GERMANIUM

By Robert D. Brown, Jr.

Domestic survey data and tables were prepared by Carolyn F. Crews, statistical assistant.

Germanium, a grayish-white element, is a semiconductor, with electrical characteristics between those of a metal and an insulator. It is commercially available as a tetrachloride and a high-purity oxide and in the form of metal ingots, single-crystal bars, castings, doped semiconductors, optical materials, optical blanks, and other specialty products. Germanium is used principally in fiber optics, infrared optics, and polymerization catalysts. Its special mechanical, optical, and electrical properties, as well as its moderate cost, also make it attractive in many aerospace applications.

In 2000, the domestic germanium industry consisted of two zinc mining operations in Alaska and Tennessee, which supplied byproduct germanium concentrates for export, and three refineries in New York, Oklahoma, and Pennsylvania. The domestic refineries processed manufacturers' scrap, imported semirefined materials, and some old (postconsumer) scrap. Domestic refinery production, which amounted to slightly less than one-third of world refinery output, was estimated to be valued at $29 million. Domestic refinery production and consumption for germanium are estimated by the U.S. Geological Survey (USGS) on the basis of discussions with domestic producers. Both domestic refinery production and U.S. consumption of germanium were estimated to have increased in 2000.

The USGS estimated domestic germanium reserves to be 450,000 kilograms (kg), equivalent to 15 years of domestic consumption at the 2000 rate; figures for worldwide reserves were not available. Worldwide, germanium resources are associated with zinc and lead-zinc-copper sulfide ores.

As a strategic and critical material, germanium was included in the National Defense Stockpile (NDS) in 1984, with an initial goal of 30,000 kg of germanium metal. In 1987, a new NDS goal of 146,000 kg was established; in 1991, this was adjusted downward to 68,198 kg. In 1995, the Defense Logistics Agency (DLA), which maintains the NDS, made plans to sell germanium at a rate of 4,000 kilograms per year (kg/yr) through 2005. This proposed rate remained the same for 1996, but it 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 (U.S. Department of Defense, 1997). The amount designated for annual sales was a significant portion of the domestic and world market, but in most years less than the amount available for sale has been sold.

At the current stockpile disposal rate, the DLA price has become not only a good indicator of the market value of germanium, but also a factor in determining that value. Sales began in 2000 at just under $1,000 per kilogram and fell gradually to $870 per kilogram during the year (Mining Journal, 2000b). After 2,843 kg was sold in 2000, the yearend inventory was 48,531 kg of germanium metal. The main factor resulting in the price decrease was a continued slowdown in the implementation of satellite communication systems in spite of brisk demand in other use sectors.

Production

In 2000, the USGS estimated U.S. refinery production of germanium from primary and semirefined materials to be 23,000 kg, 15% more than that of 1999. The Electro-Optic Materials Department of Eagle-Picher Industries, Inc., in Quapaw, OK, remained the largest domestic producer in 2000, producing germanium from reprocessed scrap, fly ash, germanium concentrates (typically containing 5% or more germanium), and semirefined germanium materials.

Cabot Corp., Revere, PA, and Atomergic Chemetals Corp., Plainview, NY, produced germanium from reprocessed scrap and semirefined foreign material. The zinc refinery at Clarksville, TN, owned by Savage Resources Ltd., continued to produce germanium-rich residues as a byproduct of processing zinc ores from its associated Elmwood-Gordonsville Mine. Savage has continued the established practice of shipping these residues to Union Minière, SA's Electro-Optic Materials Business Unit in Belgium for germanium recovery and refining.

Consumption

The USGS estimates that domestic consumption of germanium in 2000 increased to approximately 28,000 kg. The domestic use pattern was similar to the world use pattern, which was estimated to be as follows: fiber optics, 50%; polymerization catalysts, 25%; infrared optics, 15%; electrical/ solar applications, 5%; and other uses (as phosphors, in metallurgy, and in chemotherapy), 5%. The major difference between the domestic and world patterns of consumption is that the greatest U.S. germanium demand is for fiber optics, while in Japan most of the germanium is used for polymerization catalysts (Roskill's Letter from Japan, 1999).

In the fiber optics sector, germanium was used as a dopant within the core of optical fiber used by the telecommunications industry. Because germanium lenses and windows are transparent to infrared radiation, they can be used in infrared optical systems in the same ways that ordinary glass lenses and windows are used in visible light optical systems. These optics have been used principally for military guidance and weapon-sighting applications. Germanium glass was also used for nonmilitary surveillance, night vision, and monitoring systems in a wide range of fields, including satellite systems and fire alarms.

