwrought, waste and scrap, other:					
Exports	2,300	2,060	2,000	1,800	1,740
Imports	977	1,160	875	567	714
Ferrozirconium:					
Exports	566	569	2,680	2,560	1,980
Imports	(5)	45	88	5	4
Hafnium, unwrought, waste and scrap, other, imports	5	8	10	23	10

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.

⁴Includes germanium oxides and zirconium dioxides.

⁵Less than ½ unit.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM MATERIALS

(Dollars per metric ton)

Material	2012	2013
Zircon:		
Domestic, standard-grade, bulk	2,550–2,750	950–1,150
Australian, standard-grade, free on board, bulk	2,000–2,150	1,150–1,250
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	2012		2013	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Ore and concentrates:	2615.10.0000				
Belgium		1,260	\$2,580	1,080	\$2,130
Canada		4,950	2,430	3,570	2,330
Chile		301	788	572	937
China		2,280	3,140	13,200	17,300
France		700	2,220	595	1,630
Italy		1,130	3,830	882	1,400
Japan		1,080	1,990	645	1,540
Korea, Republic of		621	2,180	265	828
Mexico		2,710	7,640	3,940	7,000
Turkey		267	711	1,260	1,250
Ukraine		293	465	800	1,210
United Kingdom		1,380	3,050	1,290	3,580
Other		3,030 ^r	3,840 ^r	1,190	2,240
Total		20,000	34,900	29,200	43,300
Ferrozirconium:	7202.99.1000				
Mexico		2,400	5,990	1,850	4,730
Other		156	425 ^r	123	271
Total		2,560	6,420	1,980	5,000
Unwrought zirconium, including powder:	8109.20.0000				
Canada		10	557	10	513
China		99	5,480	(3)	5
France		50	3,160	96	4,650
Russia		16	1,040	52	3,550
Sweden		140	8,390	95	5,520
United Kingdom		118	4,410	145	3,360
Other		45 ^r	2,310 ^r	33	1,450
Total		478 ^r	25,300	432	19,100
Zirconium waste and scrap:	8109.30.0000				
Belgium		22	307	63	594
Canada		30	1,920	25	1,570
Italy		12	273	27	608
Japan		--	--	26	464
Spain		7	640	7	651
Other		5	109 ^r	20	335
Total		76	3,250	168	4,220
Other zirconium:	8109.90.0000				
Argentina		27	3,830	39	6,940
Canada		386	34,500	346	34,500
China		141	14,100	49	5,320
France		29	2,740	60	6,620
Japan		134	13,500	46	2,950
Korea, Republic of		269	20,500	246	32,000
Spain		33	5,970	82	15,800
Sweden		114	12,800	82	10,600
United Kingdom		35	3,210	49	3,270
Other		79 ^r	6,600 ^r	142	7,580
Total		1,250	118,000	1,140	126,000

^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.

³Less than ½ unit.

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	2012		2013	
		Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Zirconium ore and concentrates:	2615.10.0000				
South Africa		24,700	\$62,500	11,200	\$11,200
Other		1,100 [†]	3,940 [†]	1,160	4,360
Total		25,800	66,400	12,400	15,500
Ferrozirconium:	7202.99.1000				
Canada		1	7	4	44
United Kingdom		4	53	--	--
Other		(3) [‡]	12 [†]	--	--
Total		5	72	4	44
Unwrought zirconium, including powder:	8109.20.0000				
China		(3)	31	28	1,550
Germany		25	3,170	41	3,570
Japan		81	715	101	659
Other		10	295 [†]	17	1,340
Total		116	4,210	187	7,120
Zirconium waste and scrap:	8109.30.0000				
Australia		154	402	116	176
Canada		3	69	26	485
China		--	--	2	12
France		2	47	2	47
Japan		1	7	27	134
Korea, Republic of		1	14	32	216
Other		2 [†]	92 [†]	3	94
Total		163	631	208	1,170
Other zirconium:	8109.90.0000				
Canada		23	3,460	31	3,540
China		11	1,130	16	1,160
France		229	49,600	252	48,700
Other		25 [†]	4,090 [†]	20	3,890
Total		288	58,300	319	57,300
Unwrought hafnium, including powder:	8112.92.2000				
Australia		11	258	--	--
France		7	3,720	4	2,460
Germany		5	2,280	5	2,190
Other		(3) [‡]	189	1	380
Total		23	6,440	10	5,030

[†]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	2009	2010	2011	2012 ^e	2013 ^e
Australia	400,000	549,000 ^r	762,000	605,000 ⁴	850,000
Brazil	34,248	23,236 ^r	23,283	20,425 ^{r,4}	22,500
China ^e	130,000	140,000	150,000	140,000	150,000
India ^e	37,000	38,000	39,000	40,000	41,000
Indonesia ^e	63,000	50,000	130,000	120,000	110,000
Madagascar	4,755	7,490	13,075	17,000	14,000
Malaysia	1,145	1,267	1,685	442 ^{r,4}	500
Mozambique	21,100	37,100	43,600	46,900 ⁴	47,000
Russia ⁵	8,249 ^r	9,308 ^r	8,914 ^r	9,000 ^r	9,000
Sierra Leone	5,560	7,092	8,496	610 ^{r,4}	2,300 ^p
South Africa ^e	372,000 ^{r,4}	381,000	428,000 ^{r,4}	380,000 ^r	170,000
Sri Lanka	9,000	11,000	30,000	35,000	40,000
Ukraine ^e	31,000	30,000	26,000	20,000 ^r	35,000
United States	W	W	W	W	W
Vietnam ^{e,6}	6,800	6,900	14,000	15,600	16,000
Total	1,120,000 ^r	1,290,000 ^r	1,680,000 ^r	1,450,000 ^r	1,510,000

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

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

²Includes data available through June 9, 2014.

³Small amounts of zirconium mineral concentrates were produced in various 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.