



2007 Minerals Yearbook

GERMANIUM

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By David E. Guberman

Domestic survey data and table were prepared by Ram C. Khatri, statistical assistant.

In 2007, germanium was recovered from zinc concentrates at two zinc mines and produced at two refineries in the United States. Germanium-bearing concentrates were produced at two zinc mines in Alaska and Washington, owned by Teck Cominco Ltd. (Vancouver, British Columbia, Canada). Two refineries in New York and Oklahoma produced germanium dioxide, germanium metal, and germanium tetrachloride from manufacturers' scrap, and post-consumer scrap and processed imported germanium compounds.

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

Legislation and Government Programs

As a strategic and critical material, germanium was included in the National Defense Stockpile (NDS) in 1984. Postings for sales were conducted each Thursday on the Defense National Stockpile Center (DNSC) Web site, and price quotes from prequalified Basic Ordering Agreement holders were due the following Wednesday. According to the Defense Logistics Agency (DLA), sales began 2007 at \$1,000 per kilogram (kg) and ended the year in November at \$1,240 per kilogram. The DLA reported that sales for calendar year 2007 were 6,902 kg compared with 4,576 kg in 2006. As of December 31, 2007, the NDS inventory of germanium metal was 16,531 kg. The DLA suspended sales of germanium metal in mid-November while it awaited the passage of the National Defense Authorization Act for fiscal year 2008 (Defense National Stockpile Center, 2007b). The sale of germanium was limited by a revenue cap that is adjusted by legislation each year as part of the National Defense Authorization Act. The revenue cap for fiscal year 2007 was reached in November. The DLA was authorized to sell up to 8,000 kg during fiscal year 2008 (Defense National Stockpile Center, 2007a).

Production

Domestic refinery production of germanium was estimated by the U.S. Geological Survey (USGS) based on data provided by North American producers. The USGS estimated that U.S. refinery production of germanium from fly ash, imported primary material and germanium compounds, and new scrap in 2007 was 4,600 kg.

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

and its Pend Oreille zinc-lead underground mine in Washington State. Approximately 25% of zinc concentrate produced at Red Dog and 100% of the concentrate produced at Pend Oreille were sent to the company's metallurgical complex in Trail, British Columbia, Canada. The zinc concentrates were then treated in roasters or pressure-leach facilities to extract germanium and other byproducts. In 2007, Teck Cominco produced about 40,000 kg of germanium at its Trail facility (Teck Cominco Ltd., 2008a, p. 98).

In 2007, Umicore Optical Materials USA Inc. (a subsidiary of Umicore s.a., Brussels, Belgium), continued production of germanium metal and compounds at its plant in Quapaw, OK, and remained the leading domestic producer of germanium. Umicore produced germanium from fly ash, germanium concentrates (typically containing 5% germanium or more), scrap, and imported germanium compounds. This facility refined the raw material into germanium tetrachloride, which was used as an additive in the manufacturing of optical fibers, germanium blanks (lenses and windows) for infrared (IR) devices, and proprietary (GASIR) lenses which were designed for large-scale commercial and military applications where there is a need for infrared optical systems. These GASIR lenses were produced from a germanium arsenic selenium compound and were manufactured with a lower germanium content than traditional infrared optical lenses, allowing for lower production costs (Umicore s.a, 2007, p. 3). The company also provided lens polishing and thin-film coating as well as recycling services at the Quapaw facility.

Germanium Corp. of America (a subsidiary of Indium Corp. of America, Clinton, NY) produced germanium products including germanium dioxide, germanium metal, and germanium tetrachloride at its facility in Utica, NY.

In June, Strategic Resources Acquisition Corp. (SRA) (Toronto, Ontario, Canada) began the first phase of a mine restart program at the Middle Tennessee Zinc Mining Complex (MTM) near Gordonsville, TN. The mining complex, previously operated by Pasminco Ltd., was composed of five zinc mines (Carthage, Cumberland, Elmwood, Gordonsville, and Stonewall) and a mill that had been acquired by SRA in late 2006. From 1975 through 2003, the mine complex produced almost 34 million metric tons of ore grading 3.28% zinc. When the mine was placed on care-and-maintenance-status owing to low zinc prices and corporate restructuring, remaining resources were estimated to be equivalent to those produced from 1975 to 2003 (The Northern Miner Online, 2007). By yearend, SRA reported that it had made significant progress in rehabilitating the Gordonsville mine and milling facilities and was close to delivering the first zinc concentrate from that mine. SRA expected the byproduct residues produced from the processing of the zinc concentrates to contain both gallium and germanium. In November, SRA entered into a 5-year agreement with Nyrstar

