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Germanium

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In 2010 in the United States, germanium-bearing concentrates were produced at a zinc mine in Alaska owned by Teck Resources Ltd. (Vancouver, British Columbia, Canada). The germanium-bearing concentrates were exported to Canada for processing or directly to customers in Asia and Europe. Two refineries in New York and Oklahoma produced germanium dioxide, germanium metal, and germanium tetrachloride from manufacturers' scrap, post-consumer scrap, and processed imported germanium compounds.

Germanium is a hard, brittle semimetal that first was used about a 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 electronic circuitry and solar cells.

Legislation and Government Programs

As a strategic and critical material, germanium was included in the National Defense Stockpile in 1984. The Defense Logistics Agency, DLA Strategic Materials (formerly Defense National Stockpile Center) reported that there were no germanium metal sales in 2010 compared with 68 kilograms (kg) in 2009. Germanium was last sold in February 2009 at an average price of $1,331 per kilogram. As of December 31, 2010, the total inventory of germanium metal held by the DLA was 16,362 kg valued at $17.3 million.

During fiscal year 2010 (October 1, 2009, through September 30, 2010), the DLA did not sell any units of germanium metal. The DLA announced that beginning June 1, germanium would be offered on a quarterly basis instead of monthly as it had in the past. The Annual Materials Plan for fiscal year 2011 (October 1, 2010, through September 30, 2011) did not allocate for sale any germanium metal (Defense Logistics Agency, DLA Strategic Materials, 2010; 2011).

Production

The multiple stages of the germanium production process yield germanium compounds and metals that are associated with specific applications. Germanium is initially recovered from the leaching of zinc residues or coal ash and the subsequent precipitation of a germanium concentrate. All germanium concentrates are purified using similar techniques, regardless of the source of the concentrates. The concentrated germanium is chlorinated and distilled to form the first usable product, germanium tetrachloride, a colorless liquid that is primarily used as a reagent in fiber-optic cable production. Germanium tetrachloride can be hydrolyzed and dried to produce germanium dioxide, another commonly used compound. Germanium dioxide appears as a white powder and is used to manufacture certain types of optical lenses and as a catalyst in the production of PET resin. Germanium dioxide can be reduced with hydrogen to produce a germanium metal powder, which is subsequently melted and cast into first-reduction bars. The germanium bars are then zone-refined (a refining process that involves melting and cooling germanium bars to isolate and remove impurities and ultimately yield extremely pure germanium) to produce electronic-grade germanium metal. Zone-refined germanium metal can then be grown into crystals and sliced for use as semiconductors or recast into forms suitable for lenses or window blanks in infrared optical devices.

In 2010, germanium was not recovered from zinc concentrates or coal in the United States. 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 metal from imported primary material and germanium compounds was about 9,300 kg. Domestic refinery production of germanium metal recovered from end-of-life products, such as decommissioned military vehicles and thermal weapons sights, was estimated to be about 3,000 kg in 2010.

Teck Alaska Inc. (a wholly owned subsidiary of Teck Resources) produced germanium-containing zinc concentrates at its Red Dog zinc-lead open pit mine in Alaska. Approximately 25% of the zinc concentrate produced at Red Dog was sent to Teck's metallurgical complex in Trail, British Columbia, Canada. Residues from zinc concentrates were treated in roasters or pressure-leach facilities and purified to produce germanium dioxide, germanium tetrachloride, and other byproduct metals. Teck reported that zinc and lead concentrate production at Red Dog in 2010 was less than that of 2009 owing to a decrease in mill feed grades (Teck Resources Ltd., 2011, p. 32–34).