A significant factor influencing germanium consumption in 2000 involved satellite communication systems. Satellite launch delays at the Teledesic Project, which is to be a large satellite based communications system, resulted in a decline in solar cell manufacture. This project, when restarted, would require about 12,000 kg of germanium for solar cells (Mining Journal, 2000a). The decline in consumption for solar cell applications was overcome by increases in other sectors in 2000. The use of germanium as a dopant in optical fibers continued to grow.

General Motors Corp. began incorporating a germanium-based night vision system in its top-of-the-line cars. Several manufacturers have begun production of SiGe chips.

Prices

In 1995, domestic producer prices for germanium metal and dioxide were, for the first time, set higher than the longstanding price levels established in late 1981 ($1,060 and $660 per kilogram, respectively). Throughout the 1981-1995 period, producers significantly discounted prices in response to competition from imported materials. In 1995 and 1996, however, producer prices for zone refined metal reportedly reached $1,375 and $2,000 per kilogram, respectively; germanium dioxide producer prices rose to $880 and $1,300 per kilogram, respectively. In 1997, the producer prices fell back to $1,475 per kilogram for the metal and $950 per kilogram for the dioxide. In 1998, they increased again to $1,700 per kilogram for the metal and $1,100 per kilogram for the dioxide. In 1999, the prices were reduced to $1,400 and $900 per kilogram, respectively, owing to sluggish demand. In 2000, prices continued to fall, reaching $1,250 and $800 per kilogram, respectively, mainly due to plentiful supply rather than lack of demand.

Free market prices for germanium dioxide, published by Metal Bulletin, began 2000 in the $680 to $750 per kilogram range and ended the year in the $620 to $700 range. The price for Belgian-produced germanium dioxide, published by Metal Bulletin, remained at $750 per kilogram all year.

In 1998, germanium prices increased despite an oversupply that resulted from: (1) slight decreases in world demand for optical fibers and polyethylene terephthalate (PET); and (2) an increase in total supply owing to greater amounts of recycling and continued releases of germanium from national stockpiles in Russia, Ukraine, and the United States. This increase in price was probably due to anticipated demand in the satellite communications sector, and, when this increase in demand did not occur in 1999, germanium prices began to fall. This same mechanism prevailed in 2000. Demand in satellite applications did not increase, and prices continued to fall.

Trade

In 2000, the estimated germanium content of imports was approximately 8,210 kg, compared with 12,400 kg in 1999. China, Belgium, and Russia, in descending order of shipments, accounted for approximately 87% of U.S. germanium imports in 2000 (table 1). Imports directly attributable to China and countries of the former Soviet Union amounted to about 53% of the total. Trade reliance on large shipments from these countries began in the early 1990s.

World Review

In 2000, world refinery production of primary germanium was estimated to be slightly more than 70,000 kg, an increase of more than 20% from that of 1999. Recycling supplied 25,000 kg of germanium worldwide, the same as in 1999. The world total market supply was about 105,000 kg in 2000, counting 3,000 kg released from the U.S. NDS and 6,000 kg taken from non-Government stockpiles. World consumption matched the total supply. This exceeded production, but supply was made adequate owing to the amounts gained from recycling and stockpile releases. World consumption for 2000 was 19% higher than that in 1999.

Austria.—Austria Mikro Systeme International AG is constructing a modern facility for the production of application-specific integrated circuits and application-specific standard products, including silicon-germanium devices. These products will be for automotive, communication, and industrial applications. The budget for the construction of the new production line is 305 million euro (Austria Mikro Systeme International AG, 2000).

Belgium.—Union Minière, SA, Brussels, made nearly $16 million profit when it sold its share of EMCORE Corp., a semiconductor technology company with headquarters in Somerset, NJ. A joint venture between the two companies to develop new applications for germanium-based components and supply germanium substrates for space solar cells will continue (American Metal Market Online, March 3, 2000, UM posts profit on EMCORE stake sale, accessed March 17, 2000, via URL http://www.AMM.com).

