science for a changing world

2014 Minerals Yearbook

GERMANIUM [ADVANCE RELEASE]

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Germanium

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In 2014, three domestic zinc operations produced recoverable byproduct germanium. In Alaska, the Red Dog Mine, owned by Teck Resources Ltd. (Canada), produced zinc concentrates that were exported to Teck's facilities in Canada for processing or to processors in Asia and Europe. Teck Washington Inc. (a wholly owned subsidiary of Teck Resources) operated the underground Pend Oreille zinc and lead mine in northeast Washington. All concentrates were trucked to Teck's facilities in Canada for processing. In Tennessee, the Clarksville zinc smelter owned by Nyrstar NV (Balen, Belgium) produced and exported germanium leach concentrates recovered from processing zinc concentrates from its Middle Tennessee mine complex. The U.S. Geological Survey (USGS) estimated that combined U.S. refinery production of germanium metal recovered from end-of-life products, such as decommissioned military vehicles and thermal weapons sights, industry-generated scrap, and imported germanium dioxide, was about 15,000 kilograms (kg) in 2014. The world's total production of germanium in metal and compounds was estimated to be about 165,000 kg including germanium recovered from zinc concentrates, coal ash, and recycled material. The increase in global production from that in 2013 was owing to an increase in production in China. The amount of germanium recovered from scrap in 2014 was about 30% of world production of germanium metal.

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. It is commercially available as tetrachloride, high-purity oxide, and forms of metal. Its current principal uses 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.

Legislation and Government Programs

As a strategic and critical material, germanium was added to the National Defense Stockpile (NDS) in 1984. The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) reported that no germanium metal was sold in 2014. Germanium was last sold in February 2009 at an average price of $1,331 per kilogram. As of December 31, 2014, the total inventory of germanium metal held by the DLA Strategic Materials was 13,364 kg. The Annual Materials Plan for fiscal year 2015 (October 1, 2014, through September 30, 2015) did not allocate germanium metal for sale. In fiscal year 2012, the DLA Strategic Materials awarded two contracts to convert 3,000 kg of the germanium ingots held in the stockpile to epitaxial wafers for use as substrates required by the National Security Space Strategy photovoltaic solar cell applications. As of yearend 2014, the germanium had been upgraded and 101,939 germanium wafers were held in the stockpile. In fiscal year 2014, the DLA Strategic Materials initiated a program (authorized under section 8c of the Strategic and Critical Materials Stock Piling Act) to increase domestic reclamation of germanium from defense-related products that were at the end of their life cycle (Defense Logistics Agency Strategic Materials, 2014; U.S. Department of Defense, 2015).

Production

In 2014, germanium intermediates were domestically recovered from zinc concentrates at a smelter in Tennessee. Secondary germanium metal was recovered by secondary processors from end-of-life products, such as decommissioned military vehicles and thermal weapons sights.

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

In the third quarter of 2012, Nyrstar began to produce an intermediate germanium leach product at its Clarksville zinc smelter. The germanium-bearing zinc concentrates processed at Clarksville were from Nyrstar's Middle Tennessee mine complex (the Cumberland Mine, Elmwood Mine, and Gordonsville Mine and mill) where mining restarted in 2009 after being idle for about 1 year. The company did not disclose how much germanium leach product was produced in 2014, but Nyrstar reported that production was slightly affected by supply shortfalls of zinc concentrates from the Middle Tennessee mines. The Clarksville smelter reportedly had the capacity to produce 20 metric tons per year (t/yr) of germanium-rich, zinc-refining residues (Jorgenson, 2004, p. 32.1). The germanium leach produced at Clarksville was most likely exported for further refining (Nyrstar NV, 2013, p. 16–17; 2015a, p. 25).

Teck Alaska Inc. produced germanium-containing zinc concentrates at its Red Dog zinc-lead open pit mine in Alaska.

Approximately 30% of the zinc concentrate produced at Red Dog was sent to Teck's metallurgical complex in Trail, British Columbia, Canada, for processing. Residues from zinc concentrates were treated in roasters or pressure-leach facilities and purified to produce germanium dioxide, germanium tetrachloride, and other byproduct metals. Teck reported that zinc-in-concentrate production at Red Dog in 2014 was 596,000 metric tons (t), 8% more than that of 2013 owing to increased mill throughput and recovery rate. In December 2014, Teck restarted the Pend Oreille Mine in Washington and expected that the mine would reach full production rates by the middle of 2015. The mine was expected to operate for at least 5 years (Teck Resources Ltd., 2015, p. 27).

