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 2001, 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 almost $20 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 was estimated to have decreased, and U.S. consumption of germanium was estimated to have remained about the same in 2001.

The USGS estimated domestic germanium reserves to be 450,000 kilograms (kg), equivalent to more than 20 years of domestic consumption at the 2001 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. In most years, however, less than the amount available for sale has been sold.

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 2001 at just over $900 per kilogram and rose gradually to about $940 per kilogram during the year. After 5,729 kg was sold in 2001, the yearend inventory was 42,802 kg of germanium metal. The DLA amended its solicitation for purchase bids on germanium metal, which will now be negotiated by bid rather than by a sealed bid, thus allowing negotiation on issues such as market price, quantity, and removal period. The first amended solicitation for purchase bids was on June 11, 2001, for 3,000 kg of germanium (Mining Journal, 2001a).

Production

The USGS estimates that U.S. refinery production of germanium from primary and semirefined materials in 2001 was 20,000 kg, 15% less than that of 2000. The Electro-Optic Materials Department of Eagle-Picher, Inc. in Quapaw, OK, remained the largest domestic producer in 2001, producing germanium from reprocessed scrap, fly ash, germanium concentrates (typically containing 5% germanium or more), and semirefined germanium materials. During 2001, Eagle-Picher expanded its Oklahoma plant, which doubled its production of germanium tetrachloride in response to growing demand expected in the fiber optics industry.

Indium Corp. purchased the assets of Cabot Corp. (Revere, PA) and Atomergic Chemetals Corp. (Plainview, NY), which produced germanium from reprocessed scrap and semirefined imports. Indium Corp. began to install equipment in its Utica, NY, facility to produce germanium tetrachloride for optical fiber producers. 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 the optical materials unit of Umicore, SA (previously named Union Minière, SA) in Belgium for germanium recovery and refining. Umicore began construction of a secondary germanium tetrachloride facility in North Carolina.

Consumption

The USGS estimates that domestic consumption of germanium in 2001 was 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%.

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.

In the polymerization catalysts sector, polyethylene terephthalate (PET) consumption weakened primarily due to economic conditions in the Far East. However, new types of materials are expected to use forms of germanium catalyst and contribute to its overall growth.

Infrared equipment use by the military and civilian security forces increased following the September 2001 terrorist attacks and were used in U.S. military operations in Afghanistan. Although the consumption of germanium is not as high as several years ago, these increased security needs may have helped to slow declining demand.

A significant factor influencing germanium consumption in 2001 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, 2000). The decline in consumption for solar cell applications was overcome by increases in other sectors in 2001. The use of germanium as a dopant in optical fibers continued to grow. Germanium-based night vision systems were incorporated in General Motors' top-of-the-line cars and Volvo's new sport utility vehicles. 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 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, 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, producer prices 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. In 2001, prices again were lower, falling to $890 per kilogram for the metal and $575 per kilogram for the dioxide; dioxide prices reflected the ready availability of material from China.

Free market prices for germanium dioxide, published by Metal Bulletin, began 2001 in the $620 to $660 per kilogram range and ended the year in the $640 to $700 range. The price for Belgian-produced germanium dioxide, published by Metal Bulletin, remained at $750 per kilogram all year.

Trade

In 2001, the estimated germanium content of imports was approximately 8,240 kg, compared with 8,220 kg in 2000. China, Belgium, and Russia, in descending order of shipments, accounted for approximately 89% of U.S. germanium imports in 2001 (table 1). Trade reliance on large shipments from these countries began in the early 1990s. Germanium export data are not available.

World Review

In 2001, world refinery production of primary germanium was estimated to be slightly less than 70,000 kg, a decrease of almost 3% from that of 2000. Recycling supplied 30,000 kg of germanium worldwide, 20% more than in 2000. The world total market supply was about 110 metric tons (t) in 2001, including about 6 t released from the U.S. National Defense Stockpile and 6 t taken from nongovernment stockpiles. World consumption matched the total supply and was about the same as in 2000.

Belgium.—Umicore reported that its electro-optic materials unit was awarded a $4.2 million research contract by Estec, the research and technology center of the European Space Agency. The research contract will develop germanium substrates for use in high-efficiency solar cells for satellite communication. Modern solar cells consist of a number of thin layers of gallium arsenide deposited on a germanium substrate. The next generation of solar cells will have a higher conversion efficiency and thinner layers which will require a higher-grade germanium substrate (American Metal Market, 2001d).

