



2016 Minerals Yearbook

ZIRCONIUM AND HAFNIUM [ADVANCE RELEASE]

ZIRCONIUM AND HAFNIUM

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In 2016, production of zirconium ores and concentrates in the United States decreased and production of milled zircon increased by 7% from that of 2015. U.S. imports of zirconium ores and concentrates increased by about 20% (table 1). World production of zirconium mineral concentrates in 2016, excluding U.S. production, was about 1.33 million metric tons (Mt), a 12% decrease from the revised 2015 production total (table 5).

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 rare natural form of zirconia [zirconium oxide (ZrO_2)] recovered from a single source in Kovdor, Russia. In 2016, the leading producers of zircon were Australia and South Africa. Zircon was also the primary source of hafnium; most natural zircon has a zirconium-to-hafnium ratio of 33.6:1 (Jones and others, 2017, p. V5). Zirconium and hafnium metal were produced in China, France, India, Russia, and the United States.

Production

Zircon is a coproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile. In 2016, the U.S. producers of zircon were The Chemours Co. (Wilmington, DE) and Southern Ionics Inc. (West Point, MS). Chemours produced zircon concentrate from its operation near Starke, FL, and Southern Ionics produced zircon concentrate from its operation in Nahunta, GA. Iluka Resources, Inc. (a wholly owned subsidiary of Iluka Resources Ltd., Perth, Western Australia, Australia), terminated its operations near Stony Creek, VA, at the end of 2015 owing to low market prices, weak demand, and exhaustion of reserves. It continued to hold mineral leases of resources located near Aurelian Springs, NC, and Hickory, VA (Iluka Resources Ltd., 2015, p. 19, 25). Iluka Resources, Inc. had no production of zircon in 2016.

The two domestic producers of zircon concentrate responded to a U.S. Geological Survey (USGS) voluntary survey of domestic mining operations. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data.

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.

Data for zirconium and hafnium manufactured materials were collected from a voluntary survey of domestic operations. Of the 38 operations surveyed, 10 responded, representing about 90% of estimated domestic production of milled zircon of 49,000 metric tons (t) in 2016. Data for nonrespondents were estimated on the basis of prior-year levels (table 1).

Consumption

Globally, the leading end uses for zircon were ceramics, zirconia, zirconium-based chemicals, refractories, and foundry and casting applications. Zircon sand is preferred in casting applications where high-quality finishes and tight tolerances are required owing to its lower expansion coefficient and greater stability at high temperatures compared with other materials. Zircon recovered from hard-rock mining was valued as a natural gemstone, and zirconia powder in minor quantities was 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.

Zirconia 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 biomedical applications, such as dental bridges, crowns, and inlays, because it has two to three times the fracture resistance and 1.4 times the strength of alternative 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. Fused-cast and bonded alumina-zirconia-silica-base refractories were used in glass-tank furnaces.

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 antiperspirants, as paper and board coatings, and in printing and paper manufacturing. Zirconium chemicals were also used in inks to promote adhesion to metals and plastics.

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 chemical process industries because of its excellent corrosion resistance. Hafnium metal also was used as an additive in superalloys.

Prices

The 2016 yearend published price range of standard-grade bulk domestic zircon concentrate was \$950 to \$1,100 per metric ton, unchanged from yearend prices of 2015. The published yearend price range of refractory or abrasive zirconia was \$6,000 to \$7,000 per metric ton, also unchanged from the previous year (table 2). According to U.S. Census Bureau data, the average unit value of imported zirconium ores and concentrates in 2016 was \$992 per metric ton, a 15% decrease from that of 2015 (table 4).