In 2010, 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 and germanium-base materials. Umicore recovered and refined germanium from industry-generated new scrap and from imported germanium compounds. The Quapaw facility refined the material into germanium tetrachloride, germanium metal, and proprietary [chalcogenide glass (GASIR®)] lenses, which were designed for large-scale commercial and military infrared optical systems. In 2010, construction work was completed on a new germanium substrate plant in Quapaw that was expected to nearly double Umicore's global wafer production capacity to about 1 million substrates (10 centimeter diameter) per year. The 3,720-square-meter plant was modeled after Umicore's germanium substrate facility in Olen, Belgium, and was built adjacent to Umicore's existing operations in Quapaw. The company expected global demand for germanium substrates used in solar cells and light-emitting diodes (LEDs) to increase significantly during the next several years (Umicore s.a., 2010c; 2011, p. 26).

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 May 2009, Nyrstar N.V. (Balen, Belgium), a leading global zinc and lead producer, announced that it had acquired the idled Middle Tennessee zinc mining complex near Gordonsville, TN, from Mid-Tennessee Zinc Corp. for about $13.3 million. The complex consisted of zinc mines in Cumberland, Elmwood, and Gordonsville, TN, which had historically produced zinc concentrates containing germanium and gallium. Nyrstar also owned the Clarksville, TN, smelter, which was originally built to treat concentrates from the Middle Tennessee zinc mining complex, and the mine complex was expected to be an important source of concentrate for the Clarksville zinc smelter. Nyrstar began ramping up production at the mines in 2010 and by yearend, the Middle Tennessee Mines were operating at about 35% of total production capacity, producing 13,000 metric tons (t) of zinc in concentrate. Nyrstar expected to have the mines operating at full capacity in early 2011. Nyrstar had not publicly released details of plans to recover germanium from zinc residues by yearend 2010 (Nyrstar N.V., 2011, p. 13).

Consumption

The USGS estimated that domestic apparent consumption of germanium increased by about 3% to 40,000 kg in 2010 from 38,800 kg in 2009 (revised) owing to increased demand for germanium for use in electronic, fiber-optic, infrared-optic, and solar-cell applications. Worldwide, the end-use pattern of germanium was estimated to be as follows: infrared optics, 30%; fiber optics, 20%; catalysts for PET, 20%; electronics and solar applications, 15%; and other uses (such as phosphors, metallurgy, and chemotherapy), 15%. The domestic end-use pattern, however, was different, 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.

Infrared Systems.—Germanium was used in the manufacture of lenses and windows for infrared optical systems owing to its transparency to part of the infrared spectrum and to its high refractive index. Germanium is easily machinable, relatively strong, resistant to atmospheric oxidation, and able to withstand exposure to chemicals and moisture. The lenses and windows manufactured from germanium are often incorporated into thermal imaging systems that detect infrared radiation and convert it into an electronic signal, which is then processed and displayed on a video screen. Thermal imaging systems are different from other types of “low light” vision systems in that they are not adversely affected by the presence of light, so they can be used day or night. It was estimated that about 60% of lower- and midrange infrared-optical systems and 50% of all high-end devices used lenses made from germanium crystals.

According to the most recent data available, the sales value of the global infrared thermal imaging market was estimated to be about $6.6 billion. Military and other government applications represented 88% of this market, with commercial applications accounting for the remaining 12%. All branches of the military continued to rely heavily on infrared devices for around-the-clock force protection and intelligence, surveillance, and reconnaissance (ISR) as well as target acquisition applications on multiple platforms. Products used by the military typically range in price from under $10,000 for hand-held and weapon-mounted systems to more than $1 million for advanced stabilized targeting systems. The majority of infrared imaging systems use cooled technology to identify objects from long distances; however, uncooled thermal imaging systems were growing rapidly in certain markets such as weapon sights, hand-held monoculars/binoculars, military vehicles, and unmanned aerial vehicles. These devices are substantially smaller and more lightweight than their cooled counterparts because they operate at ambient temperatures while retaining their sensitivity to infrared light. Air-, land-, and sea-based vehicles were routinely equipped with multiple infrared systems that allowed soldiers to perform a variety of combat-related functions in even the most adverse battlefield conditions. A typical ground transport vehicle might be outfitted with separate infrared imaging systems for driver and observer’s vision enhancers, weapons sights, and roof-mounted imaging systems that perform long-range scans in search of improvised explosive devices. A leading domestic producer of infrared devices for military use reported a reduction in procurement activity by the U.S. Government in 2010 compared with that in 2009 (FLIR Systems, Inc., 2011, p. 41).