NV (Balen, Belgium) for the sale of a significant portion of its zinc production from the MTM complex. According to the agreement, Nyrstar was to process up to 90,000 metric tons per year (t/yr) of SRA's zinc concentrate at its Clarksville, TN, refinery and then return all the residues to SRA. The returned residues were expected to contain up to 45,000 kilograms per year (kg/yr) of gallium and 35,000 kg/yr of germanium (Strategic Resources Acquisition Corp., 2007a).

Consumption

The USGS estimated that domestic consumption of germanium increased to 60,000 kg in 2007 from 55,000 kg in 2006 owing to continued growth in infrared optics and fiber-optic applications. Worldwide, the end-use pattern was estimated to be as follows: catalysts for polyethylene terephthalate (PET), 31%; fiber-optics, 24%; infrared optics, 23%; electronics and solar applications, 12%; and other uses (such as phosphors, metallurgy, and chemotherapy), 10% (Metal-Pages, 2007a). The domestic end-use pattern was significantly different, however, with infrared optics accounting for 50%; fiber-optics, 30%; electronics and solar applications, 15%; and other uses (phosphors, metallurgy, and chemotherapy), 5%. Germanium was not used in PET catalysts in the United States.

Germanium lenses and windows are transparent to infrared radiation, which allows them to be used in infrared optical systems in the same way that ordinary glass lenses and windows are used in visible-light optical systems. Production of germanium optical lenses typically begins with the raw material going through a grinding machine, where it is formed into the specific lens shape and size required for the intended application. The lenses are then polished until the faces are flawless and coated with a material such as carbon to ensure durability (Kirk, 2008). Domestically, germanium continued to be used extensively for military applications such as navigation systems, detection and search equipment, optical imaging, and target evaluation systems. The U.S. Marine Corps recently announced that it was expecting to equip nearly 900 vehicles with detection and targeting systems based on infrared technology (Raytheon Co., 2006). Infrared sighting systems allow for the operation of military vehicles at night as well as in adverse weather conditions such as dust, rain, sand storms, and smoke. The ability to locate targets from long distances in harsh conditions is considered both a strategic advantage and a safeguard for troops in combat. Infrared technology was being utilized in unmanned drone aircraft conducting reconnaissance missions, high-speed missiles, and scopes mounted to rifles. Germanium optical glass also was used within nonmilitary equipment such as the search and rescue devices often carried by firefighters as well as the night-vision goggles worn by law enforcement officials conducting surveillance. Automobile manufacturers continued to offer infrared-based night vision systems in some higher end luxury cars (Kirk, 2008).

In the fiber-optics sector, germanium was used as a dopant (a substance added in small amounts to the pure silica glass core to increase its refractive index while not absorbing light) within the core of optical fibers used by the telecommunications industry. Demand for fiber-optics in North America was reported to have

grown at a rate of 15% per year since the telecommunications industry recovered from a downturn that began in late 2001 (Metal-Pages, 2007c). Recent growth had been fueled by consumer demand for a multitude of broadband and high-speed services that were being delivered straight to the home via fiber-optic cable. According to a study released by the Fiber-to-the-Home (FTTH) Council, more than 9.5 million homes in North America had fiber-optic cable running to the premises by the end of 2007. This was almost a 57% increase from that of the previous year. Furthermore, the number of subscribers paying for high-speed fiber-optic networks to access the internet as well as for video services (known as IPTV) had increased by more than 100% from that in 2006 (Fiber-to-the-Home Council, 2007). According to another FTTH report, fiber-optic installations had increased dramatically on a global scale as well in 2007. Several Asian countries and regions, specifically Hong Kong, Japan, and the Republic of Korea, had significantly outpaced the rest of the world with their implementation rates of fiber-to-the-home connections by yearend 2007 (Fiber-to-the-Home Council, 2008).

