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2023 Minerals Yearbook

GERMANIUM [ADVANCE RELEASE]

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Germanium

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In 2023, two domestic zinc operations produced byproduct germanium. In Alaska, the Red Dog Mine, operated by Teck Resources Ltd. (Canada), produced germanium-containing zinc concentrate that was exported to Teck's metallurgical facility in Trail, British Columbia, Canada, and to processors in Asia, Europe, and Australia. In Tennessee, the Middle Tennessee zinc mines, operated by Nyrstar NV (Netherlands), produced a zinc concentrate with a recoverable amount of germanium. The zinc concentrate was sent to the company's zinc smelter in Clarksville, TN, for processing. There was no primary production of germanium metal or compounds from concentrates in the United States, and data on secondary production from the processing of scrap were not available.

Germanium is a hard, brittle semimetal that first was used as a semiconductor material in radar units and in 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 metals 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 optical fiber production. Fiber-optic technology was used for high-speed data networking and telecommunication, among other uses. Germanium tetrachloride can be hydrolyzed and dried to produce germanium dioxide, a white powder used as a catalyst in the production of PET resin and in the manufacture of germane gas. Germanium metal powder is produced through the reduction of germanium dioxide with hydrogen, and first-reduction bars are cast from melted germanium metal powder. The germanium bars are zone-refined (a process that involves melting and cooling to isolate and remove impurities) to produce high-purity germanium metal. The zone-refined germanium metal then is grown into single crystals using the Czochralski process. The resulting monocrystalline germanium can be sliced for use as semiconductors, recast into forms suitable for lenses or window blanks for infrared optical devices, or used in gamma-ray detectors.

Government Actions and Legislation

As a strategic and critical material, germanium was identified for the National Defense Stockpile (NDS) in 1984. The Defense Logistics Agency Strategic Materials' Annual Materials Plan for fiscal year 2024 (October 1, 2023, through September 30, 2024) allocated 5,000 kilograms (kg) of germanium for potential disposals, and no potential acquisitions of germanium metal were allocated in fiscal year 2024 (Defense Logistics Agency Strategic Materials, 2023a, b).

Production

Mine.—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 amount of germanium production was not available. The remainder of the zinc concentrate was sent to Asia, Europe, and Australia for processing (Teck Resources Ltd., 2024a, p. 20, 39).

Nyrstar's Middle Tennessee zinc mines also produced germanium-containing zinc concentrates. These concentrates were sent to the company's zinc smelter near Clarksville, TN, for processing. The Clarksville zinc smelter had produced a byproduct germanium concentrate in the past that was sold for additional processing for germanium recovery. Nyrstar recently proposed to build a $150 million facility at the smelter to recover gallium and germanium products and was exploring opportunities for Government support. In late November, Nyrstar suspended production at the Middle Tennessee mines owing to market conditions, which included decreasing zinc prices and increasing operating costs owing to inflation. Nyrstar still planned to invest in the recovery of byproduct gallium and germanium at the Clarksville smelter and would conduct exploration and definition drilling at Middle Tennessee to identify additional gallium, germanium, and zinc resources (Nyrstar NV, 2020, 2023, 2024).

Plant.—Umicore Optical Materials USA in Quapaw, OK, produced primarily germanium tetrachloride for the fiber-optics industry, and 5N Plus Semiconductors LLC's facility in St. George, UT, produced single-crystal germanium metal and fabricated substrates for multijunction solar cells used in space applications. Both facilities consumed imported germanium materials and recycled germanium scrap to produce germanium products. The total amount of production was not available (5N Plus Inc., 2024, p. 6, 10).

Consumption

Domestic consumption of germanium (including metal and the germanium content of compounds such as dioxide and tetrachloride) was not available. The major global end uses of germanium 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 and tetrachloride were consumed by the fiber-optics industry for the manufacture of fiber-optic glass. Germanium is 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. Major optical fiber producers in the United States included Corning Inc. (Corning, NY), OFS Fitel LLC [Norcross, GA, a subsidiary of Furukawa Electric Co. Ltd. (Japan)], and Prysmian Group S.p.A. (Italy).