Consumption

The USGS estimated that domestic apparent consumption of germanium metal (including metal content of compounds) was about 32,000 kg in 2014, about 16% less than that in 2013. According to industry sources, consumption for fiber optics and substrates for space-based applications increased from that in 2013, but use in infrared optics for defense applications declined. Germanium-containing infrared optics were primarily for military use, and defense-related spending has declined during the past few years. Growth in the commercial and personal markets for thermal-imaging devices that use lenses containing germanium partially offset the decline in defense consumption. The domestic end-use distribution was estimated to be fiber-optic systems, 40%; infrared optics, 30%; electronics and solar applications, 20%; and other uses, 10%. Germanium was not used in polymerization catalysts in the United States. The worldwide end-use pattern of germanium was estimated to be fiber optics, 30%; infrared optics, 20%; polymerization catalysts, 20%; electronics and solar applications, 15%; and other uses (such as phosphors, metallurgy, and chemotherapy), 15%.

Infrared Systems.—Germanium was used in the manufacture of lenses and windows for infrared optical systems owing to its transparency to part of the infrared spectrum and to its high refractive index. Global demand outside of China for germanium used in infrared products declined in 2014 partially owing to a reduction in defense spending. FLIR Systems, Inc. (Wilsonville, OR), a leading domestic producer of infrared surveillance devices, reported a 7% decrease in sales revenue for those products owing to reduced purchases by the U.S. Government in 2014 compared with those in 2013. FLIR reported an increase in revenue from its original equipment manufacturer and emerging markets business segment that includes commercial infrared optics and infrared imaging devices that are designed for smartphones (FLIR Systems, Inc., 2015, p. 36–37).

Fiber Optics.—In the fiber-optics sector, germanium dioxide 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. Global consumption of germanium for use in fiber optics increased in 2014 owing to the expansion of telecommunications networks. According to the most recent data available from the Fiber-to-the-Home Council, as of May 2013, 22.7 million North Americans were connected directly into optical fiber networks and about 9.7 million of those households subscribed to the service offered. The organization estimated that about $18 billion would be invested in expanding the fiber-to-the-home (FTTH) network infrastructure in North America from 2013 to 2017. During the past few years there has been an increased emphasis placed on providing more rural parts of the United States with access to optical networks. Three producers in Japan (Fujikura Ltd.; Furukawa Electric Co., Ltd.; and Sumitomo Electric Industries, Ltd.) and Corning Inc. in the United States accounted for a substantial portion of global production of germanium-doped silica glass used in optical fiber cable. In 2014, Corning reported that sales of its optical communications products increased by 14% from that in 2013 owing primarily to increased sales of fiber-optic cable and hardware for FTTH installations in North America and Europe (Fiber-to-the-Home Council, 2013; Yi, 2013; Corning Inc., 2015, p. 36).

Solar Cells.—Germanium-based solar cells were used in space-based applications and terrestrial installations. According to industry sources, demand for satellites increased steadily from 2007 through 2014 owing to demand for commercial, military, and scientific applications. Umicore s.a. (Belgium), a leading germanium substrate producer, reported that sales of substrates for solar cells in space-based applications increased but sales of those used in terrestrial photovoltaics declined in 2014 compared with those in 2013, as was the case in the previous year. The industry has started to move towards larger and more efficient germanium substrates for solar cells that contain more germanium per unit (Umicore s.a., 2015, p. 33).

In April, 5N Plus Inc. (Montreal, Quebec, Canada) acquired the remaining 33.33% of its subsidiary, Sylarus Technologies, LLC (St. George, UT), and changed Sylarus' name to 5N Plus Semiconductors LLC. Sylarus produced germanium substrates for optical, semiconductor, and solar applications from germanium dioxide feedstock primarily imported from Canada. In late 2012, Sylarus was awarded a $1.32 million contract from the DLA Strategic Materials to upgrade a portion of the germanium metal held in the NDS to substrates. Sylarus was the sole domestic supplier of space-qualified substrates to the National Security Space (NSS) program. The DLA Strategic Materials intended to have the substrates available for future use in multijunction photovoltaic solar cells for NSS applications (5N Plus Inc., 2014).

Electronic Components.—According to a leading producer, sales revenue from high-brightness, light-emitting diodes (with germanium substrates) used in such devices as automobile taillights, cameras, flashlights, mobile telephone display screens, televisions, and traffic signals in 2014 was essentially unchanged from that in 2013. Germanium subtrates compare favorably to the leading alternative, gallium arsenide, owing to increased strength, less breakage during production, lower cost, and fewer disposal issues (Umicore s.a., 2015, p. 33).