Many of the thermal imaging manufacturers have made efforts to enter the commercial market to pursue growth opportunities that are expected in the near future. As the cost of infrared imaging technology has declined, demand has increased in markets such as airborne law enforcement, automotive night-vision, commercial security, firefighting, and recreational marine applications. Hand-held thermal imaging systems that can detect and measure small temperature differences were used for a variety of commercial and industrial applications, such as predictive and preventive maintenance. A leading thermal imaging device manufacturer reported that its revenue from commercial vision systems increased at a compound annual rate of 25% from 2005 to 2009 (FLIR Systems, Inc., 2010, p. 1).

Fiber Optics.—In the fiber-optics sector, germanium tetrachloride is converted to germanium dioxide and used as a dopant (a substance added in small amounts to the pure silica glass core to increase its refractive index, preventing signal loss while not absorbing light) within the core of optical fibers. In 2010, an estimated $300 billion of capital expenditure was dedicated globally to construction and improvements of telecommunication infrastructure. Growth areas that utilize fiber-optics to meet increasing demand for more bandwidth included enterprise data-storage applications, fiber-to-the-home (FTTH) installations, and wireless communications networks. Demand for fiber-optic cable in North America has been increasing at a slower rate during the last couple of years compared with that of 2008, reflective of an overall reduction in business activity owing to the global financial slowdown. In September 2010, the Fiber-to-the-Home Council estimated that about 20 million homes in North America had FTTH connectivity available at the premises compared with 17.2 million in September 2009. Producers of germanium tetrachloride for fiber optics and fiber-optic cable producers indicated that sales volumes in 2010 were slightly greater than those in 2009. A leading manufacturer of fiber-optic cable indicated that net sales for their telecommunications segment in 2010 were greater than those in 2009 owing to increased sales of enterprise network products and optical fiber and cable in North America and Europe that were offset somewhat by declining sales of fiber-to-the-premises products and optical fiber and cable products in Asia (Fiber-to-the-Home Council, 2010; Corning Inc., 2011, p. 32).

Solar Cells.—The use of germanium as a substrate in the production of solar cells is segmented into two markets—space-based applications and terrestrial installations. Demand for satellites has increased steadily from 2007 to 2010 owing to demand for commercial, military, and scientific applications. It was estimated that about 400,000 germanium substrates were consumed each year for space-based applications, and the majority of all satellites were powered by germanium-based solar cells. Germanium substrates were smaller in size and weight, more efficient at converting light into energy, and provided greater power output than the most common alternative substrate, silicon. Germanium substrates constitute the building blocks of multilayer (often referred to as multijunction) solar cells. Ultrathin layer combinations of materials, such as gallium, indium, phosphide, and gallium arsenide, are “grown” on top of the germanium substrate, each capturing a specific part of the solar spectrum and converting it into electricity. The solar energy conversion efficiency of these multijunction cells was typically greater than 25%. Currently, triple-junction cells are most common, but technological advancements have allowed for multijunction cells to combine more layers and junctions onto one cell, increasing performance capabilities. In late 2010, Spectrolab Inc. (a subsidiary of The Boeing Co.), in Sylmar, CA, produced its 3 millionth multijunction space-based solar cell. In 2010, the company provided the NASA Jet Propulsion Laboratory with panels containing germanium-based multijunction solar cells for the first mission to Jupiter powered by solar cells. The company began adapting space-based solar technology for terrestrial applications in 2001 and has been able to convert concentrated sunlight to electricity at efficiencies as great as 41.6%. In 2010, Spectrolab expected to deliver 50 megawatts (MW) of solar cells to terrestrial-based solar cell customers and expected that number to triple in 2011 (Spectrolab Inc., 2010; Umicore s.a., 2010a, p. 52).