Infrared Optics.—Germanium metal was used in infrared optics owing to its transparency to part of the infrared spectrum and its high refractive index. Single-crystal germanium metal was fabricated into lenses and windows in infrared optical systems, which were used in commercial, industrial, Government, and military markets. Several companies in the United States imported and processed germanium metal into germanium lenses and windows.

Solar Cells.—Single-crystal germanium metal was fabricated into substrates to produce multijunction solar cells. The germanium substrates were used as the bottom layer to grow the top semiconducting layers of the solar cell. Multijunction solar cells were used primarily 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 (European Space Agency, 2020; National Renewable Energy Laboratory, 2023a, b). SolAero Technologies Inc. (Albuquerque, NM, a subsidiary of Rocket Lab USA Inc.) and Spectrolab Inc. (Sylmar, CA, a subsidiary of The Boeing Co.) produced multijunction solar cells using germanium substrates in the United States.

Other Applications.—Germanium dioxide and germanium tetrachloride were used in the production of germane gas, an electronic specialty gas used in certain types of semiconductor and solar cell manufacturing. Germanium metal was used in high-purity germanium radiation detectors, also known as HPGe detectors, and germanium wafers were used as substrates in some types of electronics manufacturing.

Prices

The estimated average United States import unit value of unwrought germanium metal in 2023 was $1,334 per kilogram, slightly less than $1,361 per kilogram in 2022, with imports from Belgium averaging $1,550 per kilogram and imports from China averaging $1,260 per kilogram. The estimated average unit value of U.S. imports of germanium dioxide in 2023 was $760 per kilogram, slightly less than that in 2022. On a country basis, the average unit value was $770 per kilogram for both Belgium and Canada, the two main suppliers of germanium dioxide to the United States (tables 1, 2).

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. On an annual average basis, the germanium metal price (minimum 99.999% germanium; cost, insurance, and freight; Europe) increased by 8% to $1,392 per kilogram in 2023 from $1,294 per kilogram in 2022, and the germanium dioxide price (minimum 99.999% germanium dioxide; approximately 69% germanium content; cost, insurance, and freight; Europe) increased by 7% to $883 per kilogram in 2023 from $828 per kilogram in 2022 (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, U.S. imports for consumption of germanium metal (unwrought, wrought, and powder) increased to an estimated 22,000 kg in 2023 from 14,000 kg (revised) in 2022 (tables 1, 2). In 2023, China, Germany, and Belgium, in descending order of quantity, accounted for 98% of all types of germanium metal imported into the United States. Unwrought metal imports [Harmonized Tariff Schedule of the United States (HTS) code 8112.92.6000], which accounted for 68% of total germanium metal imports in 2023, increased to an estimated 15,000 kg compared with 13,000 kg (revised) in 2022 (table 2). China and Belgium, in decreasing order of import quantity, had 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 2019 and 2023. Germanium metal powder imports (HTS code 8112.92.6500) increased to an estimated 5,700 kg in 2023 from an estimated 340 kg imported in 2022 owing to a 5,500-kg increase in powder imports from Germany. Wrought germanium metal imports (HTS code 8112.99.1000) increased to an estimated 1,400 kg in 2023 from 1,100 kg in 2022. More than 85% of these imports were sourced from Germany and China, in descending order of import quantity, in 2023. Russia was previously a significant supplier of germanium metal to the United States, particularly in the form of wrought metal. However, there were no imports of germanium metal from Russia in 2023. Germanium metal waste and scrap were imported under HTS code 8112.92.0700 (other base metal waste and scrap not elsewhere specified or included) and could not be quantified.

The estimated germanium content of germanium dioxide imports (HTS code 2825.60.0000, germanium oxides and zirconium dioxide) decreased to 14,000 kg in 2023 from 15,000 kg in 2022 (table 1). Belgium and Canada accounted for most of the imports in 2023. Germanium tetrachloride was imported under HTS code 2827.39.9000 (other chlorides not elsewhere specified or included) and could not be quantified.

