



2021 Minerals Yearbook

GERMANIUM [ADVANCE RELEASE]

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GERMANIUM

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In 2021, 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, Europe, and Australia. 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 from the processing of scrap was withheld to avoid disclosing company proprietary data.

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 principal uses of germanium included 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 initially recovered 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 2022 (October 1, 2021, through September 30, 2022) allocated 5,000 kilograms (kg) of germanium scrap for potential disposals, and no potential acquisitions of germanium metal were allocated in fiscal year 2022 (Defense Logistics Agency Strategic Materials, 2021a, b). At yearend 2021, the NDS held 14,000 kg of uncommitted germanium metal, unchanged from stocks at yearend 2020 (table 1).

In November, the Infrastructure Investment and Jobs Act was signed into law, which included \$65 billion for investment in broadband infrastructure to increase the availability and affordability of reliable high-speed internet across the United States. Most of the funds would be distributed under the Broadband Equity, Access, and Deployment Program, administered by the National Telecommunications and Information Administration, with funding prioritized for areas of the United States that lacked access to high-speed internet (National Telecommunications and Information Administration, 2022). Germanium dioxide and tetrachloride are used by fiber-optics manufacturers to produce fiber-optic glass.

Production

Teck produced germanium-containing zinc concentrates at its Red Dog zinc-lead open pit mine in Alaska. A portion of the zinc concentrate produced at Red Dog was sent to Teck's metallurgical complex in Trail, British Columbia, Canada, for processing. Residues from the processing of zinc concentrates were purified to produce a range of germanium products including germanium dioxide, germanium tetrachloride, and a germanium-based PET catalyst solution. The remainder of the concentrate was sent to Asia, Europe, and Australia for processing (Teck Resources Ltd., 2022a, p. 36; 2022b). Nyrstar's Clarksville zinc smelter in Tennessee had produced byproduct germanium concentrate processed from zinc concentrate feedstock from the company's Middle Tennessee mines (Nyrstar NV, 2020a, b).

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 primarily germanium tetrachloride. 5N Plus's facility in St. George, UT, produced germanium wafers (5N Plus Inc., 2021b, p. 9; Umicore S.A., undated).

Consumption

The U.S. Geological Survey (USGS) estimated that domestic consumption of germanium metal (including metal content of compounds) was about 30,000 kg in 2021, unchanged from that in 2020 (table 1). The major global end uses were electronics, fiber-optic systems, infrared optics, polymerization catalysts, solar applications, and other uses (such as chemotherapy, metallurgy, and phosphors).

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), a major producer of optical fiber and cable in the

United States, announced that it planned to invest \$150 million to expand its optical cable manufacturing facility in Hickory, NC, to support AT&T's expansion of broadband networks. In 2021, Corning reported an increase in net sales in its optical communication segment compared with that in 2020 owing to strong growth in fifth generation (5G) and broadband networks and cloud computing (Catawba County Economic Development Corp., 2021; Corning Inc., 2021; 2022, p. 4, 27). OFS Fitel LLC (a subsidiary of Furukawa Electric Co., Ltd., Japan) and Prysmian S.p.A. (Italy) also produced optical fiber in the United States.

Infrared Optics.—Germanium metal 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. However, the commercial and personal markets for thermal-imaging devices that use germanium lenses grew during the past few years. In May, Teledyne Technologies Inc. (Thousand Oaks, CA) announced that it had acquired FLIR Systems Inc. (Wilsonville, OR) for \$8.2 billion. FLIR, a leading manufacturer of thermal imaging infrared cameras in the United States, would be included in Teledyne's Digital Imaging segment and renamed Teledyne FLIR (Teledyne Technologies Inc., 2021).

Solar Cells.—Germanium metal was fabricated into wafers that were used to produce multijunction solar cells. These solar cells were primarily used in commercial and defense space applications, such as powering satellites, owing to their record-high solar energy conversion and stability in high radiation and thermally extreme conditions. Germanium wafers were used as the bottom layer substrate to grow the top semiconducting layers of the multijunction solar cell (National Renewable Energy Laboratory, 2023a, b).

Prices

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 an average of \$1,090 per kilogram and increased several times during the year, reaching a high of \$1,380 per kilogram by late December. On an annual average basis, the germanium metal price increased by 13% to \$1,187 per kilogram in 2021 from \$1,046 per kilogram in 2020 (tables 1, 3).