No published prices were available for zirconium or hafnium metal. In 2016, the average duty-paid unit value of imported unwrought zirconium (including sponge and powder) from China, the leading source of United States zirconium imports, was \$33 per kilogram, more than double that of 2015. The average duty-paid unit value of zirconium from France, a major producer of nuclear-grade zirconium, which accounted for 7% of imports, was \$46 per kilogram, a decrease of 3% from that in 2015. The average duty-paid unit value of imported unwrought hafnium (including sponge and powder) from France was \$160 per kilogram, a decrease of 73% from the previous year, likely because of the misclassification of materials containing hafnium (table 4).

Foreign Trade

In 2016, exports of zirconium ores and concentrates were 5,050 t, a slight increase from those of 2015 (table 3). Imports of zirconium ores and concentrates totaled 38,400 t, an increase of 20% from those of 2015. South Africa, Senegal, and Australia supplied most of the zirconium ores and concentrates (50%, 29%, and 16%, respectively) into the United States (table 4).

Most zirconium metal, excluding ferrozirconium, was exported in wrought products classified as “Other zirconium” in the Harmonized Tariff Schedule of the United States (HTS) code 8109.90.0000 (table 3). Exports of zirconium metal totaled 788 t in 2016, a 22% decrease from those of 2015 (table 3). Most zirconium metal imports were as unwrought zirconium, including powder, as HTS code 8109.20.0000, and totaled 841 t in 2016, a decrease of 12% from those of 2015 (table 4).

Imports of hafnium metal, HTS code 8112.92.2000, totaled 180 t, more than double the imports in 2015 (table 4). Imports of ferrozirconium alloys were 59 t in 2016, less than half of those in 2015.

World Review

Excluding U.S. production, world production of zirconium mineral concentrates in 2016 was about 1.33 Mt. The major global zircon producers were Iluka Resources Ltd. (Australia), Rio Tinto plc (Australia), and Tronox Ltd. (Stamford, CT). Australia and South Africa accounted for about 61% of all production outside the United States (table 5).

Australia.—Iluka produced 347,000 t of zircon from its operations in Australia, a slight decrease from that of 2015. In April, Iluka suspended mining activities at the Jacinth-Ambrosia Mine in South Australia for a planned period of 18 to 24 months in order to draw down the heavy-mineral concentrate inventory held there (Iluka Resources Ltd., 2017, p. 16–17).

During the first full year of production, MZI Resources Ltd.’s (East Perth, Western Australia, Australia) Keysbrook project in Western Australia produced 15,900 t of zircon. In March, MZI announced that ore reserves had increased to more than 72 Mt (containing about 220,000 t of zircon), using a cutoff grade of 1% total heavy minerals to extend the mine life of Keysbrook to more than 15 years (MZI Resources Ltd., 2016, p. 1–2; 2017, p. 3).

Alkane Resources Ltd. continued to develop its Dubbo Zirconia Project (DZP) in New South Wales. The DZP contained significant resources of zirconium, hafnium, niobium, yttrium, and rare-earth elements. Based on recoveries developed from the demonstration pilot plant, 25,200 metric tons per year (t/yr) of combined output was expected, including zirconium carbonate (equivalent to 16,400 t/yr of ZrO₂) and more than 200 t/yr of hafnium oxide. Alkane finalized land acquisitions in June and in August and signed a 5-year sales and distribution agreement with Minchem Ltd. (United Kingdom) for all zirconium materials produced at the DZP. Contingent on financing, construction was expected to begin in 2017 with production to begin in 2018 (Alkane Resources Ltd., 2015, p. 17; 2016, p. 20, 27).

China.—China imported 1.05 Mt of zircon concentrates in 2016, virtually unchanged from that of 2015, but the average value decreased by 21% to \$595 per metric ton (Global Trade Information Services Inc., 2017).

India.—In Odisha State, India’s state-controlled Indian Rare Earths Ltd. (IREL) was planning to build a processing plant to produce an additional 120,000 t/yr of mixed heavy-mineral concentrate. The additional concentrate was intended to supply the Orissa Sands Complex (commonly referred to as OSCOM) heavy-mineral separation operations. In December, IREL invited bids for construction and operation, and the plant was expected to be commissioned within 6 months of an agreement (Metal-Pages, 2016).