Several other manufacturers of germanium substrates, multijunction solar cells, and solar systems have focused capital investment and research efforts on the emerging terrestrial solar market. While there is fairly widespread agreement that global demand for solar power generation and other sources of renewable energy will continue to increase during the next several decades, multiple solar cell technologies will compete for a portion of the solar power market. The multijunction solar cells that use germanium substrates and germanium layers are typically more expensive to manufacture than other technologies, such as cadmium telluride, crystalline silicon, or copper-indium-gallium diselenide thin-film cells, but are considerably more efficient at converting solar energy into electricity so fewer cells are required in a panel to produce equivalent amounts of power. To obtain the most energy possible from each multijunction cell in a solar panel, concentrator photovoltaic (CPV) technology is used. A concentrator system uses optics (mirrors or lenses) to focus high concentrations of direct sunlight onto the solar cells. The lenses or mirrors concentrate sunlight hundreds of times before it reaches the solar cell, making each cell more efficient. Concentrating panels must receive direct sunlight to operate so CPV installations are limited to geographic regions that receive proper levels of sunlight. CPV systems typically require tracking systems that allow the solar panels to follow the Sun’s path during the day. CPV systems are marketed to the large-scale power generation industry and not considered a feasible solar power option for private homeowners.

As of 2009, CPV installations in China, Europe, and North America had about 24.5 megawatts (MW) of electrical generating capacity. By yearend 2009, new CPV projects under development in the United States were expected to increase electrical generating capacity by about 17 MW. It was estimated that, in current CPV installations, 1 MW of solar power generation capacity required about 10 kg of germanium contained in 1,500 substrates. Multijunction solar cells have continued to become a viable option for use in large-scale concentrated solar power projects because their energy conversion efficiencies have been increasing at a rate of about 1% per year during the past decade. The Federal Government has also been actively involved in advancing solar energy technologies, including CPV systems. The U.S. Department of Energy (DOE) Solar Energy Technologies Program (SETP) was aggressively funding a diverse set of photovoltaic (PV) technologies that had potential applications in a range of different markets. Through its primary research and development efforts, the PV subprogram’s goal was for PV technology to achieve grid parity (the point at which the cost of generating electricity using alternative technologies such as solar power is at least equal to the cost of generating electricity from conventional sources such as burning coal) by 2015. In 2010, the DOE was also ramping up its concentrating solar power (CSP) research, development, and deployment efforts. The DOE’s goals included increasing the use of CSP in the United States, making CSP competitive in the intermediate power market by 2015, and developing advanced technologies that would reduce systems and storage costs, enabling CSP to be competitive in the baseload power market by 2020. Separately, Emcore Corp. (Albuquerque, NM) was collaborating with the National Renewable Energy Laboratory and the U.S. Air Force Research Laboratory to develop new advanced multijunction solar cells that could achieve greater conversion efficiencies than existing multijunction cells. These new inverted metamorphic multijunction cells were built using a different manufacturing process where the layers of the semiconductor were grown “upside down” on the germanium substrate so that the top layer of the cell is grown on the bottom of the stack, closest to the substrate. When completed, the cell is removed from the germanium substrate and encapsulated. The process allows for higher quality development of the most important layer of the solar cell, the top layer, and had the potential to achieve energy conversion efficiencies of 50% in the future (Umicore s.a, 2010b, p. 5; Emcore Corp., 2011a, p. 16–17; 2011b, p. 9; U.S. Department of Energy, 2011).

