



2020 Minerals Yearbook

GERMANIUM [ADVANCE RELEASE]

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GERMANIUM

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In 2020, two domestic zinc operations produced recoverable byproduct germanium. In Alaska, the Red Dog Mine, owned by Teck Resources Ltd. (Canada), produced germanium-containing zinc concentrates that were exported to Teck's metallurgical facility in Trail, British Columbia, Canada, and to processors in Asia and Europe. In Tennessee, the Clarksville zinc smelter, owned by Nyrstar NV (Belgium), produced byproduct germanium leach concentrates. There was no primary production of germanium metal or compounds in the United States, and secondary production data from the processing of scrap were withheld to avoid disclosing company proprietary data. Total world production (excluding the United States) of germanium in metal and compounds, including germanium recovered from zinc concentrates, coal fly ash, and recycled materials, was estimated to be 140,000 kilograms (kg), 7% more than that in 2019 (table 1).

Germanium is a hard, brittle semimetal that first was used about 60 years ago as a semiconductor material in radar units and as the material for the first transistors. Germanium is commercially available as tetrachloride, high-purity oxide, and various forms of metal. The current principal uses of germanium include lenses or windows in infrared night-vision devices; a component of glass in telecommunications fiber-optic cable; polymerization catalysts for polyethylene terephthalate (PET), a commercially important plastic; and semiconductors and substrates in electronic circuitry and solar cells.

The germanium production process yields various compounds and metal for use in specific applications. Germanium is recovered initially through the leaching of zinc-refining residues or coal ash, followed by precipitation of a germanium concentrate from the leachate. The concentrate, regardless of its source, is chlorinated, distilled, and purified to form the first usable product, germanium tetrachloride, a colorless liquid that is used primarily in fiber-optic cable production. Germanium tetrachloride can be hydrolyzed and dried to produce germanium dioxide, a white powder used in the manufacture of certain optical lenses, and as a catalyst in the production of PET resin. Germanium metal powder is produced through the reduction of germanium dioxide with hydrogen, and first-reduction bars are cast from melted powder. The germanium bars are zone-refined (a process that involves melting and cooling to isolate and remove impurities) to produce high-purity electronic-grade germanium metal. Zone-refined germanium metal is grown into crystals that are sliced for use as semiconductors or recast into forms suitable for lenses or window blanks for infrared optical devices.

Government Actions and Legislation

As a strategic and critical material, germanium was added to the National Defense Stockpile (NDS) in 1984. The Annual Materials Plan for fiscal year 2021 (October 1, 2020, through September 30, 2021) allocated 3,000 kg of germanium scrap for potential disposals and no potential acquisitions

of germanium metal (Defense Logistics Agency Strategic Materials, 2020a, b). At yearend 2020, the NDS held 14,000 kg of uncommitted germanium metal, unchanged from stocks at yearend 2019 (table 1).

In October, the U.S. Department of Defense announced that it had awarded \$600 million for the experimentation and testing of fifth-generation (5G) wireless network technology at several U.S. military sites (U.S. Department of Defense, 2020). Germanium-containing fiber-optic cable is a necessary component for the development of 5G technology infrastructure.

Production

Teck produced germanium-containing zinc concentrate at its Red Dog zinc-lead open pit mine in Alaska. Approximately one-third of the zinc concentrate produced at the Red Dog Mine was sent to Teck's metallurgical complex in Trail, British Columbia Province, Canada, for processing. Residues from zinc concentrate were treated in roasters or pressure-leach facilities and purified to produce germanium dioxide and other byproduct metals. The remainder of the concentrate was sent to several countries in Asia and Europe for processing. Nyrstar's Clarksville zinc smelter in Tennessee produced byproduct germanium concentrate processed from the Middle Tennessee Zinc Complex zinc concentrate feedstock (Nyrstar NV, 2020).