Domestic exports of germanium metal (including unwrought, powder, and wrought) and germanium dioxide (Ge content) were estimated to be 6,100 kg in 2023, based on trade data from the U.S. Census Bureau that were adjusted by the USGS to remove low unit-value shipments, a decrease from the 6,700 kg exported in 2022 (table 1).

World Review

In 2023, available 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). Based on industry reports, it was estimated that global germanium production ranged between 100,000 and 200,000 kg. Global changes in zinc mine and coal production were not generally an indicator for changes in the supply of germanium,

as germanium was produced at a limited number of mines and plants globally. 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.

Scrap was an important source for the world's total production of germanium. Owing to the high value of refined germanium, new scrap generated during the manufacture of optical fiber, infrared optics, and substrates typically was reclaimed and fed back into the production process. Recycling of germanium from old scrap, such as windows from decommissioned military vehicles or fiber-optic cables, increased during the past decade.

Belgium.—In addition to its plant in Quapaw, OK, Umicore produced germanium products at its refinery and recycling plant in Olen, Belgium, including germanium compounds, germanium metal, single-crystal germanium, and germanium substrates and lenses. Umicore reported strong demand for germanium substrates in 2023, particularly for space applications. The company also noted that it had increased its germanium recycling throughput during the year, and most of its germanium production was from recycled feed (Umicore S.A., 2024, p. 51).

Canada.—Several germanium products were produced at a lead-zinc metallurgical complex operated by Teck in Trail, British Columbia, which included specialty metal plants that produced byproduct metals. At the Trail complex, germanium was recovered from the zinc concentrate produced at Teck's Red Dog zinc-lead open pit mine in Alaska. Residues from the processing of these zinc concentrates were purified to produce a range of germanium products including germanium dioxide, germanium tetrachloride, and a germanium-based PET catalyst solution. Germanium production at Trail was not publicly disclosed by Teck (Teck Resources Ltd., 2024a, p. 39; 2024b).

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. Significant germanium-containing coal deposits in China were the Lincang lignite deposit in Yunnan Province and the Wulantuga lignite deposit in Inner Mongolia (Liu and others, 2021).

Two of China's largest germanium producers included Yunnan Chihong Zinc and Germanium Co. Ltd. and Yunnan Lincang Xinyuan Germanium Industry Co. Ltd. Both companies were vertically integrated, involved in mining and refining germanium, producing downstream germanium products (including high-purity germanium tetrachloride for fiber optics, germanium substrates for multijunction solar cells, and germanium lenses for infrared optics), and developing value-added germanium materials. Yunnan Chihong reported that it produced 65,900 kg of germanium in germanium products in 2023, 18% more than production in 2022 and surpassing its capacity of 60,000 kilograms per year (kg/yr). The company owned polymetallic mines that contained recoverable amounts of germanium, including the Huize and Yiliang (Maoping) lead-zinc-silver mines in Yunnan Province. In 2023, Yunnan Lincang Xinyuan Germanium produced 47,700 kg of germanium products and reported an annual production capacity of 47,600 kg of germanium ingot. The company mined germanium from within the Lincang coal deposit (Yunnan Chihong Zinc and Germanium Co. Ltd., 2024, p. 4–5, 10; Yunnan Lincang Xinyuan Germanium Industry Co. Ltd., 2024, p. 12, 16).