Polymerization Catalysts.—Estimates indicated that consumption of germanium for PET outside the United States has been declining since 2012 owing to germanium price increases that led to substitutions for germanium. Most of the consumption of germanium used in PET resin production was in Japan where producers have substituted lower cost antimonyand titanium-based products for germanium dioxide catalysts. In 2014, in addition to increased substitution for germanium, Japan's PET resin production decreased by 11% to 670,000 t (Roskill's Letter from Japan, 2015, p. 2).

Prices

Germanium is generally traded through long-term supply contracts between consumers, producers, and traders. Publicly available prices represent estimates of representative prices in trades being executed on a particular day and are compiled through recurring interviews with individual traders.

Germanium dioxide prices began the year at about $1,225 per kilogram, increased to about $1,300 per kilogram in late May, and remained at $1,300 per kilogram for the rest of the year. Germanium metal prices began the year at about $1,900 per kilogram, increased to $1,950 per kilogram in late February, and ended the year at $1,900 per kilogram. Germanium metal price increases at midyear were partially driven by stockpiling activities in China. Germanium metal and dioxide prices have generally trended upward since 2010. By 2011, the price of the germanium contained in germanium oxide (typically about 69% germanium) was greater than the market price of pure germanium metal, as a result of a 5% export tax of germanium dioxide in China in 2010 (fig. 1, table 2).

Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (wrought, unwrought, and powder) decreased by 31% to 23,700 kg in 2014 from 34,200 kg in 2013. Decreased imports from Canada, China (including Hong Kong), Japan, and Russia offset increases from Belgium and Germany. In 2014, China and Belgium, in descending order of quantity, accounted for 87% of germanium metal imported into the United States (table 1). The estimated germanium content of the germanium dioxide imported in 2014 was about 12,400 kg compared with 11,400 kg in 2013.

Domestic exports of germanium metal and articles thereof were estimated to be about 12,000 kg in 2014, based on trade data from the U.S. Census Bureau that were adjusted by the USGS to exclude scrap. Belgium, Canada, China, Japan, and the United Kingdom accounted for most of the germanium exported from the United States in 2014. The estimated germanium content of germanium dioxide exported from the United States in 2014 was less than 100 kg.

World Review

In 2014, the world's total production of germanium was estimated to be about 165,000 kg, which consisted of germanium recovered from zinc concentrates, coal ash, and recycled material. The recycling level remained about the same as that in 2013, and scrap was estimated to have supplied about 30% of the world's total production of germanium. Owing to the 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 window blanks from decommissioned military vehicles or fiber-optic cables, has increased during the past decade. World-wide, 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), zinc residues in Finland [concentrates from Congo (Kinshasa)], and coal ash in Russia. Most germanium production was concentrated in Canada, China, and Russia.

Becasue germanium is a byproduct metal, its supply was heavily reliant on zinc mine production, which increased slightly in 2014 from that in 2013. Although an important factor, global changes in zinc mine production may not be an indicator of a corresponding change in the supply of germanium. It has been estimated that less than 5% of the germanium contained in zinc concentrates reaches refineries that are capable of extracting and producing germanium (Mikolajczak, 2013, p. 9).

Belgium.—Umicore produced germanium metal, germanium tetrachloride for fiber optics, germanium substrates, and germanium optical products at its refinery and recycling plant in Olen. The company reported that sales of its finished optical devices containing germanium increased in 2014 from those of 2013 owing to increased consumption for commercial infrared applications; however, consumption of blank optics typically used for defense application declined from the previous year. Sales of germanium tetrachloride for use in fiber optics in 2014 were essentially unchanged from those in 2013, and sales of substrates for solar cells were mixed with increases in space-based applications that were offset by declines in sales for terrestrial-based solar cells (Umicore s.a., 2015, p. 33).

In 2014, Umicore's Electro-Optic Materials (EOM) division conducted an internal life cycle assessment of germanium. The main objective was to quantify the potential environmental impacts of the production of germanium from new scrap generated by the photovoltaic industry and to compare them to the potential impacts of the primary production of germanium from coal ash. The study, published in The Journal of the Minerals, Metals and Materials Society, indicated that the recycling of germanium resulted in lower impacts than the primary production, by at least 95%, across most environmental impact categories (Umicore s.a., 2015, p. 22, 32–33).

Canada.—The metallurgical complex operated by Teck Resources in Trail, British Columbia, included two specialty metal plants that produced byproduct metals, including germanium. Historically, Teck has been one of the leading germanium producers in the world. The last year for which the company released production data was 2007, when Teck produced about 40,000 kg of germanium dioxide at Trail. In 2014, it was estimated that Canada exported about 15,500 kg of germanium contained in dioxide (Teck Cominco Ltd., 2008; Statistics Canada, 2015).