Secondary processors recovered secondary germanium metal from end-of-life products, such as decommissioned military vehicles and thermal weapon sights. Major secondary producers included Umicore S.A. (Belgium) and 5N Plus Semiconductors LLC (St. George, UT). Umicore's facility in Quapaw, OK, produced germanium tetrachloride and other germanium materials. 5N Plus's facility in St. George, UT, produced germanium wafers (5N Plus Inc., 2021, p. 9; Umicore S.A., undated).

Consumption

The U.S. Geological Survey (USGS) estimated that domestic consumption of germanium metal (including germanium content of compounds) was about 30,000 kg in 2020, unchanged from that in 2019 (table 1). The major global end uses were electronics, fiber-optic systems, infrared optics, polymerization catalysts, solar applications, and other uses (such as chemotherapy, phosphors, and metallurgy).

Fiber-Optic Systems.—Germanium dioxide was used as a dopant (a substance added in small amounts) in the pure-silica glass core of optical fibers to increase the refractive index, preventing signal loss while not absorbing light. Corning Inc. (Corning, NY) and Prysmian S.p.A. (Italy) were major producers of fiber-optic cable in the United States. In October, Umicore and Prysmian announced a partnership to supply and use, respectively, sustainably sourced germanium for fiber-optic cable production (Umicore S.A., 2020).

Infrared Optics.—Germanium was used in lenses and windows for infrared optical systems owing to its transparency to part of the infrared spectrum and its high refractive index. Germanium-containing infrared optics were primarily for military use, although the commercial and personal markets for thermal-imaging devices that used germanium lenses had grown during the previous few years.

Polymerization Catalysts.—Consumption of germanium for PET outside the United States was thought to have declined since 2011, owing to germanium price increases that led to use of germanium substitutes. Producers substituted lower cost antimony- and titanium-based products for germanium dioxide catalysts.

Solar Cells.—Germanium-based solar cells were used in space-based applications and terrestrial installations.

Prices

Germanium was generally traded through long-term supply contracts among consumers, producers, and traders. Argus Metals International prices were compiled through interviews with market participants and based on estimates of representative prices in trades carried out on a particular day. Argus' reported germanium metal (minimum 99.999% germanium; cost, insurance, and freight; Europe) price began the year at \$1,050 per kilogram and decreased to an annual low of \$1,015 per kilogram in mid-February. The price then increased several times during the remainder of the year to \$1,028 per kilogram in late February, then to \$1,048 per kilogram in early June, and finally to an annual high of \$1,090 per kilogram in mid-November. On an annual average basis, the germanium metal price decreased for the second year in a row to \$1,046 per kilogram in 2020, a 15% decrease compared with \$1,236 per kilogram in 2019 (tables 1, 3).

The germanium dioxide (minimum 99.99% germanium dioxide, approximately 69% germanium content, in-warehouse, Rotterdam) price began the year at \$773 per kilogram and decreased to an annual low of \$720 per kilogram in mid-February, where it remained unchanged for the rest of the year. On an annual average basis, the germanium dioxide price decreased for the second year in a row to \$724 per kilogram in 2020, 21% less than \$913 per kilogram in 2019 (tables 1, 3).

Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (unwrought, wrought, and powder) increased by 28% to 18,000 kg in 2020 compared with 14,100 kg in 2019 (tables 1, 2). Unwrought imports, which accounted for most of the germanium metal imports, increased by 19% to 13,000 kg in 2020 compared with 10,900 kg in 2019 (table 2) and were mostly sourced from China (50%), Belgium (32%), and Russia (14%). Germanium powder imports totaled 2,880 kg in 2020, a 70% increase from 1,700 kg imported in 2019. Canada and Germany supplied nearly 90% of the germanium metal powder imports. Wrought germanium metal imports equaled 2,160 kg, 48% more than the 1,450 kg imported in 2019. More than 90% of these imports were sourced from China, Russia, and Germany, in descending order of import

quantity. In 2020, China, Belgium, Russia, Germany, and Canada, in descending order of quantity, accounted for 99% of all types of germanium metal imported into the United States. The estimated germanium content of the germanium dioxide imported in 2020 was 12,000 kg, a 43% decrease from the estimated content in 2019, but only slightly less and essentially unchanged compared with the estimated content of imports in 2018 and 2017, respectively (table 1). Canada and Belgium, in descending order of estimated content, accounted for most of the germanium dioxide imports (IHS Markit Ltd., 2021).