Argus' germanium dioxide (minimum 99.999% germanium dioxide; approximately 69% germanium content; cost, insurance, and freight; Europe) price began the year at an average of \$720 per kilogram and remained level through late April. Prices then increased several times during the remainder of 2021 to a high of \$885 per kilogram at monthend December. On an annual average basis, the germanium dioxide price increased by 6% to \$770 per kilogram in 2021 from \$724 per kilogram in 2020 (tables 1, 3).

Foreign Trade

Based on trade data from the U.S. Census Bureau that were adjusted by the USGS to exclude low-unit-value shipments, imports for consumption of germanium metal (unwrought, wrought, and powder) decreased to an estimated 13,000 kg in 2021 from 14,000 kg (revised) in 2020 (tables 1, 2). Unwrought imports, which accounted for most of the germanium metal imports, decreased to an estimated 9,100 kg in 2021 compared with 11,000 kg in 2020 (table 2). China and Belgium, in descending order by import quantity, have been the main suppliers of unwrought germanium metal to the United States in recent years, accounting for more than 90% of unwrought imports annually between 2017 and 2021. Germanium powder imports were estimated to be 1,300 kg in 2021, a decrease from an estimated 1,400 kg imported in 2020. Belgium and Germany supplied about 85% of the germanium metal powder imports in 2021, similar compared with their share in 2020. Wrought germanium metal imports increased to an estimated 2,800 kg in 2021 from 2,100 kg in 2020. About 87% of these imports were sourced from Russia and China, in descending order by import quantity. In 2020, these two countries accounted for 79% of wrought metal imports. In 2021, China, Belgium, Russia, and Germany, in descending order of quantity, accounted for 97% of all types of germanium metal imported into the United States. The estimated germanium content of the germanium dioxide imported in 2021 increased to 17,000 kg from 12,000 kg in 2020 (table 1). Belgium and Canada accounted for most of the germanium dioxide imports.

Domestic exports of germanium, including metal and the germanium content of germanium dioxide, were estimated to be 7,500 kg in 2021, based on trade data from the U.S. Census Bureau that were adjusted by the USGS, an increase from an estimated 4,800 kg exported in 2020 (table 1).

World Review

In 2021, sufficient data on the world production of germanium recovered from zinc concentrates, coal fly ash, and recycled material were not available to make reliable estimates (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 the majority of global germanium production capacity. 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.—In addition to its plant in Quapaw, OK, Umicore also produced germanium metal and other germanium products at its refinery and recycling plant in Olen. Umicore reported recovery in demand for high-purity chemicals used in optical fibers and strong demand from the space industry for germanium substrates in 2021. Demand for infrared materials declined in 2021 to levels before the coronavirus disease 2019 (COVID-19) pandemic, following a significant increase in demand for infrared cameras in 2020 in relation to the COVID-19 pandemic (Umicore S.A., 2022, p. 28, 37; undated). Thermal imaging cameras can be used for measuring variations in body surface temperature.

Canada.—Germanium dioxide and other germanium products, including germanium tetrachloride and a germanium-based PET catalyst solution, were produced at a lead-zinc metallurgical complex operated by Teck in Trail, British Columbia Province, which included specialty metal plants that produced byproduct metals including germanium. Germanium was recovered from germanium-containing zinc concentrates produced at Teck's Red Dog zinc-lead open pit mine in Alaska (Teck Resources Ltd., 2022b).

China.—China continued to be the leading global producer and exporter of germanium metal, which was recovered from domestic germanium-bearing coal ash and domestic and imported 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. China's reported exports of germanium metal [including Harmonized System (HS) codes 8112.99.10 and 8112.30.00] increased to 42,200 kg in 2021 from 29,000 kg in 2020. Exports equaled 22,800 kg in 2019 and 20,300 kg in 2018. In 2021, germanium was mostly exported to Germany (22%), Russia (20%), Belgium (19%), Hong Kong (17%), and Japan (10%). Germanium metal production in China was estimated by state-owned Beijing Antaike Information Co., Ltd. to be 110,000 kilograms (kg) in 2021 (Liu and others, 2021; Yunnan Chihong Zinc and Germanium Co. Ltd., 2022, p. 17; Zen Innovations AG, 2022).

