GERMANIUM

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Germanium is a hard, brittle semimetal that first came into use a half-century ago as a semiconductor material in radar units and as the material from which the first transistors were made. Today, it is used principally as a component of the glass in telecommunications fiber optics; as a polymerization catalyst for polyethylene terephthalate (PET), a commercially important plastic; in infrared night-vision devices; and as a semiconductor and substrate in electronics circuitry.

In 2003, the domestic germanium industry consisted of byproducts from two zinc mines and two refineries. The zinc-mining operations in Alaska and Tennessee supplied byproduct germanium concentrates for export. The mine in Tennessee was closed in May 2003. The two refineries, which operated in Oklahoma and New York, processed manufacturers' scrap and imported semirefined materials and some postconsumer scrap.

Domestic refinery production and consumption for germanium were estimated by the U.S. Geological Survey (USGS) on the basis of data provided by North American producers. Although domestic refinery production in 2003 dropped as compared with 2002, estimated U.S. consumption of germanium remained unchanged.

The USGS estimated domestic germanium reserves to be 400,000 kilograms (kg), equivalent to about 25 years of domestic consumption at the 2003 rate; figures for worldwide reserves were not available. Worldwide germanium resources were associated with zinc and lead-zinc-copper sulfide ores. Germanium was also recovered to a lesser extent from coal ash and cobalt-copper ores.

Legislation and Government Programs

As a strategic and critical material, germanium was included in the National Defense Stockpile (NDS) in 1984. In 1995, the Defense Logistics Agency (DLA), which maintained the NDS, made plans to sell germanium at a rate of 4,000 kilograms per year (kg/yr) through 2005. This proposed rate was increased to 6,000 kg/yr in 1997 and to 8,000 kg/yr in 1998. All the material offered is zone-refined polycrystalline germanium metal. The amount designated for annual sales was a significant portion of the domestic and world market. In most years, however, less than the amount available for sale has been sold (U.S. Department of Defense, 2003, p. 1-10).

The DLA price had not only become a good indicator of the market value of germanium, but also a factor in determining its value. According to the DLA, sales began in 2003 at $446 per kilogram and stayed between $436 and $500 per kilogram, ending the year at $450 per kilogram. After the meager sale of only 681 kg of germanium metal in 2002, 1,760 kg was sold in 2003, still far below the authorized amount (Defense Logistics Agency, 2004§[1]).

The DLA reported that, as of March 31, 2004, the NDS inventory of germanium metal was 38,320 kg, all of which has been authorized for sale. Germanium was offered for sale on the fourth Monday of each month, and the DLA was authorized to sell up to 8,000 kg during fiscal year 2004 (Defense Logistics Agency, 2004§).

Production

The USGS estimated that U.S. refinery production of germanium from primary and semirefined materials in 2003 was 12,000 kg, 3,000 kg less than the revised production for 2002.

Teck Cominco Limited produced a germanium-containing zinc concentrate at its Red Dog Mine in Alaska. This concentrate was shipped to Trail, British Columbia, Canada, for smelting, refining, and germanium extraction. Teck Cominco announced that the Pend Oreille zinc mine, located in northern Washington, planned to start producing in the first quarter of 2004. The deposit is very rich in germanium, and the ore will also be processed at the Trail refinery, 80 kilometers away (Teck Cominco Limited, 2004§).

Pasminco Limited (Australia) sold its Gordonsville Mine in Tennessee to Tennessee Valley Resources, Inc. (TVR) in September 2003. TVR has no metal processing facilities and planned to use the mine to supply limestone to produce agricultural limes and other limestone-based products. Consequently, the 300,000 tons (t) of germanium reserves at the mine will not be recovered. The Clarksville, TN, refinery will continue to operate but without germanium-rich concentrates from the Gordonsville Mine as feed for the 20 metric-ton-per-year (t/yr), high-grade zinc residues plant. The plant will continue to process material from the Clinch Valley Mine in Tennessee until the zinc ore is exhausted, some time in 2004; then the mine will be turned over to TVR. There are no resources in the Clinch Valley Mine from which germanium could be economically extracted (American Metal Market, 2003b; Plachy, 2003; Pasminco Limited, 2003§; Tennessee Valley Resources, Inc., 2004§).