Electronic Components.—Germanium substrate consumption for production of high-brightness LEDs used in such devices as automobile taillights, cameras, flashlights, mobile telephone display screens, televisions, and traffic signals increased in 2010 compared with that in the previous year. In electronics, silicon germanium (SiGe) components have replaced gallium arsenide in some high-tech products, such as components for cellular telephones. In high-speed wireless telecommunications devices, SiGe transistors can attain greater switching speeds and require less power than traditional, silicon-base components, increasing overall performance. In 2010, Samsung Electronics Co., Ltd. (Seoul, Republic of Korea) announced plans to produce phase change memory modules made from an alloy of antimony, germanium, and titanium that could potentially boost battery life in mobile devices by as much as 20% compared with the current flash memory technology used in those devices. SiGe-base microchips were also used in radar systems for automobiles to increase driving safety. Known as radar-on-chip-for-cars technology, these devices are capable of alerting drivers of impediments that are in the path of the vehicle in order to prevent potential accidents. A joint research cooperation project, supported by a financial grant from the German Federal Ministry of Education and Research, was launched in mid-2009 to advance this technology and make it available in all vehicle classes. Several automobile manufacturers and suppliers were working with semiconductor manufacturer Infineon Technologies AG (Neubiberg, Germany) on this project to develop new, cost-effective SiGe-chip-based automotive radar systems (Infineon Technologies AG, 2009; PC Magazine, 2010).

Polymerization Catalysts.—Outside the United States, estimates indicated that germanium dioxide used as a catalyst for PET production has declined since 2007. Japan continued to be the leading consumer of germanium for this application. Demand for germanium dioxide used in PET was estimated to be about 17,200 t in 2010, down from about 23,500 t in 2009. An increase in recycling rates of PET-based products and an increase in PET substitution contributed to the decline in germanium dioxide consumption. Substitutes, including antimony trioxide and titanium, had the potential to replace the relatively expensive germanium as a catalyst in the future (Roskills Letters from Japan, 2010, p. 8–11; 2011, p. 26).

Prices

Germanium prices were relatively volatile during 2008 through 2010. The annual average price of germanium metal has increased or decreased by 20% or more from that of the previous year nearly every year since 2000. The downturn in the global economy in 2009 caused germanium prices to decline significantly from the peaks of 2008, and prices remained at those 2009 levels during most of 2010. The market prices of germanium dioxide and metal were relatively stable during the first three quarters of 2010 and increased in the last quarter. Free market prices for germanium dioxide in 2010, published by Metal-Pages, began the year at about $580 per kilogram and increased by 24% to $720 per kilogram by yearend. The free market prices for germanium metal began the year at $940 per kilogram and increased by 28% to $1,200 per kilogram by yearend 2010.

Based on DLA Strategic Materials reports, the unit price of zone-refined germanium metal in inventory that was authorized for disposal as of December 2010 was $1,057 per kilogram.

Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (wrought, unwrought, and powder) decreased by 8% to 27,000 kg in 2010 from 29,400 kg in 2009. Decreased imports from Belgium, Canada, and Russia outweighed increases from China. In 2010, China, Russia, and Germany, in descending order of quantity, accounted for 93% of germanium metal imported into the United States (table 1). The estimated germanium content of the germanium dioxide imported in 2010 was about 17,700 kg compared with 27,500 kg (revised) in 2009. Canada accounted for about 66% of total germanium dioxide imports in 2010.

Domestic exports of germanium metal and articles thereof, including waste and scrap, were 8,000 kg in 2010, based on an analysis of trade data from the U.S. Census Bureau. Belgium, Canada, and Russia accounted for the majority of germanium exported from the United States in 2010. The estimated germanium content of germanium dioxide exported from the United States in 2010 was less than 100 kg.

World Review

In 2010, the world's total production of germanium was estimated to be between 100 and 120 t. This comprised germanium recovered from zinc concentrates, fly ash from burning coal, and recycled material. The recycling level remained about the same as that in 2009 and supplied about 30% of the world's total supply of germanium. Owing to the value of refined germanium, new scrap generated during the manufacture of fiber-optic cables, infrared optics, and substrates is typically reclaimed and fed back into the production process. Recycling of germanium recovered from used materials, such as fiber-optic window blanks in decommissioned military vehicles or fiber-optic cables, has increased during the past decade. Worldwide, primary germanium was recovered from copper or zinc residues or from coal in Canada (concentrates shipped from the United States), China (multiple sources), Finland [concentrates from Congo (Kinshasa)], and Russia (lignite coal from Sakhalin). The vast majority of germanium production was concentrated in Canada and China.