On July 4, China's Ministry of Commerce announced that it would implement export controls on gallium and germanium beginning on August 1 to "safeguard national security and interests." Several germanium materials could not be exported without permission, including germanium dioxide, germanium metal, germanium tetrachloride, and zinc germanium phosphide. After China implemented the export controls on gallium and germanium, there were virtually no exports of germanium metal in August (0 kg) and September (1 kg), and export levels in October (648 kg) and November (721 kg) were much lower than those prior to the export controls. Monthly exports returned to a comparatively normal quantity in December (3,400 kg). There were no exports of germanium metal to the United States between August and December following the export controls. For the full year, China's exports of germanium metal [including China's export codes 8112.92.10 and 8112.99.10] decreased by 10% to 39,400 kg in 2023 from 43,700 kg in 2022. Exports were 42,300 kg in 2021 and 29,000 kg in 2020. In 2023, more than 90% of China's germanium exports were sent to Russia (23%), Germany (18%), Hong Kong (15%), the United States (15%), Belgium (12%), and Japan (8%) (Ministry of Commerce, 2023; Zen Innovations AG, 2024).

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).

Outlook

Global demand for germanium will continue to be influenced by trends in the fiber-optic cable market, one of the largest uses of germanium. Germanium 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 lenses in infrared applications will continue to be attractive to commercial and industrial markets. Germanium is expected to continue to be used as the substrate to produce multijunction solar cells for commercial and defense space-based applications. In terrestrial solar applications, concentrated photovoltaic systems, which use high-performance mirrors to focus solar energy on multijunction solar cells, could be a growing market for germanium substrates

in the future. These photovoltaic systems have high conversion efficiencies of greater than 40% (European Commission, 2019).

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 STATISTICS[1]

(Kilograms unless otherwise specified)

		2019	2020	2021	2022	2023
United States:						
Refinery production		NA	NA	NA	NA	NA
Imports for consumption:[e, 2]						
Germanium metal		14,000	14,000	13,000	14,000 [r]	22,000
Germanium dioxide, Ge content		21,000	12,000 [r]	17,000	15,000	14,000
Total, Ge content		35,000	26,000	30,000	30,000	36,000
Exports:[e, 2]						
Germanium metal		3,900	4,000	5,500	6,600	6,000
Germanium dioxide, Ge content		610	810	430	130	110
Total, Ge content		4,500	4,900 [r]	5,900	6,700	6,100
Consumption, Ge content[e, 3]		30,000	30,000	30,000	NA	NA
Stocks, December 31, U.S. Government[4]		14,000	14,000	14,000	14,000	NA
Price, average:						
U.S. import, unwrought germanium metal[e, 5]	dollars per kilogram	1,235	1,083	1,196	1,361	1,334
Europe:[6]						
Germanium metal	do.	1,236	1,046	1,187	1,294	1,392
Germanium dioxide	do.	913	724	770	828	883
World, refinery production:[e]						
China		85,700	95,000	NA	NA	NA
Russia		5,000	5,000	NA	NA	NA
Other[7]		40,000	40,000	NA	NA	NA
Total		131,000	140,000	NA	NA	NA

[e]Estimated. [r]Revised. do. Ditto. NA Not available.

[1]Table includes data available through April 30, 2024. Data are rounded to no more than two significant digits, except "Price, average" and "World, refinery production"; may not add to totals shown.

[2]Data have been adjusted to exclude low-value shipments.

[3]Estimated consumption of metal and germanium dioxide (germanium content).

[4]Defense Logistics Agency Strategic Materials. Data are uncommitted germanium metal only.

[5]U.S. customs unit value. Excludes low-value trade.

[6]Source: Argus Media group, Argus Non-Ferrous Markets.

[7]Includes Belgium, Canada, Germany, and other countries or localities. Does not include U.S. production.

TABLE 2
ESTIMATED U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL AND DIOXIDE, BY COUNTRY OR LOCALITY[1]

(Kilograms unless otherwise specified)