The Specialty Materials Group of Eagle-Picher Technologies, LLC (EPT) was purchased by N.V. Umicore, s.a. in July 2003 for $15 million. The operation in Quapaw, OK, remained the largest domestic producer in 2003. It produces germanium from fly ash, germanium concentrates (typically containing 5% germanium or more), reprocessed scrap, and semirefined germanium materials (Platts Metal Week, 2003b; Metal-Pages, 2003k§). EPT retained its capability to produce germanium substrate, which is used in the production of germanium-based microchips (Metal-Pages, 2003l§).

Indium Corporation of America (NY) produced germanium products under its subsidiary Germanium Corporation of America (GCA) in Utica, NY. The chemical company Degussa AG and GCA announced a partnership in which GCA would

[1]References that include a section mark (§) are found in the Internet References Cited section.

supply Degussa with germanium tetrachloride. This partnership will supply raw materials for the global fiber optic industry (Germanium Corporation of America, 2003).

Consumption

The USGS estimated that domestic consumption of germanium in 2003 remained the same as that of 2002 at approximately 15,000 kg. The world use pattern was estimated to be as follows: polymerization catalysts, 35%; infrared optics, 25%; fiber optics, 20%; electrical/solar applications, 12%; and other uses (as phosphors in metallurgy and chemotherapy), 8%. Both world and domestic use patterns have remained the same during the past years with little improvement in the telecommunications consumption sector. The domestic use pattern was significantly different from that worldwide. Domestically the fiber and infrared optics industries accounted for the majority of the consumption of germanium, while PET manufactures used very little germanium in 2003.

In the fiber optics sector, germanium was used as a dopant (a substance added in small amounts to a pure semiconductor material to alter its conductive properties for use in transistors and diodes) within the core of optical fibers used by the telecommunications industry. Although the use of germanium as a dopant in optical fibers increased in 2003 by 50% as compared with that of 2002, the increase was small compared with that of 2001, and was still below consumption in 2001. The use of germanium is expected to continue to increase with a recovery of the telecommunications industry because metropolitan and fiber-to-home access is still underdeveloped. Currently, only one-third of home builders have broadband fiber optics as a standard feature for new homes (Cravens, 2003; Metal-Pages, 2004c§).

Because germanium lenses and windows are transparent to infrared radiation, they can be used in infrared optical systems in the same way that ordinary glass lenses and windows are used in visible-light optical systems. These germanium-based optical systems have been used principally for military guidance and weapon-sighting applications. Germanium optical glass is also used for nonmilitary purposes in monitoring systems, night-vision, and surveillance. The use of germanium optics has increased in a wide range of applications, including satellite systems and personnel detection equipments in poor visibility environments.

The use of infrared equipment by military and civilian security forces has increased since the terrorist events of September 11, 2001, and with U.S. military operations in Afghanistan and Iraq. Although the consumption of germanium is not as high as it was several years ago, these increased security applications may have helped to slow a decline in demand (Hansen, 2001§). Also, more models of automobiles now come with optional germanium-based night-vision systems; leading the way were General Motors Corporation, Hummer, and Lexus. Hummer introduced Raytheon's Nightdriver to its H2 line, allowing drivers to see three times farther (Bankrate, 2004§). These night-vision systems are also being used by fire departments to improve thermal-imaging systems to detect endangered individuals, hot spots, and team members in smoky environments (Hansen, 2001§).