Kenya.—Base Resources Ltd. (Australia) produced 39,700 t of zircon from its Kwale operation in 2016, an increase of 53% from that of 2015. In addition to primary zircon production, operations at Kwale began to reprocess tailings in the second half of 2016 to produce a lower grade concentrate. This reprocessing of tailings was expected to continue throughout the first half of 2017 (Base Resources Ltd., 2016, p. 1; 2017, p. 6–7).

Mozambique.—Kenmare Resources plc (Ireland) produced 68,200 t of zircon at its Moma Mine in 2016, an increase of 32% from that of 2015. Kenmore expected its production to increase further in 2017 to between 72,000 and 83,000 t of zircon owing to higher recovery and utilization rates (Kenmare Resources plc, 2017, p. 1–2).

Senegal.—Mineral Deposits Ltd. (Australia) produced 52,600 t of zircon at its Grand Côte project in 2016, the second full year of production. This represented a 16% increase from that of 2015 (TiZir Ltd., 2017, p. 1).

Sierra Leone.—Based on reported production of 1,050 t of zircon in the first three quarters of 2016, Sierra Rutile Ltd. produced an estimated 1,600 t of zircon in 2016. The Gangama Dry Mine was commissioned in May with a nameplate capacity of 500 metric tons per hour. Iluka acquired Sierra Rutile in December and was considering expanding Sierra Rutile’s Gangama and Lanti dry mining operations by an additional

500 metric tons per hour each (Iluka Resources Ltd., 2016; Sierra Rutile Ltd., 2016a, b, c).

South Africa.—In 2016, Tronox produced 164,000 t of zircon at its Namakwa Sands and KZN Sands operations. Fairbreeze, the mining portion of the KZN Sands operations near Empangeni, became operational in April. Its output replaced that of the company's Hillendale Mine, which closed in 2013. The Fairbreeze Mine had the capacity to produce 55,000 t/yr of zircon, and the mine life was expected to be at least 12 years (Tronox Ltd., 2017, p. 35–36).

Mineral Commodities Ltd. (Australia) produced 35,800 t of zircon-rutile concentrate, containing 74.1% zircon and 13.4% rutile, at its Tormin Mine in 2016, a decrease of 20% from that in 2015 (Mineral Commodities Ltd., 2017, p. 1).

Outlook

TZ Minerals International Pty Ltd. (TZMI), an industry analyst for the zirconium and titanium mineral sands industry, estimated global zircon inventories at yearend 2016 of 470,000 t, about 165,000 t over normal levels. TZMI expected global zircon consumption to increase by 2.5% per year from 2017 to 2020 (Mineral Sands Report, 2017, p. 13–14). According to Iluka, demand for zircon was broadly balanced in terms of inventories and producer inventories, held mostly by Iluka, would be drawn down over the course of 2017 (Iluka Resources Ltd., 2017, p. 14).

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TABLE 1
 SALIENT U.S. ZIRCONIUM STATISTICS¹

(Metric tons, gross weight)

	2012	2013	2014	2015	2016
Zirconium:					
Production:					
Ores and concentrates	W	W	W	80,000 ²	W
Milled zircon ^e	48,200	48,200	43,300	46,000	49,000
Exports	20,000	29,200	7,460 ^f	4,920 ^f	5,050
Imports for consumption ³	25,800	12,400	50,400	32,000 ^f	38,400
Consumption, apparent ⁴	W	W	W	100,000 ²	W
Zirconium oxide:⁵					
Exports	6,230	7,000	7,380	5,700 ^f	5,420
Imports for consumption	4,550	3,170	4,240	4,140 ^f	2,620
Zirconium, metal, including powder, waste and scrap, other:					
Exports	1,810 ^f	1,740	1,450 ^f	1,530 ^f	1,150
Imports for consumption	571 ^f	716 ^f	1,100	1,320	1,240
Ferrozirconium:					
Exports	2,540 ^f	1,960 ^f	1,620 ^f	973 ^f	476
Imports for consumption	6	4	131	158	59
Hafnium, unwrought, including powder, imports	24	10	21	72	180

^eEstimated. ^fRevised. W Withheld to avoid disclosing company proprietary data.