Many germanium-related projects that were in exploratory or early development stages in 2008 when germanium prices were at elevated levels were halted or delayed in 2009 when prices declined. Some germanium producers reduced production in early 2009 to avoid stockpiling material that became more difficult to sell in a surplus market. As a byproduct metal, the supply of germanium was heavily reliant on zinc production, which declined on a global basis in 2009 owing to price declines and global economic conditions. Market conditions for germanium remained relatively stable during the first three quarters of 2010, and most potential production projects were put on hold. Demand appeared to strengthen during the last quarter of the year, and prices increased during that time period as readily available supplies became tighter than they had been in the earlier parts of the year.

European Union.—The European Union (EU) has become more concerned about the security of its raw materials supply during the past several years and has initiated analysis of minerals and materials that were expected to have increased economic and technological value in the future. In June, the European Commission (EC) included germanium in a list of 14 raw materials of critical concern for members of the EU owing to their expected economic importance and relative supply risk and provided policy-oriented recommendations to ensure access to these resources in the future. A working group established by the EC analyzed 41 metals and minerals and concluded that 14 of them could be termed critical for the EU supply during the next 10 years based on each material's level of production, recycling rate, and the availability of substitutes. Many of the materials on the list were considered supply risks owing to global production being highly concentrated in a single country. The study indicated that Brazil, China, Congo (Kinshasa), and Russia were producing a significant portion of the 14 raw materials that were considered critical. The working group suggested policy actions for the EU to follow in order to avoid potential shortages of the critical materials in the future. Recommendations included policy actions that would encourage the substitution of noncritical materials for critical ones if possible, improve the recycling rates for raw materials, and promote exploration and research (Metal Bulletin, 2010).

Belgium.—Umicore produced germanium metal, germanium tetrachloride for fiber optics, germanium substrates, and germanium optical products at its refining and recycling plant in Olen. The company also operated an electro-optic materials research and design facility in Olen. Umicore's substrate manufacturing facility had the capacity to produce about 600,000 germanium substrates (100 millimeters in diameter) per year. In 2010, Umicore's Electro-Optic Division reported that sales volumes of germanium substrates had increased compared with those of the previous year. Demand had increased for germanium substrates used in space- and terrestrial-based applications and for use in LEDs. The company reported that demand for optics from government-sponsored programs was relatively weak during 2010. Sales volumes of germanium tetrachloride were relatively unchanged in 2010 compared with those in the previous year and were primarily driven by fiber-optic network projects in China (Umicore s.a., 2011, p. 26).

Canada.—The metallurgical complex operated by Teck in Trail consisted of six major metallurgical plants, one fertilizer plant, and two specialty metal plants that produced byproduct metals, including germanium and indium. Teck has historically been one of the leading germanium producers in the world. Teck did not disclose germanium production information to the public for 2010. The last year that the company had made germanium production information available was 2007, when Teck produced about 40,000 kg of germanium dioxide at Trail. Germanium was produced as a byproduct of the leaching of zinc concentrates, and in 2010, Teck's production of refined zinc from concentrates at Trail increased by 13% to 278,000 t of refined zinc from 240,000 t of refined zinc produced in 2009. Teck had curtailed zinc production at Trail in 2009 in response to the deteriorating market conditions for zinc. It was not known what effect, if any, this reduction in zinc production had on the level of germanium production in 2009. Based on trade data published by the Canadian Government, Canada exported about 29,400 kg of germanium contained in germanium dioxide in 2010 compared with about 36,000 kg in 2009 (revised). The leading destinations, in order of importance, of exported germanium dioxide were the United States, 38%; Japan, 28%; North Korea, 16%; and the Republic of Korea, 14% (Statistics Canada, 2011; Teck Resources Ltd., 2011, p. 35).