In the polymerization catalysts sector, PET consumption weakened primarily owing to economic conditions in the Far East. New types of materials are expected to replace the relatively expensive germanium as a catalyst and will reduce its overall growth for this end use. Mitsui Chemicals Inc. has switched to titanium in its Indonesia plant and will soon start to change catalysts in Japan and Thailand (Metal-Pages, 2003f§). Also, Teijin Group has announced that it will replace germanium catalysts with titanium (Metal-Pages, 2004b§). As a catalyst, titanium is cheaper but it causes yellowish discoloration to plastics. Toyobo Company (Japan) has developed a new aluminum-based PET catalyst that is inexpensive and does not cause discoloration (Metal-Pages 2003i§, j§).

New germanium-based devices have become well established for analog and digital functions. Silicon germanium enables manufacturers to produce smaller chips with less electronic noise interference from the chip itself. The germanium-based chips are more energy efficient than traditional silicon-based chips and, therefore, extend the life of battery-operated electronics. Other benefits include more stability over a wider range of temperatures and operation at ultrahigh frequencies (Compound Semiconductor, 2004). According to the Semiconductor Industry Association (SIA), world production increased by about 10% in 2003 compared with that of 2002 (Metal-Pages, 2003h§).

The sales of germanium substrates for space solar cells fell by 30% compared with those of 2002, a result of reduced activity in world satellite programs (Metal-Pages, 2004c§).

Prices

Free market prices for germanium dioxide (GeO_2), published by Metal Bulletin, began 2003 in the $620-to-$660-per-kilogram range and ended the year in the $250-to-$350-per-kilogram range. The price remained at this level until a small adjustment in mid-June, to raise the price range to $280 to $350 per kilogram, where it remained for the rest of the year. It ended the year at this level. The price of zone-refined metal remained near $450 per kilogram during 2003 (Defense Logistics Agency, 2004§).

Trade

In 2003, the reported germanium content of imports was approximately 8,380 kg compared with 13,100 kg in 2002. Based on trade data from the U.S. Census Bureau, Belgium, China, Russia, and Canada, in descending order of shipments, accounted for approximately 90% of U.S. germanium imports in 2003 (table 1). Germanium export data were not available.

World Review

In 2003, the world germanium market remained relatively stable. World refinery production of primary germanium was estimated to be 50 t, the same as that of 2002. Also, the recycling level remained the same and supplied 30 t of germanium worldwide. Since recycling and primary production remained the same, the world's total market supply also remained at the 80-t level in 2003, including about 1.8 t released from the NDS. Since 2002, producers and consumers have minimized the amount of germanium held in stockpiles. Therefore, germanium inventories were low, and with the price still low, companies were unwilling to increase stocks. As a result, producer and consumer inventories remained unchanged.

Belgium.—The standard microchip uses silicon as its base material. The potential for further reduction in the size of silicon-based chips is limited. Umicore (Belgium), Interuniversity MicroElectronics Center (IMEC) (Belgium), and Silicon on Insulator Technologies (Soitec) (France) signed an agreement to develop chip-processing technologies that will create a chip with a thickness of less than 45 nanometers. The objective of the partnership was the production of germanium-on-isolator (GeOI) substrates, which would replace silicon. Umicore was responsible for the germanium substrate and Soitec was responsible for fitting the substrate to transfer the germanium layer to make the GeOI. The responsibility for scaling the GeOI chip down to 45 nanometers fell to IMEC (Metal-Pages, 2003m§; N.V. Umicore s.a., 2003§).

Canada.—Teck Cominco announced that it has developed a new process for the direct extraction of zinc that will negatively affect the production of germanium as a byproduct of zinc. The new process, called HydroZinc, uses heap bioleaching of the ore to increase zinc concentration at the mine site. During the processing of the ore, germanium and other byproducts are not recovered (Platts Metal Week, 2003a; Stradling, 2003).

China.—Yunnan Chihong Zinc-Germanium Co., Ltd., one of China's largest producers of germanium, produces about 10 t/yr. It is a subsidiary of Yunna Metallurgical Group General Company (YMGGC), which has a capacity of 100,000 t/yr of a wide variety of germanium products (Yunnan Metallurgical Group General Company, 2004§).