In 2007, Corning Inc. (Corning, NY) announced that it had developed a new type of fiber-optic cable that could be bent around tight corners with virtually no signal loss. The company claimed that this development solved a technical challenge that had prevented telecommunications carriers from being able to install fiber-to-the-home networks in multiple-dwelling units such as apartment and condominium buildings. Previous fiber-optic cable designs were subject to signal strength loss and effectiveness when bent around corners and routed through buildings (Corning Inc., 2007). This cable solution was subsequently adopted by Verizon Communications Inc. (New York, NY) and allowed the company to offer its fiber-optic internet and television services to customers living in multiple dwelling buildings (Corning Inc., 2008).

Germanium substrates continued to be favored for use in space-based photovoltaic (PV) solar cells, accounting for more than 80% of satellite applications. Germanium substrates were used in these applications because they were smaller, more efficient at converting light into energy, and provided greater power output than the most common alternative substrate, silicon (European Commission, 2008). Germanium wafers (or substrates) constitute the building blocks of multilayer solar cells. Ultrathin layer combinations of other materials are "grown" on top of the germanium substrate, each capturing a specific part of the solar spectrum and converting it into electricity (Umicore s.a., 2008a, p. 14). Germanium substrates constitute the base material for the solar panels used in the National Aeronautics and Space Administration's Mars Exploration Rovers, the two mobile robots that have been exploring Mars since the beginning of 2004 (Umicore s.a., 2008b). Along with satellite applications, germanium-based PV solar cells were being used to a significantly lesser extent in terrestrial solar power generation as part of solar concentrator systems (an optical system that concentrates solar beams onto tiny wafers).

In the polymerization catalysts sector outside the United States, germanium consumption as a catalyst for PET production remained stable. Titanium had replaced the relatively expensive

germanium as a catalyst and could reduce its future growth for this use.

Prices

Free market prices for germanium dioxide, published by Metal-Pages, increased from about \$680 per kilogram at the beginning of the year to nearly \$950 per kilogram by yearend 2007. Based on DNSC sales, the price of zone-refined germanium metal was \$1,240 per kilogram in November 2007, which was the last month it was sold in 2007 (Defense National Stockpile Center, 2007c).

Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (wrought, unwrought, and waste and scrap material) increased to approximately 25,400 kg in 2007 from 24,100 kg in 2006. Belgium, Germany, Russia, and China, in descending order of quantity, accounted for almost 95% of imports into the United States in 2007 (table 1). The estimated germanium content of the germanium dioxide imported in 2007 was nearly 27,000 kg compared with 19,500 kg in 2006. On a contained basis, Belgium accounted for 37% of total germanium imports; Canada, 22%; Germany, 19%; China, 12%; and Russia, 9%.

Domestic exports of germanium metal and articles thereof, including waste and scrap, were 11,300 kg in 2007 according to the U.S. Census Bureau. Belgium, Canada, and China accounted for about 69% of exports of germanium from the United States in 2007. The estimated germanium content of germanium dioxide exported in 2007 was nearly 350 kg. On a contained basis, Belgium was the destination for 34% of total domestic germanium exports; Canada, 23%; and China, 12%.

World Review

In 2007, the world's total estimated supply of germanium was almost 145 metric tons (t), including 6,902 kg released from the NDS. The recycling level remained about the same and supplied about 30% of the world's total supply of germanium.

Beginning in 2001, there was a growing surplus of germanium owing to a major downturn in the fiber-optics market. By yearend 2003, production and consumption were nearly equal, followed by lower production and moderate demand growth in 2004, which resulted in a tight supply that continued through 2005. In 2006, production decreased while consumption strongly rose, resulting in a deficit. Prices of germanium metal as well as germanium dioxide increased to record levels in 2007. Supplies of germanium continued to be tight owing to strong demand coming from both the fiber-optic and infrared technology sectors (Metal-Pages, 2007c). Worldwide, the vast majority of germanium production was concentrated in Canada and China.

European Union.—The European Commission's 7th Framework contained several research priorities including the development of automotive detector systems for the protection of pedestrians. A German company, Infineon Technologies

AG, had been working on a radio frequency (RF) solution for automotive radar sensors using radar chips based on silicon-germanium (SiGe) manufacturing technology. Because this technology is smaller and less costly than current alternatives, the company thought that long-range radar could become standard equipment for the mid-range automotive segment within 3 years (Infineon Technologies AG, 2007).