Domestic exports of germanium, including metal and the germanium content of germanium dioxide, were estimated to be about 7,100 kg in 2020, based on trade data from the U.S. Census Bureau that were adjusted by the USGS, an increase from an estimated 4,600 kg exported in 2019 (table 1). Most of these exports were in the form of wrought germanium and other germanium articles (Schedule B export code 8112.99.1000).

World Review

In 2020, world production of germanium (excluding the United States) recovered from zinc concentrates, coal fly ash, and recycled material was estimated to be about 140,000 kg (table 1). Scrap was estimated to have supplied about 30% of the world's total production of germanium. Owing to the high value of refined germanium, new scrap generated during the manufacture of fiber-optic cables, infrared optics, and substrates was typically reclaimed and fed back into the production process. Recycling of germanium from old scrap, such as fiber-optic windows from decommissioned military vehicles or fiber-optic cables, has increased during the past decade. China accounted for most of the global germanium production. Primary germanium was recovered from zinc residues in Belgium and Canada (concentrates shipped from the United States), coal ash and zinc residues in China (multiple sources), and coal ash and zinc residues in Russia.

As a byproduct metal, the supply of germanium was heavily reliant on zinc mine production. Although an important factor, global changes in zinc mine production may not be an indicator of a corresponding change in the supply of germanium.

Belgium.—Umicore produced germanium metal, germanium tetrachloride for fiber optics, germanium substrates, and germanium optical products at its refinery and recycling plant in Olen (Umicore S.A., undated).

Canada.—Germanium dioxide was produced at a lead-zinc metallurgical complex operated by Teck in Trail, British Columbia Province, which included two specialty metal plants that produced byproduct metals.

China.—China continued to be the leading global producer and exporter of germanium metal, which was recovered from germanium-bearing coal ash and zinc ore. The two significant germanium-containing coal deposits in China were the Lincang lignite deposit in Yunnan Province and the Wulantuga lignite deposit in Inner Mongolia Autonomous Region (Liu and others, 2021). China's reported exports of germanium metal [including Harmonized System (HS) codes 8112.99.10 and 8112.30.00] increased for the second year in a row to 29,000 kg in 2020

from 22,800 kg in 2019 and 20,300 kg in 2018. Germanium was exported mostly to Hong Kong (30%), Russia (23%), Germany (14%), and Japan (13%) (IHS Markit Ltd., 2021). The Government increased the export tax rebate for several value-added metal products in March, including germanium fabricated products (exported under HS code 8112.99.10), to 13% from 10% (Argus Metals International, 2020).

In July, the government of Yunnan Province announced that it would provide about \$145 million¹ in subsidies for companies to purchase and stockpile certain base and minor metals, including germanium. The plan called for a stockpile of 20 t of germanium ingots and the government would provide 80% of the interest on any loan obtained by a company to purchase and stockpile germanium (Luk, 2020). Germanium metal and products were mostly produced in Hunan and Yunnan Provinces in China.

Germany.—According to news sources, the Government reportedly rejected an offer from Vital Materials Co. Ltd., a China-based specialty materials producer, to acquire PPM Pure Metals GmbH. PPM Pure Metals, a subsidiary of Recylex SA (France), produced high-purity germanium metal at its plant in Langelsheim, which later ceased operations owing to financial difficulties. However, in early December, Vital Materials announced that it had acquired the Langelsheim plant including its production equipment (Shabalala and Daly, 2020; Vital Materials Co. Ltd., 2021).

India.—Hindustan Zinc Ltd. (a subsidiary of Vedanta Resources Ltd.) continued development of a 350,000-metric-ton-per-year zinc smelter that could potentially recover germanium as a byproduct. The smelter would be built in Doswada, Gujarat State, and would process imported zinc concentrates. Hindustan Zinc completed a prefeasibility study on the project and was seeking Government approval to prepare an environmental impact assessment (Surendran, 2020).