Chinese smelters stated that the domestic prices for germanium were higher than the export market, so more germanium was sold domestically than exported. Because of the low export price, smelters were operating well below capacity. The 10-t/yr smelter in Guangdong produced less than 6 t. A Shanghai-based smelter with a 12-t/yr capacity reported that it was not at operating capacity (Metal-Pages, 2003c§). A 10-t/yr smelter in Shaogon stated it dramatically reduced production to only 300 to 400 kg of germanium metal. Many smelters also had several hundred tons of GeO_2 that they were trying to sell (Metal-Pages, 2004a).

Hebei Province unveiled plans to become the world's leading supplier of semiconductor materials. Local officials expect to triple output by 2005 (Metal-Pages, 2003d§).

France.—Metaleurop Nord SA (a division of Metaleurop SA) was placed into receivership and forced to shut down its zinc smelter at Noyelles-Gaudalt in France. The smelter produced approximately 7 t/yr of germanium (American Metal Market, 2003a).

Germany.—Germany's PPM Pure Metals GmbH (a division of Metaleurop SA) was put up for sale in 2003. The plant, which had a capacity of 50 t/yr of germanium products, was still operational in 2003, although well below capacity (Metal-Pages, 2003e§).

Japan.—Production of germanium dropped by 17% during 2003, while shipments increased by 5% compared with those of 2002. Many companies were trying to use up some of their standing stock (Roskill's Letter from Japan, 2004b).

The average value of a kilogram of imported GeO_2 decreased by 73% in 2003 compared with that of 2002. The importation of 28.8 t of GeO_2 in 2003 was a 48% reduction compared with 2002. GeO_2 is used in Japan as a catalyst for the production of PET. Although imports dropped, consumption of germanium as a catalyst remained relatively stable, even though there was some substitution of titanium oxide. As in Europe and the United States, demand for germanium dopants in optical fiber fell significantly in 2002 and has not yet recovered to the 2001 level (Roskill's Letter from Japan, 2004a).

Namibia.—ZincOx Resources plc announced that the preliminary cost of recovering germanium from Tsumbe slags was substantial, and the potential revenue for the project would not be enough to warrant development. Until the price recovers or new cost-effective methods are discovered, the project will be abandoned. An extension of the contract to process the slag was sought to keep alive the prospect of continuing the project at a later date. The slag was considered to be one of the world's largest resources of high-grade germanium (ZincOx Resources plc, 2003§). A newly discovered method was considered at Tsumbe, but the cost of the process was not released, and the future of this process was unknown (Metal-Pages, 2003n§).

Russia.—A large germanium deposit was discovered in central Russia. Russia reported that the deposit could provide several hundred tons of germanium in total and would fully meet the domestic demand for germanium (Metal-Pages, 2003g§).

Current Research and Technology

IBM announced that it had invented a new microchip that performed four times faster and reduced power consumption fivefold compared with current chips. The design combined a silicon-germanium (SiGe) bipolar and complementary metal-oxide semiconductor (CMOS) onto one silicon-on-isolator (SOI) wafer. With the increasing use of wireless devices, manufacturers will need new chips that are faster, more energy efficient, and smaller. The new chip design was suitable for both high-voltage and high-speed applications, unlike current chip designs. IBM stated that the chip could be in use within 5 years and could greatly change personal electronics (Compound Semiconductor, 2003).

Other new uses for germanium in semiconductors were discovered by Samsung Electronics. The company developed a new chip based on germanium-antimony telluride for random access memory chips that operate faster than flash memory chips. The new germanium-based chips, unlike silicon-based chips, are nonflammable. Possible uses for these chips are cellular telephones and digital cameras. Intel and Samsung are schedule to have the chips in commercial electronics by 2005 (Metal-Pages, 2003b§).

A new metallic material consisting of gallium, germanium, and ytterbium was discovered to maintain its size when heated to 400 kelvin (K) from 100 K. Researchers at Michigan State University noticed the odd behavior while studying the magnetic properties of the material as it cooled. The material is not difficult to create, but it is rather expensive to make. The researchers hoped that, with this discovery, cheaper versions of material with similar properties could be developed. The uses for a material with this property could include new alloys that would be ideal for space probes that could endure a wide range of temperatures (Metal-Pages, 2003a§).