Belgium.—Umicore operated a germanium refining and recycling plant in Olen with more than 250 employees. Along with the production of germanium metal, germanium tetrachloride for fiber-optics, germanium substrates, and germanium optical products, Umicore maintained a research and design facility at Olen. In 2007, Umicore saw year-over-year increases in sales of both germanium substrate products, germanium chemicals for fiber-optics, and germanium optical blanks. Sales of GASIR optical assemblies for automotive night vision applications slowed from those of previous years. At yearend, Umicore purchased the remaining 40% portion of a joint venture that it had previously started with a germanium refinery in Kunming, China (Umicore s.a., 2008a, p. 24).

China.—Demand for germanium was extremely strong throughout the year owing to growth seen in the fiber-optic cable industry as well as military uses. Prices in China remained at historically high levels throughout the year, and supplies were tight at yearend (Metal-Pages, 2007b). It was estimated that Chinese production of germanium, from lead-zinc ore and germanium-bearing coal ash, was nearly 100 t in 2007. At yearend, Sparton Resources Inc. (Toronto, Ontario, Canada) was exploring the possibility of acquiring an 85% share in Hua Jun Coal Industry Co. Ltd. (HJ). HJ was a privately owned coal and germanium producer and was the second-ranked germanium concentrate producer in the Lincang area of Yunnan Province (Sparton Resources Inc., 2007).

In April, China announced that it had canceled toll trading tax benefits for a number of minor metals, including germanium. Companies that had exported these metals would become subject to import and export taxes as well as value added tax (VAT) in the future. Previously, germanium exporters were exempt from these taxes under China's toll trading system (Metal Bulletin, 2007).

Mexico.—War Eagle Mining Co. Inc. (Vancouver, British Columbia, Canada) moved forward on its plans to restart mining operation at the Tres Marias zinc and germanium mine in Chihuahua, Mexico. Tres Marias is a former high-grade zinc and germanium mine first put into production in the late 1940s, which had operated until the early 1990s when the smelter being used became unable to continue processing the raw ore. War Eagle expected to complete an extensive exploration and drilling program by the end of 2008 (Mining Engineering, 2008).

Russia.—Russian germanium production was estimated to be between 5 and 6 t in 2007, and more than one-half of the metal produced was exported (Metal-Pages, 2007d). The Federal State Unitary Enterprise "Germanium" plant performed a range of germanium processing, refining, and recycling. The germanium was captured from coal ash, germanium concentrates, and production wastes.

Spain.—In November, War Eagle announced that it had signed a letter of intent with ELCOGAS S.A. (Madrid) to

test the processing of fly ash generated from the Puertollano powerplant with the aim of recovering gallium and germanium. ELCOGAS had produced nearly 12,000 t/yr of fly ash at Puertollano and held an international patent on the recovery of metals from fly ash. As part of the agreement, ELCOGAS granted War Eagle permission to use its patented procedures for recovering gallium and germanium (War Eagle Mining Co. Inc., 2007).

Outlook

A major growth area for germanium was in the IR optics area owing to increased interest in IR devices by the military, in security and surveillance equipment, and in the automobile market. Demand by the military and the defense industry will probably account for a significant portion of germanium consumption in the future.

With technological advancements, germanium substrates were expected to continue to be used for new solar power projects. New markets for germanium emerged in the form of terrestrial-based solar applications. Germanium substrates were beginning to be used in terrestrial photovoltaics and were an extremely efficient source of solar power. In Australia, a \$420 million solar photovoltaic power station was to be built in northwest Victoria. The power station was to use high-performance germanium substrate based solar cells that had been originally developed to power satellites. The power station was to generate enough electricity directly from the sun to meet the annual needs of more than 45,000 homes. This plant was expected to be fully operational by 2013 (Solar Systems, 2006).

The 2007 deficit in germanium supply owing to limited germanium production and increased consumption was expected to continue in 2008. Supply will most likely remain tight throughout the year until output increases and more recycling takes place.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL, BY COUNTRY^{1,2}

Country	2006		2007	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Belgium	11,400	\$5,900,000	10,100	\$9,250,000
Canada	426	354,000	1,300	974,000
China	3,770	2,770,000	4,410	4,080,000
Germany	4,810	5,330,000	4,990	7,080,000
Hong Kong	595	405,000	--	--
Israel	7	6,330	25	40,400
Japan	254	168,000	--	--
Russia	2,610	2,870,000	4,510	5,700,000
United Kingdom	19	27,100	2	4,810
Other	137	116,000	27	26,800
Total	24,100	17,900,000	25,400	27,200,000

-- Zero.

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

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

Source: U.S. Census Bureau.