GERMANIUM

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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 1999, 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 manufacturer's scrap, imported semirefined materials, and some old (postconsumer) scrap. Domestic refinery production, which amounted to slightly more than one-third of world refinery output, was estimated to be valued at $28 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. Domestic refinery production of germanium was estimated to have decreased moderately in 1999, but U.S. consumption has remained steady for 3 years.

The USGS estimated domestic germanium reserves to be 450,000 kilograms (kg), equivalent to 16 years of domestic consumption at the 1999 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 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. 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 the year slightly above $1,250 per kilogram (Mining Journal, 1999b) and remained steady until the fourth quarter when the price fell to $1,100 per kilogram (Mining Journal, 1999c), with a bid accepted for a small amount at $1,000 per kilogram in December (American Metal Market, 1999b). After 3,854 kg was sold in 1999, the yearend inventory was 51,374 kg of germanium metal. The main factor resulting in the price decrease was a slowdown in the implementation of satellite communication systems.

Production

In 1999, the USGS estimated U.S. refinery production of germanium from primary and semirefined materials to be 20,000 kg, nearly 10% less than that of 1998, but still more than twice as much as the production of the early 1990's. The Electro-Optic Materials Department of Eagle-Picher, Inc. in Quapaw, OK, remained the largest domestic producer in 1999, producing germanium from reprocessed scrap, fly ash, germanium concentrates (typically containing 5% germanium or more), 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 1999 remained at the 1998 level of 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, 20%; infrared optics, 15%; electrical/solar applications, 10%; 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 were used principally for military guidance and weapon-sighting applications. Germanium glass was also used for nonmilitary surveillance and monitoring systems in a wide

range of fields, including satellite systems and fire alarms.

The most significant factors influencing germanium consumption in 1999 involved satellite communication systems. Funding problems at the Iridium Telecommunications Project (Mining Journal, 1999a) and communication satellite launch delays at the Teledesic Project resulted in a decline in solar cell manufacture. The Teledesic Project, the more likely to recover, would require about 12 tons of germanium for solar cells (Mining Journal, 2000).

Prices

In 1995, domestic producer prices for germanium metal and dioxide were, for the first time, set higher than the long-standing price levels established in late 1981 ($1,060 and $660 per kilogram, respectively). Throughout the 1981-95 period, producers significantly discounted prices in response to competition from imported materials. In 1995 and 1996, 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.

Free market prices for germanium dioxide, published by Metal Bulletin, began 1999 in the $800 to $840 per kilogram range and ended the year in the $697.50 to $757.50 range. The price for Belgian- produced germanium dioxide, published by Metal Bulletin, remained at $935 per kilogram, unchanged since February 1996, until April 1999, when it was increased to $1,122 per kilogram. The fall in prices during 1997 was caused by a weakening of demand and an increasing supply from worldwide national stockpile sales. In 1998, 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 demand did not increase in 1999, metal prices fell.

Foreign Trade

In 1999, the estimated germanium content of imports was approximately 12,400 kg, compared with 14,600 kg in 1998. China, Taiwan, and Belgium, in descending order of shipments, accounted for approximately 75% of U.S. germanium imports in 1999 (table 1). Imports directly attributable to China and countries of the former Soviet Union amounted to about 60% of the total. Trade reliance on large shipments from these countries began in the early 1990's.

Russia included germanium in a list of metals to be covered by a 5% export tax. Originally set to cover only copper and nickel, the new tariff now includes several minor metals. One American trader indicated that the tariff would have little impact because Russia is not a major producer (American Metal Market, 1999a). However, Russia has been ranked as the 4th or 5th largest supplier of germanium to the United States during the last 2 years.

World Review

In 1999, world refinery production of primary germanium was estimated to be 58,000 kg, an increase of nearly 4% from that of 1998. Recycling supplied 25,000 kg of germanium worldwide, a slight decrease. The world total market supply was about 91 t in 1999, counting 4 t released from the U.S. National Defense Stockpile and 4 t taken from non-Government stockpiles. World consumption balanced this total. World consumption exceeded production, but supply was adequate, owing to the amounts gained from recycling and stockpile releases. World consumption for 1999 was 7% higher than that in 1998.

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 at URL http://www.AMM.com-non ferrous metal news).

Canada.—SiGe Microsystems, Inc., an Ottawa company that designs and manufactures integrated circuits for wireless communication systems, shipped its first SiGe-enhanced chips in May 1999. The company had raised CAN$4 million in capital by the end of November and planned to raise US$10 million during the first quarter of 2000. The company was "incubated" at Canada's National Research Council (SiGe Microsystems, 1999).

Current Research and Technology

Research at the University of Delaware has shown that adding germanium to silicon carbide could form the basis for a new class of high-power, high temperature semiconductor devices. Silicon carbide has been developed for use in high-power and high-operating-temperature integrated circuits. The research at the University of Delaware indicates that germanium may improve the stability and the speed of the microelectronic and microelectrical devices made with the new material. These findings suggest that research with silicon-germanium circuits, which has reached the commercial stage at a number of companies, might be successfully applied to the silicon carbide system as well (Katulka, and others, 1999).

Outlook

In recent years, germanium supplies have met the demand only because material was available through recycling and from national and non-Government stockpiles. Although consumption remained sluggish in 1999, future germanium

supply could tighten if demand increases, as has been projected (Talmedge, 1997). For example, the recently commercialized SiGe chips, which are fast, cheap, and consume less power in applications such as cellular phones, commanded a $0.5 million dollar market share in 1998, with expectations of a $1 billion share by 2003 (Markoff, 1998). The 1999 market share is $15 million, with $1.8 billion projected by 2005 (Semiconductor Business News, August 23, 1999, Siemens, IBM to collaborate on SiGe ICs, accessed March 17, 2000, at URLhttp://www.semibiznews.com/story/OEG19990823S0030). Such optimism demands attention. These expectations will probably keep the price of germanium high despite a plentiful supply for the current weaker-than-expected demand. With the implementation of major satellite communications systems currently on hold, up to 12 tons of germanium eventually could be consumed, stockpiled, or returned to the market (Mining Journal, 2000). Although some balancing mechanisms, such as stockpiling and recycling, have thus far tended to moderate price swings, greater volatility in the germanium market may occur during the next few years.

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

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

Class and country	1998 Gross weight (kilograms)	1998 Value	1999 Gross weight (kilograms)	1999 Value
Wrought, unwrought, and waste and scrap:				
Barbados	5	$2,160	--	--
Belgium	6,130	12,200,000	1,620	$2,740,000
Brazil	80	157,000	--	--
Canada	5	10,100	8	4,680,000
China	3,400	3,080,000	5,210	8,000
France	167	13,800	--	--
Germany	29	33,900	136	89,100
Israel	139	200,000	160	257,000
Japan	--	--	124	13,900
Netherlands	12	19,800	4	2,250
Romania	6	3,980	--	--
Russia	1,570	1,510,000	1,100	684,000
Spain	500	604,000	--	--
Taiwan	1,990	131,000	2,490	84,100
Ukraine	130	107,000	1,210	1,470,000
United Kingdom	445	460,000	382	411,000
Total	14,600	18,500,000	12,400	10,400,000

-- Zero

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

Source: Bureau of the Census.