Outlook

Higher recycling rates of PET and replacements for germanium as a catalyst in PET plastics will erode the consumption of germanium in Asia. The closure of zinc mines in Australia, Canada, and the United States as well as the closures of smelting facilities in Europe will continue to lower the output of byproduct germanium in the short term.

The leading domestic use for germanium in 2003 was for optical fiber production, which has declined considerably during the past few years. A recovery in the telecommunications sector for metropolitan and fiber-to-home consumption of fiber optics could mean a strong surge in demand for germanium.

With the increased demand for infrared devices for use by the military, in security and surveillance equipment, and in private automobiles, there is still significant strength and growth potential in the infrared optics area. Germanium continues to be used for thermal-imaging in night-vision systems using infrared rays. The germanium lens focuses the infrared rays from the observed object to a detector. All objects emit heat to some degree, but animals, humans, and moving vehicles are quite visible in the infrared spectrum because of the large amount of heat emitted, which contrasts with the background. The night-vision segment of the surveillance equipment market was expected to grow to $750 million by 2004 from $560 million in 1999 (Hindus, 2000).

There is also growth potential in the thin-film application for digital video discs, SiGe chips, germanium-based semiconductors, and other electronic uses for germanium. According to the SIA, the growth potential for all semiconductor use was 15.8% for 2004 (Metal-Pages, 2003h§).

References Cited

American Metal Market, 2003a, Metalurope Nord shutters plant: American Metal Market, v. 111, no. 10-3, March 12, p. 6.

American Metal Market, 2003b, Pasminco in deal to sell Tenn. zinc mines to power company: American Metal Market, v. 111, no. 35-4, September 5, p. 5.

Compound Semiconductor, 2003, IBM demos SiGe transistor on SOI: Compound Semiconductor, v. 9, no. 10, November, p. 14.

Compound Semiconductor, 2004, SiGe BiCMOS shines at IDEM: Compound Semiconductor, v. 10, no. 1, January/February, p. 31-32.

Cravens, Amy, 2003, More builders make home broadband a priority: Fiber Optics News, April 28, p. 6.

Germanium Corporation of America, 2003, Degussa and Germanium Corporation announce partnership to supply silicon tetrachloride and germanium tetrachloride: Utica, NY, Germanium Corporation of America press release, October 31, 2 p.

Hindus, Leonard, 2000, New estimate—U.S. night vision surveillance devices to pass $750 million by 2004: Advanced Imaging, v. 15, no. 4, April, p. 38.

Plachy, Jozef, 2003, Zinc in August 2003: U.S. Geological Survey Mineral Industry Surveys, October, 7 p.

Platts Metal Week, 2003a, Teck has new zinc extraction process: Platts Metal Week, v. 74, no. 35, September 1, p. 5.

Platts Metal Week, 2003b, Umicore buys germanium assets: Platts Metal Week, v. 74, no. 30, July 28, p. 7.

Roskill's Letter from Japan, 2004a, Non-ferrous metals—Japanese production in January to November 2003: Roskill's Letter from Japan, no. 331, March, p. 21.

Roskill's Letter from Japan, 2004b, Trade—2003 sees record level of trade between Japan and China: Roskill's Letter from Japan, no. 330, February, p. 21-25.

Stradling, Andy, 2003, Teck Cominco unveils HydroZinc: Mining Journal, v. 341, no. 8752, September 5, p. 174.

U.S. Department of Defense, 2003, Strategic and critical materials report to the Congress: Washington, DC, U.S. Department of Defense, February 12, 64 p.

Internet References Cited

Bankrate 2004, Auto safety—Fantasy's just ahead, accessed May 20, 2004, via URL http://bankrate.com.

Defense Logistics Agency, 2004 (May 4), Annual materials plan for FY 2004 revised, News Release, accessed May 19, 2004, via URL https://www.dnsc.dla.mil/DNSC/news_releases1.asp.