	2019		2020		2021		2022		2023	
Country or locality	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Metal:										
Unwrought:[2]										
Belgium	2,900	$5,000,000	4,200	$5,700,000	3,500 r	$5,100,000 r	4,800 r	$8,000,000 r	3,600	$5,600,000
China	7,700	8,000,000	6,400	5,900,000	5,200	5,400,000	7,300 r	8,700,000 r	11,000	14,000,000
Russia	50	50,000	49	45,000	560	600,000	140 r	160,000 r	--	--
Other	85 r	180,000 r	110 r	73,000 r	270 r	240,000 r	540 r	460,000 r	160	280,000
Total	11,000	13,000,000	11,000	12,000,000	9,500 r	11,000,000	13,000 r	17,000,000 r	15,000	20,000,000
Powder:[3]										
Belgium	380	840,000	200	1,400,000	260	980,000	46 r	150,000 r	99	180,000
China	82	74,000	63 r	95,000 r	2	3,500	100	99,000	13	16,000
Germany	1,100	1,800,000	980	1,400,000	870	1,300,000	60 r	120,000 r	5,600	5,900,000
Russia	22	30,000	37	47,000	16	25,000	2 r	3,000 r	--	--
United Kingdom	3	2,100	78	51,000	--	--	36	50,000	44	30,000
Other	1	3,000	--	--	75 r	110,000	95 r	100,000 r	33	22,000
Total	1,600	2,700,000	1,400	3,000,000	1,200	2,500,000	340	520,000	5,700	6,200,000
Wrought:[4]										
Belgium	5	55,000	110	270,000	150	310,000	96 r	110,000 r	68	98,000
China	630	930,000	850	1,100,000	1,000	1,300,000	530 r	690,000 r	250	320,000
Germany	230	420,000	330	470,000	220	430,000	410 r	710,000 r	970	1,900,000
Russia	470	520,000	780	750,000	1,300	1,300,000	25 r	40,000 r	--	--
Other	25	28,000	7 r	16,000 r	6	21,000	46 r	150,000 r	120	92,000
Total	1,400	1,900,000	2,100	2,600,000	2,700	3,400,000	1,100	1,700,000	1,400	2,400,000
Metal total	14,000	18,000,000	14,000	17,000,000	13,000	17,000,000	14,000	20,000,000	22,000	28,000,000
Dioxide:[5]										
Belgium	11,000	12,000,000	6,500	5,000,000	13,000	8,300,000	14,000	11,000,000	11,000	8,400,000
Canada	18,000	14,000,000	9,000	5,200,000	9,000	5,500,000	7,100	5,200,000	9,000	6,900,000
China	450	300,000	640	330,000	170	140,000	240	230,000	200	140,000
Germany	720	380,000	220	92,000	500	180,000	130	45,000	200	73,000
Japan	610	520,000	100	61,000	610	270,000	710	410,000	380	190,000
Russia	610	450,000	120	58,000	640	380,000	100	87,000	--	--
Other	12	11,000	24	17,000	120	75,000	81	56,000	90	89,000
Total	31,000	27,000,000	17,000	11,000,000	24,000	15,000,000	22,000	17,000,000	21,000	16,000,000
Total, Ge content	21,000	XX	12,000	XX	17,000	XX	15,000	XX	14,000	XX

rRevised. XX Not applicable. -- Zero.

[1]Table includes data available through April 30, 2024. 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.

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

[3]Includes HTS code 8112.92.6500.

[4]Includes HTS code 8112.99.1000.

[5]Includes HTS code 2825.60.0000.

Source: U.S. Census Bureau.

TABLE 3
ANNUAL AVERAGE PRICES[1]

(Dollars per kilogram)

Year	Germanium metal[2]	Germanium dioxide[3]
2014	1,918	1,291
2015	1,792	1,211
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
2022	1,294	828
2023	1,392	883

[1]Table includes data available through April 30, 2024.
[2]Cost, insurance, and freight value; Europe; minimum 100-kilogram (kg) lots. For 2014–17, prices are for minimum 99.99% purity. For 2018–23, prices are for minimum 99.999% purity.
[3]In-warehouse, Rotterdam; minimum 100-kg lots. As of September 2021, prices were cost, insurance, and freight value; Europe. For 2014–17, prices are for minimum 99.99% purity. For 2018–23, prices are for minimum 99.999% purity.

Source: Argus Media group, Argus Non-Ferrous Markets.