¹Table includes data available through March 1, 2018. Data are rounded to no more than three significant digits.

²Data are rounded to one significant digit to avoid disclosing company proprietary data.

³Includes insignificant amounts of baddeleyite.

⁴Defined as production plus imports for consumption minus exports plus or minus Government shipments.

⁵Includes germanium oxides and zirconium dioxides.

TABLE 2
 PUBLISHED YEAREND PRICES OF ZIRCONIUM MATERIALS

(Dollars per metric ton)

Material	2015	2016
Zircon:		
Domestic, standard-grade, bulk	950–1,100	950–1,100
Australian, standard-grade, free on board, bulk	1,000–1,050	950–1,000
Zirconia, fused, monoclinic, refractory or abrasive	6,000–7,000	6,000–7,000

Source: Industrial Minerals.

TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY OR LOCALITY¹

Class and country or locality	HTS ² code	2015		2016	
		Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Zirconium ores and concentrates:	2615.10.0000				
Belgium		728	\$1,840	832	\$2,000
Brazil		314	920	161	478
Canada		498 ^r	1,470 ^r	562	1,660
Chile		179	253	717	1,010
China		194 ^r	451 ^r	173	382
France		631	1,860	453	1,080
Germany		87	254	91	239
India		100 ^r	271 ^r	65	170
Italy		96	269	134	348
Japan		327	1,010	296	746
Mexico		743 ^r	2,010 ^r	681	1,730
United Kingdom		629	2,100	710	1,940
Other		391 ^r	865 ^r	176	406
Total		4,920 ^r	13,600 ^r	5,050	12,200
Ferrozirconium:	7202.99.1000				
Mexico		940 ^r	2,230 ^r	74	174
Venezuela		--	--	389	600
Other		33	90	14	65
Total		973 ^r	2,330 ^r	476	839
Unwrought zirconium, including powder:	8109.20.0000				
Canada		16	535	6	176
Russia		10	660	25	1,170
Sweden		49	2,590	61	2,990
United Kingdom		76	1,350	46	1,130
Other		61 ^r	2,190 ^r	66	1,890
Total		213 ^r	7,320 ^r	203	7,350
Zirconium waste and scrap:	8109.30.0000				
Belgium		110	1,190	57	1,130
Canada		92	4,460	57	2,660
Italy		6 ^r	113 ^r	9	170
Japan		7	176	13	406
United Kingdom		82	876	16	317
Other		5	112	7	212
Total		302 ^r	6,940 ^r	160	4,900
Other zirconium:	8109.90.0000				
Argentina		38	3,790	25	2,350
Canada		351 ^r	37,600 ^r	364	41,100
China		103	10,300	9	720
France		18	2,560	2	239
Germany		30	1,300	18	929
Japan		89	6,360	33	2,910
Korea, Republic of		164 ^r	21,400 ^r	153	21,900
Sweden		111	14,400 ^r	94	13,000
Taiwan		41	3,190	1	129
United Arab Emirates		31	3,480	31	3,510
United Kingdom		7	734	38	1,320
Other		31	3,950 ^r	19	2,520
Total		1,020	109,000	788	90,600

^rRevised. -- Zero.