Umicore also reported a doubling of profits during fiscal year 2001 in its advanced materials unit, which produces cobalt compounds and germanium substrates. Emphasis will continue to be placed on advanced materials because, when an economic upturn does occur, the demand for cobalt and germanium alloys from the telecommunications sector are expected to soar (American Metal Market, 2001c).

Congo (Kinshasa).—OM Group (Cleveland, OH) began producing germanium from its Big Hill slag pile in the Congo in April 2001. By the end of 2001, 10,000 kg of germanium output was expected, and as much as 20,000 kg was anticipated at full production capacity. The finished germanium metal product will be processed at facilities in either Finland or Utah. Currently, the Big Hill smelter at the slag pile, which was running at 72% of capacity, was being used to process the material for its copper and cobalt content (American Metal Market, 2001b).

Namibia.—Ogopogo Mining and Processing Ltd., which took over the Tsumeb Corp. Ltd. copper and lead operations in March 2000, began to develop a zinc-germanium deposit in 2001. The deposit also contains a significant amount of gallium and indium (Mining Journal, 2001b).

United Kingdom.—Cominco Ltd. (Vancouver, British Columbia, Canada) purchased germanium catalyst producer Meldform Germanium Ltd. and moved Meldform's U.K. facilities to British Columbia. Cominco's germanium dioxide is produced at the main Trail, British Columbia, operations, which are closer to its end market—bottle manufacturers in Japan (American Metal Market, 2001a).

Current Research and Technology

Germanium is being used for the optics 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 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. The General Motors Corp. installed such systems (manufactured by Raytheon Corp.) in its Cadillac DeVille model in 2000 (Siuru, 1999). Cadillac predicted sales of 3,500 units in 2000 and asked Raytheon to quadruple production. In the first year that it was marketed, 7,000 units of the night vision system were installed, with Cadillac dealers demanding more. The device reportedly adds about $2,000 to the cost of the DeVille. High volume production could cut the cost by 50% (Truett, 2001). The night vision device was adopted by Bendix Commercial Vehicle Systems LLC as optional equipment for buses and trucks. The night vision segment of the surveillance market is expected to grow from $560 million in 1999 to $750 million by 2004 (Hindus, 2000).

New applications which employed germanium alloys during 2001 included silicon-germanium semiconductor chips substituting for gallium arsenide in wireless telecommunications; a new sterling silver alloy that is tarnish resistant; and a new catalyst that combines germanium, oxygen, and silicon. The latter facilitates the breakdown of heavy oil into fuel and raw materials. The resulting fuel mixture has a higher octane number, is more efficient at turning oil into light hydrocarbons, and is less likely to detonate prematurely in engines (Nature Science Update, 2002§[1]).

Silicon-germanium (SiGe) technology is poised for growth. With the proven viability of implanting germanium in silicon 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). 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 compatible, 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 and 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).

[1]A reference that includes a section twist (§) is found in the Internet Reference Cited section.

Outlook

Demand will remain weak with a continued oversupply of both germanium metal and oxide. Higher recycling rates and declining demand as a catalyst in the production of PET plastic bottles will cause germanium oxide stocks to increase. Furthermore, European and U.S. consumers have completed their long-term delivery germanium contracts, resulting in a further increase of germanium supply to the global market place. With an abundance of supply, germanium metal and oxide prices will continue to decline.

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

Class and country	2000 Gross weight (kilograms)	2000 Value	2001 Gross weight (kilograms)	2001 Value
Wrought, unwrought, waste and scrap:				
Bangladesh	--	--	3	$4,510
Belgium	3,030	$3,940,000	2,960	3,550,000
Bermuda	--	--	2	3,630
Canada	77	51,700	1	2,740
China	3,290	3,450,000	3,470	2,450,000
France	1	3,050	--	--
Germany	342	364,000	701	940,000
Israel	76 r/	105,000 r/	69	83,900
Japan	316	268,000	--	--
Netherlands	3	4,840	--	--
Russia	857	805,000	905	613,000
Ukraine	176	166,000	--	--
United Kingdom	53	84,600	131	196,000
Total	8,220 r/	9,240,000	8,240	7,840,000

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.