China.—The Nei Mongol Coalfield Geology Bureau has discovered a large germanium deposit at Xilinhaote in Nei Mongol. The germanium contained in the deposit is estimated to be up to 1,600 metric tons, which would make it account for 30% of China's reserves. It is a paragenetic coal/germanium deposit, the largest in China. It would be amenable to large scale open pit mining (Engineering and Mining Journal, 1999). China is the leading supplier of germanium to the United States, accounting for 42% of germanium imports in 1999 and 40% in 2000. China is also a leading supplier of germanium oxide to Japan for use in the production of PET bottles. China provided more than one third of Japanese imported germanium oxide in 1999.

Germany—PPM Pure Metals AG, a subsidiary of Metaleurop GmbH, produces many high-purity metals and compounds including germanium oxide for use as a polymerization catalyst in the production of PET polymer and as a reflective dopant in the core of optical fibers. The company expects to grow with the expanding germanium market (Karpel, 2000).

Current Research and Technology

Germanium is being used for the optics in night vision systems that utilize infrared rays. The germanium lens focuses the infrared rays from the object observed to a detector. All objects emit heat to some degree, but humans, animals, and moving vehicles are quite visible in the infrared spectrum because of the large contrast of emission from the object compared to its background. General Motors installed these systems called night vision, manufactured by Raytheon Corp., on its Cadillac DeVille model in 2000 (Siuru, 1999). Cadillac predicted sales of 3,500 units in 2000, but then asked Raytheon to quadruple production. In its first year, 7,000 of the night vision systems were installed, with Cadillac dealers demanding more. It is expected that production will double again in 2001. Currently the device adds about $2,000 to the cost of the DeVille. High-volume production could cut the cost in half (Truett, 2001). The night vision segment of the surveillance market is expected to grow from $560 million in 1999 to $750 million by 2004 (Hindus, 2000).

Silicon-germanium (SiGe) technology is poised for growth. With the proven viability of implanting silicon with germanium to produce transistors, a number of manufacturers have begun production (Bindra, 2000). By depositing a layer of germanium onto the silicon, one can engineer the energy band structure, the band gap, electron mobilities, and numerous other properties while using conventional silicon processing (Paul, 2000). The only additional step is the actual deposition of the germanium. The cost of this kind of processing is proportional to the number of steps; since 10 to 30 steps are typically involved in the fabrication of a chip, however, the one extra step increases the cost very little (Pool, 2001). SiGe chips combine the high speed properties of germanium with the low cost, well established production techniques of the silicon-chip industry. Most semiconductor technologies that use more than one material are complicated because of the physical and chemical differences between the components. Because silicon and germanium are fairly similar, SiGe processing can be relatively simple.

SiGe also requires less power to perform the same function as its silicon counterpart (Pool, 2001). Thus, SiGe has great potential for mobile phone applications because talk time or battery life is very important in wireless communication. SiGe is expected to provide faster, smaller, and cheaper microchips for third generation mobile phones (Pool, 2001). Gallium arsenide also may be vulnerable to substitution by SiGe in microwave devices (Metal Bulletin, 2000). Strategies Unlimited, a market analysis firm, has predicted that the market for SiGe wireless and digital applications will reach $1.8 billion by 2005 (Paul, 2000).

Outlook

Expected demand increases for fiber optics and new uses could fuel a drive for the development of new germanium resources. The industry appears poised for expansion in spite of recent lackluster price performance (Karpel, 2000). Balancing mechanisms of stockpile releases and increased recycling have thus far tended to hold prices down in spite of increasing demand. Further, even significant increases in demand do not drive prices up if these increases are somewhat less than expected. Greater volatility in the germanium market, however, could occur during the next few years if stockpiles and recycling cannot adequately balance supply and rising demand.

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TABLE 1
U.S. IMPORT OF GERMANIUM, BY CLASS AND COUNTRY 1/

Class and country	1999 Gross weight (kilograms)	1999 Value	2000 Gross weight (kilograms)	2000 Value
Wrought, unwrought, waste, and scrap:				
Belgium	1,620	$2,740,000	3,030	$3,940,000
Canada	8	8,000 r/	77	51,700
China	5,210	4,680,000 r/	3,290	3,450,000
France	--	--	1	3,050
Germany	136	89,100	342	364,000
Israel	160	257,000	70	101,000
Japan	124	13,900	316	268,000
Netherlands	4	2,250	3	4,840
Russia	1,100	684,000	857	805,000
Taiwan	2,490	84,100	--	--
Ukraine	1,210	1,470,000	176	166,000
United Kingdom	382	411,000	53	84,600
Total	12,400	10,400,000	8,210	9,240,000

r/ Revised. -- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.