Russia.—Germanium and Applications Ltd. recovered germanium from fly ash from coal mined at the Spetsugli Mine within the massive Pavlovskoye coal deposit in the Russian Far East. The company reported that coal production from the open pit mine could yield as much as 21,000 kilograms per year (kg/yr) of germanium, and its facilities in Moscow and Novomoskovsk could produce germanium blanks for optical use, germanium oxide and metal, and substrates for electronics (Germanium and Applications Ltd., 2018).

JSC Germanium operated an integrated refinery in Krasnoyarsk, Siberia, that processed concentrates, fly ash, and waste to produce germanium compounds, finished products, and metal. The company reported that it could produce germanium at a rate of about 20,000 kg/yr, but it did not specify whether that included the germanium content of finished products, such as germanium lenses. JSC Germanium exported more than 80% of the germanium that it produced (JSC Germanium, 2018).

Outlook

The global demand for fiber-optic cable is expected to continue to increase during the next several years. Germanium-based optical blanks and windows incorporated into infrared devices are expected to continue to experience heavy use by

military and law enforcement agencies. Strong demand from the defense industry for thermal imaging applications is expected to increase the use of germanium in coming years. New applications for infrared products that use germanium lenses in commercial and industrial markets are expected to become more prevalent and represent a significant potential for consumption growth. However, an increase in the substitution of specialty glass for pure germanium in infrared applications will continue to be attractive to commercial and industrial markets.

On the supply side, the availability of recycled germanium recovered from end-of-life products, such as fiber optics, military vehicles, and solar cells, is expected to increase during the next two decades as aging products are taken out of service. In China, germanium producers are expected to continue to expand their product lines to include downstream germanium products for export.

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¹Where necessary, values have been converted from Chinese yuan renminbi (CNY) to U.S. dollars (US\$) at the rate of CNY6.90=US\$1.00, for 2020.

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TABLE 1
SALIENT GERMANIUM STATISTICS¹

(Kilograms, unless otherwise specified)

	2016	2017	2018	2019	2020
United States:					
Refinery production	W	W	W	W	W
Imports for consumption:					
Germanium metal ²	11,000	11,100	11,900	14,100	18,000
Germanium dioxide ^{e, 3}	15,200	12,000	12,200	21,000	12,000
Exports, germanium metal and dioxide ^{e, 4}	4,780	3,670	4,880	4,600	7,100
Consumption, germanium metal ^{e, 5}	30,000	30,000	30,000	30,000	30,000
Price, average:					
Germanium metal ⁶	1,087	1,082	1,543	1,236	1,046
Germanium dioxide ⁷	830	731	1,084	913	724
Stocks, December 31, U.S. Government ⁸	13,400	13,400	14,000	14,000	14,000
World, refinery production: ^e					
China	82,000	79,100	94,900	85,700	95,000
Russia	5,000	5,000	5,000	5,000	5,000
Other ⁹	40,000	40,000	30,000	40,000	40,000
Total	127,000	124,000	130,000	131,000	140,000

^cEstimated. do. Ditto. W Withheld to avoid disclosing company proprietary data; not included in “World, refinery production.”

¹Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

²Includes Harmonized Tariff Schedule of the United States (HTS) codes 8112.92.6000, 8112.92.6500, and 8112.99.1000.

³Includes HTS code 2825.60.0000. Data have been adjusted to exclude low-value shipments, then multiplied by 69% to account for germanium content.

⁴Includes Schedule B codes 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Dioxide data were multiplied by 69% to account for germanium content.

⁵Estimated consumption of germanium content of metal and germanium dioxide.

⁶Cost, insurance, and freight value; Europe; minimum 100-kilogram (kg) lots; minimum 99.999% purity. Source: Argus Media group—Argus Metals International.

⁷In-warehouse, Rotterdam; minimum 100-kg lots; minimum 99.999% purity. Source: Argus Media group—Argus Metals International.

⁸Source: Defense Logistics Agency Strategic Materials. Data are uncommitted germanium metal only.