Hansen, Christine, 2001 (May/June), Thermal imaging cameras, National Fire & Rescue Magazine, v. 25, no. 3, accessed March 14, 2003, at URL http://www.raytheoninfrared.com/newsroom/pressItem50.html.

Metal-Pages, 2003a (October 22), Exotic alloy that doesn't expand when heated developed, accessed October 23, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003b (July 9), Germanium, antimony, and tellurium to be used in prams, accessed July 10, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003c (March 13), Germanium prices higher in China, accessed March 14, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003d (September 17), Hebei plans semiconductor expansion, accessed September 22, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003e (March 19), Metaleurop puts up for sale as it prepares case against liquidation, accessed March 20, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003f (October 8), Mitsui Chemical switch to titanium from germanium and antimony, accessed October 9, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003g (November 7), New germanium deposit found in Russia, accessed November 10, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003h (November 6), Semiconductor sales recovery predicted, accessed November 7, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003i (March 26), Toyobo develops new Al based PET catalyst, accessed March 27, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003j (February 3), Toyobo develops new catalyst using aluminium, accessed February 4, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003k (July 23), Umicore buys Eagle-Picher Ge assets, accessed July 24, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003l (July 23), Umicore deal offers little hope for current Ge price, accessed July 24, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003m (July 14), Umicore teams up to advance GeOI substrates, accessed July 15, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2003n (October 6), ZincOx turns FSU technology to process zinc and germanium from slags, accessed October 7, 2003, via URL http://www.metal-pages.com.

Metal-Pages, 2004a (January 12), Germanium still in the doldrums, accessed January 13, 2004, via URL http://www.metal-pages.com.

Metal-Pages, 2004b (January 14), Ti could replace Ge for PET, accessed January 23, 2004, via URL http://www.metal-pages.com.

Metal-Pages, 2004c (March 4), Umicore profits up, expects more, accessed March 5, 2004, via URL http://www.metal-pages.com.

N.V. Umicore, s.a., 2003 (July 14), IMEC, UMICORE and SOITEC study germanium as an alternative to silicon chips, Press Release, accessed May 2, 2004, via URL http://www.umicore.com.

Pasminco Limited, 2003 (October 30), Annual report 2003, accessed May 24, 2004, at URL http://www.pasminco.com.au/resources/uploads/annual2003.pdf.

Teck Cominco Limited, 2004, Pend Oreille year in review, accessed May 19, 2004, via URL http://www.teckcominco.com.

Tennessee Valley Resources, 2004, Limestone, accessed May 18, 2004, via URL http://www.tennesseevalleyresources.com.

Yunnan Metallurgical Group General Company, 2004, Investors guide, accessed May 2, 2004, via URL http://www.sinohost.com/ynm.
ZincOx Resources plc, 2003, Annual report 2002, accessed May 24, 2004, via URL http://www.zincox.com.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Gallium, Germanium, and Indium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Germanium. Ch. in Mineral Commodity Summaries, annual.

Other

Germanium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Platts Metals Week.

TABLE 1
U.S. IMPORTS OF GERMANIUM, BY CLASS AND COUNTRY[1, 2]

	2002		2003	
Class and country	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Wrought, unwrought, waste, and scrap:				
Belgium	2,720	$3,210,000	3,120	$3,310,000
Brazil	--	--	2	4,680
Canada	712	313,000	691	388,000
China	1,780	815,000	2,650	1,190,000
France	15	2,480	--	--
Germany	865	933,000	555	476,000
Israel	96	101,000	93	98,000
Latvia	--	--	3	4,410
Netherlands	2	4,860	--	--
Russia	927	741,000	1,260	830,000
Taiwan	5,630	37,200	--	--
Ukraine	176	96,500	--	--
United Kingdom	222	151,000	6	10,900
Total	13,100	6,410,000	8,380	6,310,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Does not include germanium dioxide imports.

Source: U.S. Census Bureau.