China.—China continued to be the leading global producer of germanium metal and germanium compounds, which it recovered from germanium-bearing coal ash and zinc ore. In 2014, five or six producers accounted for most of the estimated 110,000 kg of the germanium content of metal produced in China. The Chinese Government attempted to limit exports of raw materials and encourage the export of more processed products, such as germanium ingots and optical lenses, through export tax rebates on those products and a 5% export tax on germanium dioxide. According to the China Nonferrous Metals Industry Association, China exported 13,800 kg of germanium dioxide in 2014, a 38% decline from than that in 2013, and exported 12,800 kg of germanium metal, 50% less than that in 2013. The combination of stockpiling activity and the export tax led to a buildup of germanium stocks in China. Stockpiling activities in China have contributed to global price increases since 2010 by limiting the amount of germanium that is available to consumers. In 2014, China's State Reserve Bureau (SRB) purchased 30,000 kg of germanium for its national stockpile (20,000 kg was stockpiled in 2013) and analysts expected that China would continue to stockpile germanium during the next several years. The Fanya Metal Exchange in China, established for investing in "rare" metals, reportedly held more than 91,000 kg of germanium in warehouses as of late November 2014 and had the capacity to hold 200,000 kg (Pugsley, 2014a, b). National and Provincial governments in China encouraged producers to integrate operations and focus on producing value-added products. In 2014, China produced about 62,300 kg more germanium than it consumed and exported, which contributed to the increase in stocks. Consumption of germanium was estimated to be about 22,000 kg in 2014, about 4% less than that in 2013. It was estimated that China held about 159,300 kg of germanium in combined Government and industry stocks by yearend 2014 compared to 55,000 kg at yearend 2013 (Nian and Wujun, 2015, p. 28).

Japan.—According to industry reports, consumption of germanium in Japan in 2014 declined from that in 2013 with the exception of fiber optics. Imports of germanium metal, power, and scrap were 3,820 kg in 2014, 29% less than that in 2013. Imports of germanium dioxide (gross weight) were about 14,700 kg in 2014, 21% less than that in 2013. Most of the germanium metal was imported from China, and most of the germanium dioxide was imported from Canada. Japanese production of fiber-optic cable cores increased by about 19% from that in the previous year, most of which was exported (Roskill's Letter from Japan, 2015, p. 1–3).

Russia.—During the past few years, it was thought that Russia's germanium production and exports increased. Germanium and Applications Ltd. recently began recovering germanium from fly ash from coal mined at 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 t/yr of germanium, and its facilities in Moscow and Novomoskovsk had the capability to produce germanium oxide and metal, germanium blanks for optical use, and substrates for electronics (Germanium and Applications Ltd., 2014).

JSC Germanium operated an integrated refinery in Krasnoyarsk with the capabilities to process germanium from concentrates, coal ash, and waste, and to produce intermediate and finished germanium products. The company reported that it produces about 20,000 kg of germanium per year, but it did not specify if that included the metal content of finished products such as germanium lenses. JSC exported more than 80% of the germanium that it produced (JSC Germanium, 2015).

Outlook

Global germanium consumption in the fiber-optics sector is likely to increase during the next several years. Global demand for fiber-optic cable, led by the emerging Asian economies and Brazil, is forecast to increase at a compound annual growth rate of 5% to 7% through 2015. The increases in fiber-optics consumption may be partially offset by declines in consumption for other applications such as optical blanks. Germanium-based optical blanks and windows that are incorporated in infrared devices are expected to continue to be heavily used by military and law enforcement agencies; however, cuts in Government military spending could limit growth in this area. Increased substitution of specialty glass for pure germanium in infrared applications may continue to be attractive to some consumers owing to the high price of germanium. 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. Infrared cameras that are designed to be used with smartphones could become more appealing for commercial uses as prices decline and quality increases. These cameras typically use small quantities of germanium per unit but the overall volume could be great based on the global proliferation of smartphones.

Global support for the increased use of solar energy during the next several years could increase demand for germanium substrates that are used to manufacture high-efficiency multijunction solar cells. Satellites launched for defense and private industry are expected to continue to fuel consumption of germanium substrates in solar cells (Mikolajczak, 2013).

On the supply side, limited new sources of germanium production are expected to open in the next few years. In 2015, Nyrstar NV announced plans to upgrade production capacity at its zinc smelter in Hobart, Tasmania, Australia. The upgrades included construction of a side-leach plant that would enable the smelter to split base metals from minor metals and produce germanium and indium (Nystar NV, 2015b). Germanium production will continue to be reliant on the zinc market. 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 to downstream products and manufacture finished infrared products for export. Overall, the germanium market is expected to remain tight during the next several years owing to limited sources of supply. This could change if some of the germanium stocks held in China begin to enter the global market; however, it is believed that the SRB would continue purchasing germanium through 2017 (Pugsley, 2014b).