⁹Includes Belgium, Canada, Germany, and other countries or localities. Excludes U.S. production.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL, BY COUNTRY OR LOCALITY¹

Country or locality	2016		2017		2018		2019		2020	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Unwrought:²										
Belgium	1,560	\$2,070,000	1,450	\$1,680,000	2,280	\$3,830,000	2,890	\$4,970,000	4,170	\$5,660,000
Canada	--	--	--	--	--	--	--	--	10	10,100
China	4,930	4,590,000	5,220	5,070,000	5,610	6,480,000	7,660	8,000,000	6,480	5,730,000
Germany	31	25,700	123	148,000	463	211,000	253	136,000	472	135,000
Israel	--	--	--	--	--	--	--	--	27	188,000
Japan	140	112,000	--	--	--	--	--	--	--	--
Korea, Republic of	--	--	--	--	8	19,300	36	84,800	--	--
Russia	--	--	200	111,000	159	86,500	50	50,000	1,760	522,000
United Kingdom	--	--	189	113,000	322	23,700	35	7,790	64	34,400
Other	--	--	--	--	6	38,500	2	2,520	--	--
Total	6,660	6,800,000	7,180	7,120,000	8,850	10,700,000	10,900	13,200,000	13,000	12,300,000
Powder:³										
Belgium	712	860,000	29	165,000	453	1,120,000	494	901,000	201	1,380,000
Canada	--	--	--	--	--	--	--	--	1,520	241,000
China	618	620,000	391	427,000	173	153,000	94	96,800	73	132,000
Germany	639	868,000	611	753,000	611	1,020,000	1,080	1,790,000	978	1,440,000
Netherlands	--	--	--	--	--	--	1	3,000	--	--
Russia	263	282,000	591	572,000	21	32,500	22	29,600	37	46,700
Switzerland	--	--	257	275,000	--	--	--	--	--	--
United Kingdom	3	4,370	49	5,850	--	--	3	2,120	78	50,600
Total	2,240	2,630,000	1,930	2,200,000	1,260	2,320,000	1,700	2,820,000	2,880	3,280,000
Wrought:⁴										
Belgium	66	105,000	17	73,200	2	12,800	5	55,100	112	268,000
China	682	872,000	1,190	1,470,000	780	1,170,000	719	987,000	917	1,200,000
Germany	225	325,000	304	438,000	416	806,000	229	419,000	327	471,000
Romania	277	615,000	--	--	--	--	--	--	--	--
Russia	838	1,270,000	452	481,000	543	748,000	474	517,000	787	749,000
South Africa	--	--	23	19,700	--	--	23	25,300	--	--
United Kingdom	20	35,200	1	13,100	3	9,070	--	--	5	11,900
Other	9	10,500	27	12,800	8	6,620	2	2,840	7	71,400
Total	2,120	3,230,000	2,020	2,500,000	1,750	2,750,000	1,450	2,010,000	2,160	2,780,000

-- Zero.

¹Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes Harmonized Tariff Schedule of the United States (HTS) code 8112.92.6000.

³Includes HTS code 8112.92.6500.

⁴Includes HTS code 8112.99.1000.

Source: U.S. Census Bureau.

TABLE 3
ANNUAL AVERAGE PRICES¹

(Dollars per kilogram)

Year	Germanium metal ²	Germanium dioxide ³
2011	1,539	1,218
2012	1,464	1,179
2013	1,771	1,309
2014	1,917	1,291
2015	1,785	1,207
2016	1,087	830
2017	1,082	731
2018	1,543	1,084
2019	1,236	913
2020	1,046	724

¹Table includes data available through June 22, 2021.

²Cost, insurance, and freight value; Europe; minimum 100-kilogram (kg) lots. For 2011–15, prices are for minimum 99.99% purity. For 2016–20, prices are for minimum 99.999% purity.

³In-warehouse, Rotterdam; minimum 100-kg lots. For 2011–15, prices are for minimum 99.99% purity. For 2016–20, prices are for minimum 99.999% purity.

Source: Argus Media group—Argus Metals International.