The Yunnan Provincial government sold 4,660 kg of germanium metal stocks to Anhui Guangzhi Technology Co. Ltd. for \$5.24 million through an auction held in October. The germanium metal was produced by Yunnan Tianhao Rare and Precious Metals Co. Ltd., a germanium and indium producer in China, and was acquired by the government following the company's bankruptcy after the collapse of the Fanya Metal Exchange (FME) in 2015. The Yunnan Provincial government previously auctioned off 92,000 kg of FME's germanium stocks in October 2019 to Vital Materials Co. Ltd. (Argus Metals International, 2021).

Yunnan Chihong Zinc and Germanium Co. Ltd. was one of China's leading producers of germanium and germanium products. According to news sources, the company produced 34,300 kg of germanium metal and dioxide in 2021, an increase of 17% from 29,200 kg in 2020. Yunnan Chihong Zinc and Germanium reported that it produced 46,600 kg of germanium in germanium products in 2021, 8% less than production in 2020, and had the capacity to produce 60,000 kilograms per year (kg/yr) of germanium contained in germanium

products. The company produced several germanium products, including germanium lenses, germanium tetrachloride, and monocrystalline germanium wafers, through several subsidiaries (Argus Metals International, 2022; Shanghai Metals Market, 2022; Yunnan Chihong Zinc and Germanium Co. Ltd., 2022, p. 14, 24).

Xinlingol Mengdong Germanium Technology Co. Ltd. announced its plans to stop producing germanium metal owing partially to high production costs and that it would begin producing a germanium concentrate instead. The company had the capacity to produce 15,000 kg/yr of germanium metal (minimum 99.99% germanium). Yunnan Kaiyu Optoelectronic Technology Co. Ltd. began producing germanium metal in August. The company would process germanium concentrate procured on the spot market and would have a capacity of 12,000 kg/yr of germanium metal (minimum 99.99% germanium) (Asian Metal, 2021a, b).

Congo (Kinshasa).—Ivanhoe Mines Ltd. (Canada) announced that a definitive feasibility study on the reopening of the Kipushi zinc-copper mine was near completion. The mine, which had been on care-and-maintenance status since 1993, was a past producer of byproduct germanium. Ivanhoe Mines held a 68% share in the Kipushi project, and state-owned La Générale des Carrières et des Mines SARL (Gécamines) owned the remaining 32% share. The company planned to construct a new mill at the mine site capable of processing 800,000 metric tons per year of ore (Ivanhoe Mines Ltd., 2021, p. 26–27; 2022).

Germany.—In November, 5N Plus Inc. announced that it had acquired AZUR SPACE Solar Power GmbH in Heilbronn, a technology developer and producer of multijunction solar cells, for \$88 million¹ (74.6 million euros). AZUR SPACE's multijunction solar cells are composed of several semiconductor layers grown on germanium substrates. The acquisition would expand 5N Plus' advanced materials production capabilities (5N Plus Inc., 2021a; AZUR SPACE Solar Power GmbH, 2022).

Russia.—Germanium and Applications Ltd. recovered germanium from coal fly ash produced 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 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 if 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, 2016).

¹Where necessary, values have been converted from euro area euros (EUR) to U.S. dollars (US\$) at an annual average exchange rate of EUR0.846=US\$1.00 for 2021.

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. 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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TABLE 1
SALIENT GERMANIUM STATISTICS¹
(Kilograms unless otherwise specified)

	2017	2018	2019	2020	2021
United States:					
Refinery production	W	W	W	W	W
Imports for consumption: ^c					
Germanium metal ²	11,000 ^r	10,000 ^r	14,000 ^r	14,000 ^r	13,000
Germanium dioxide, Ge content ³	11,000 ^r	12,000 ^r	21,000	12,000	17,000
Exports, germanium metal and dioxide, Ge content ^{c,4}	3,000 ^r	3,600 ^r	4,500 ^r	4,800 ^r	7,500
Consumption, Ge content ^{c,5}	30,000	30,000	30,000	30,000	30,000
Price, average: ⁶					
Germanium metal	1,082	1,543	1,236	1,046	1,187
Germanium dioxide	do.	731	1,084	913	724
Stocks, December 31, U.S. Government ⁷	13,400	14,000	14,000	14,000	14,000
World, refinery production: ^c					
China	79,100	94,900	85,700	95,000	NA
Russia	5,000	5,000	5,000	5,000	NA
Other ⁸	40,000	30,000	40,000	40,000	NA
Total	124,000	130,000	131,000	140,000	NA

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

¹Table includes data available through May 26, 2022. Data are rounded to no more than two significant digits, except prices and world production; 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. Data have been adjusted to exclude low-value shipments.