¹Table includes data available through March 1, 2018. Data 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 COUNTRY OR LOCALITY¹

Class and country or locality	HTS ² code	2015		2016	
		Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Zirconium ores and concentrates:	2615.10.0000				
Australia		4,610	\$5,710	6,260	\$6,890
China		318	846	358	1,390
Russia		680	2,910	678	2,990
Senegal		7,690	9,490	11,300	12,300
South Africa		17,800	16,700	19,100	13,000
Other		929 ^r	1,640 ^r	659	1,510
Total		32,000 ^r	37,300 ^r	38,400	38,100
Ferrozirconium:	7202.99.1000				
Argentina		20	45	--	--
Canada		23	81	4	46
China		114	540	55	193
United Kingdom		1	2	--	--
Total		158	669 ^r	59	240
Unwrought zirconium, including powder:	8109.20.0000				
Canada		(3)	29	4	426
China		787	11,800	511	17,000
France		11	528	58	2,690
Germany		92	4,460	199	6,650
Japan		63 ^r	552 ^r	63	507
Russia		--	--	4	366
Other		(3)	25	2	87
Total		953 ^r	17,400	841	27,700
Zirconium waste and scrap:	8109.30.0000				
Australia		97	121	135	154
Canada		31	62	12	37
France		7	81	1	16
Germany		(3) ^r	2	3	54
Japan		19	90	32	253
Korea, Republic of		13	210	13	201
Other		23	237	8	128
Total		190	804	204	844
Other zirconium:	8109.90.0000				
Canada		16	2,050	13	1,500
France		100	16,900	125	19,000
Germany		28 ^r	5,420 ^r	29	4,050
Other		27 ^r	2,670 ^r	28	3,970
Total		171	27,100 ^r	195	28,500
Unwrought hafnium, including powder:	8112.92.2000				
France		15	8,920	62	9,920
Germany		32 ^r	7,130	87	18,700
Other		26 ^r	3,380 ^r	31	4,010
Total		72	19,400	180	32,600

^rRevised. -- Zero.

¹Table includes data available through March 1, 2018. Data 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 MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY OR LOCALITY¹

(Metric tons, gross weight)

Country or locality ²	2012	2013	2014	2015	2016 ^p
Australia	605,000	388,000	798,000	601,111 ^r	450,000
Brazil	20,425	21,154	23,659 ^r	21,000	21,000 ^c
China ^c	140,000	150,000	150,000	140,000	140,000
India	40,000	40,000	40,000 ^r	40,000	40,000 ^c
Indonesia ^c	120,000	120,000	110,000	110,000	110,000
Kenya	--	--	15,004	25,951 ^r	39,687
Madagascar	31,242	31,300 ^e	27,300 ^{r,c}	20,000 ^{r,c}	8,500
Malaysia	442	379	677 ^r	826 ^r	800 ^c
Mozambique	46,900	39,000 ^r	63,100 ^r	64,000 ^r	68,200
Nigeria	4,000 ^r	2,000 ^r	1,034 ^r	1,000 ^r	1,000 ^c
Russia ³	7,969	8,504	7,903 ^r	8,000	8,000 ^c
Senegal	--	--	9,040	45,248	52,627
Sierra Leone	1,120	2,951	2,357	1,400	1,600 ^c
South Africa	367,190	224,446	390,000 ^r	330,000 ^r	360,000 ^c
Sri Lanka ^c	293 ^r	323 ^r	600	600 ^r	600
Turkey	200 ^r	200 ^r	1,100 ^r	1,500 ^r	1,500 ^c
Ukraine	20,000 ^c	41,000 ^c	27,000 ^c	25,000 ^r	22,200
United States	W	W	W	80,000 ⁴	W
Vietnam ^c	15,600	7,600	8,500	3,400	8,700
Total	1,420,000	1,080,000 ^r	1,680,000 ^r	1,520,000	1,330,000

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

¹Table includes data available through March 23, 2017. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²In addition to the countries and (or) localities listed, small amounts of zirconium mineral concentrates were produced in other countries and (or) localities; however, information was not sufficient to make reliable estimates of output.

³Production of baddeleyite concentrate averaging 98% ZrO₂.

⁴Rounded to one significant digit to avoid disclosing company proprietary data.