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL, BY COUNTRY[1, 2]

Country	2013 Gross weight (kilograms)	2013 Value	2014 Gross weight (kilograms)	2014 Value
Belgium	5,530 r	$6,790,000 r	7,690	$14,400,000
Canada	2,450	1,130,000	510	101,000
China	23,200	36,900,000	13,000	21,700,000
Germany	341	836,000	1,180	2,270,000
Hong Kong	193	368,000	--	--
Japan	200	354,000	1	3,950
Russia	2,320	3,080,000	1,290	1,730,000
United Kingdom	--	--	6	7,430
Other	11	27,100	12	48,800
Total	34,200 r	49,500,000 r	23,700	40,300,000

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Data include wrought, unwrought, and powder, but exclude germanium dioxide.

Source: U.S. Census Bureau.

TABLE 2
ANNUAL AVERAGE PRICES

(Dollars per kilogram)

	Germanium dioxide (minimum 99.99% purity)	Germanium metal (minimum 99.99% purity)
2005	403	618
2006	564	834
2007	767	1,106
2008	948	1,456
2009	677	1,054
2010	575	953
2011	1,218	1,539
2012	1,179	1,464
2013	1,309	1,772
2014	1,291	1,917
Average	893	1,271

Source: Metal-Pages.

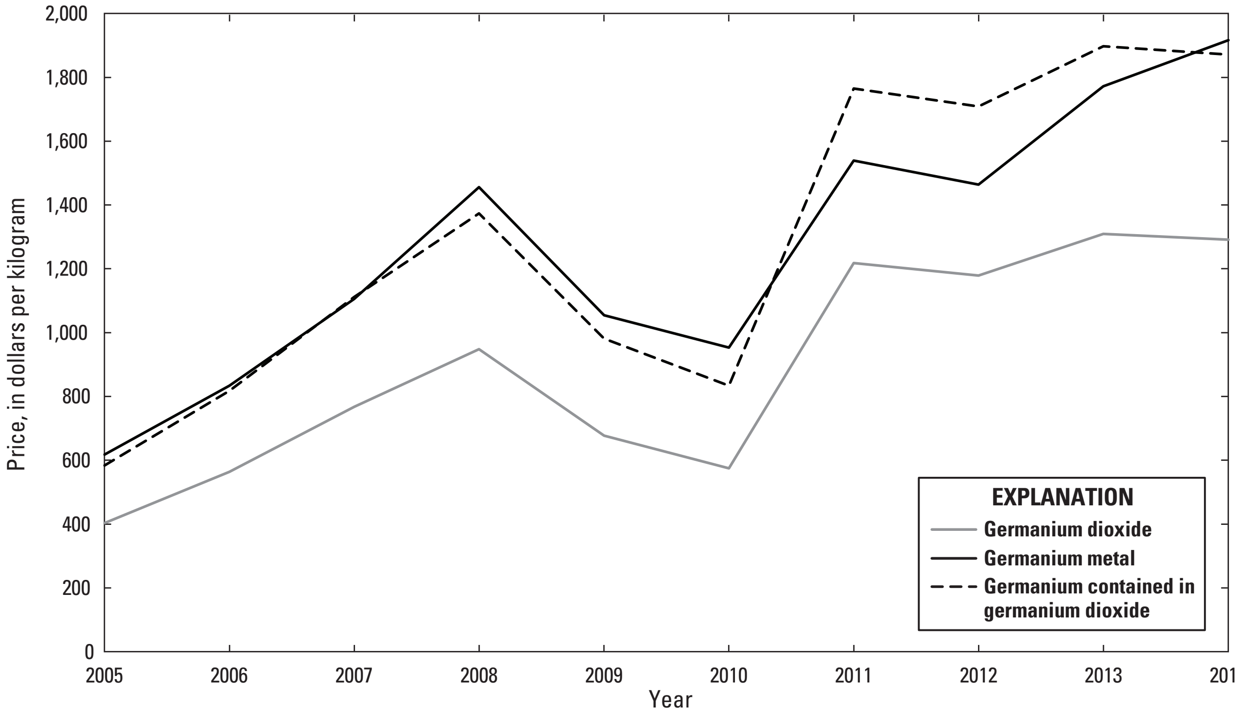

Figure 1. Average annual prices for germanium metal and germanium dioxide and the calculated price of germanium contained in germanium dioxide from 2005 through 2014. Source: Metal-Pages.