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 contained in metal and germanium dioxide.

⁶Source: Argus Media group – Argus Metals International.

⁷Source: Defense Logistics Agency Strategic Materials. Data are uncommitted germanium metal only.

⁸Includes Belgium, Canada, Germany, and other countries or localities. Excludes U.S. production.

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

(Kilograms unless otherwise specified)

Country or locality	2017		2018		2019		2020		2021	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
<u>Unwrought:²</u>										
Belgium	1,500 r	\$1,700,000 r	2,300 r	\$3,800,000 r	2,900 r	\$5,000,000 r	4,200 r	\$5,700,000 r	3,100	\$4,500,000
China	5,100 r	5,000,000 r	5,200 r	6,300,000 r	7,700 r	8,000,000	6,400 r	5,800,000 r	5,200	5,400,000
Germany	100 r	140,000 r	63 r	110,000 r	37 r	85,000 r	6 r	10,000 r	4	44,000
Russia	200	110,000 r	28 r	41,000 r	50	50,000	49 r	45,000 r	560	600,000
United Kingdom	100 r	95,000 r	25 r	19,000 r	10 r	5,300 r	64	34,000 r	210	110,000
Other	--	--	14 r	58,000 r	38 r	87,000 r	37 r	200,000 r	56	87,000
Total	7,000 r	7,100,000 r	7,600 r	10,000,000 r	11,000 r	13,000,000 r	11,000 r	12,000,000 r	9,100	11,000,000
<u>Powder:³</u>										
Belgium	29	160,000 r	450 r	1,100,000 r	380 r	840,000 r	200 r	1,400,000 r	260	980,000
China	390 r	430,000 r	91 r	130,000 r	89 r	81,000 r	73	130,000 r	2	3,500
Germany	560 r	740,000 r	520 r	980,000 r	1,100 r	1,800,000 r	980 r	1,400,000 r	870	1,300,000
Russia	590 r	570,000 r	21	33,000 r	22	30,000 r	37	47,000 r	16	25,000
Other	260	270,000	--	--	4	5,100	78	51,000	180	160,000
Total	1,800 r	2,200,000	1,100 r	2,300,000 r	1,600 r	2,700,000 r	1,400 r	3,000,000 r	1,300	2,500,000
<u>Wrought:⁴</u>										
Belgium	17	73,000 r	2	13,000 r	5	55,000 r	110 r	270,000 r	150	310,000
China	1,200 r	1,500,000 r	730 r	1,200,000 r	630 r	930,000 r	880 r	1,200,000	1,000	1,300,000
Germany	300 r	440,000 r	420 r	810,000 r	230 r	420,000 r	330 r	470,000 r	220	430,000
Russia	450 r	480,000 r	540 r	750,000 r	470 r	520,000 r	780 r	750,000 r	1,400	1,500,000
Other	33 r	42,000 r	6 r	14,000 r	25 r	28,000 r	7	16,000 r	6	21,000
Total	2,000 r	2,500,000	1,700 r	2,700,000 r	1,400 r	1,900,000 r	2,100 r	2,700,000 r	2,800	3,600,000

¹Revised. -- Zero.

²Table includes data available through April 7, 2022. Data are rounded to no more than two significant digits; may not add to totals shown. Data have been adjusted to exclude low-value shipments.

³Includes Harmonized Tariff Schedule of the United States (HTS) code 8112.92.6000.

⁴Includes HTS code 8112.92.6500.

⁴Includes HTS code 8112.99.1000.

Source: U.S. Census Bureau.

TABLE 3
ANNUAL AVERAGE PRICE¹

(Dollars per kilogram)

Period	Germanium metal ²	Germanium dioxide ³
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
2021	1,187	770

¹Table includes data available through May 26, 2022.

²Cost, insurance, and freight value (Europe), minimum 100-kilogram (kg) lots. For 2012–15, prices are for minimum 99.99% purity. For 2016–21, prices are for minimum 99.999% purity.

³In-warehouse (Rotterdam), approximately 69% germanium content, minimum 100-kg lots. As of September 2021, prices reflected the cost, insurance, and freight value (Europe). For 2012–15, prices are for minimum 99.99% purity. For 2016–21, prices are for minimum 99.999% purity.

Source: Argus Media group – Argus Metals International.