In March, 5N Plus Inc. (Montreal, Quebec), a producer and provider of high-purity metals and compounds for electronic applications, announced that its wholly owned subsidiary [Firebird Technologies Inc. (Trail, British Columbia)] had entered into a long-term supply agreement with Teck for germanium and indium feedstocks. Under the terms of the agreement, Teck was to provide a long-term stable supply of germanium and indium for Firebird to process into downstream products such as semiconductor wafers, semifinished optics, and high-purity metals and compounds. In June, 5N Plus entered into a supply agreement with Sylarus Technologies, LLC (St. George, UT), a North American producer of germanium substrates for solar cells used in satellites and high-efficiency terrestrial installations. Under the terms of the agreement, 5N Plus would provide Sylarus with germanium feedstock and also recycle byproducts of Sylarus' germanium substrate manufacturing (5N Plus Inc., 2010, American Metal Market, 2010).

China.—China continued to be the leading global producer of germanium metal and germanium compounds. In 2010, five to six producers accounted for the majority of the estimated 85 to 100 t of germanium metal and germanium compounds produced in China. About 44% of this production was in the form of germanium metal, 42% was germanium dioxide (metal content), and 14% was in the form of other compounds. Germanium-bearing coal ash and zinc ore were the sources for the Chinese germanium production. The germanium market slowed during the second half of 2008, and this slowdown continued until the fourth quarter of 2010. From June 2008 to June 2009, the market price of germanium metal in China declined by more than 33% to less than $1,000 per kilogram from $1,500 per kilogram. Domestic germanium prices remained at these levels during the first three quarters of 2010. Domestic producers had difficulty selling germanium compounds and metal even at the lower price levels owing to lackluster demand, and some decided to stockpile germanium or curtail production until prices increased again. Producers were not willing to sell germanium metal at prices that approached their production costs, and consumers of the material tried to buy smaller quantities than usual in anticipation of further price declines. The market changed significantly during the fourth quarter of 2010 as prices increased steeply, approaching levels of late 2008, and producer stocks became tighter. The change in the domestic market during this time period was attributed to a combination of factors. The available supply of germanium was tightened by the announcement of strategic stockpiling initiatives at the National and Provincial level and the forced closure of some germanium producing smelters owing to environmental concerns. Internal demand from consumers of germanium in China had also increased as more companies attempted to export value-added products instead of raw materials. A 5% export tax on germanium dioxide had encouraged producers to develop downstream production capabilities in recent years, and Chinese exports have shifted to germanium metal and finished products such as fiber optics and optical lenses. This has reduced the amount of Chinese-produced germanium dioxide that reached the global market in 2010 (Metal-Pages, 2010b; 2011).

In late 2010, China announced that it had set aside more than $4 billion for one of the largest "treasure hunts" for new resources in the country's recent history. The government was looking for new deposits of iron ore, copper, chromium, manganese, tungsten, germanium, indium, and rare-earth elements according to the Chinese ministry of land resource at a forum in Henan Province. The plan involved large-scale prospecting operations in all of China's Provinces, with a focus on 45 key prospecting areas. Provinces and regions of particular interest included Hunan, Inner Mongolia, Jiangxi, Qinghai, Shanxi, and Yunnan (Metal-Pages, 2010a).

Japan.—The Japanese markets for germanium products have moved in diverging directions since 2008. Demand for germanium tetrachloride has been strong and increased during that time period, but consumption of germanium dioxide and germanium metal have declined. The growth in germanium tetrachloride consumption between 2008 and 2010 was driven by the fiber-optic industry. Japanese production of fiber-optic cable increased by 14% from 2008 to 2009, and the majority of these cables were exported to China and India, where infrastructure development has been increasing. Conversely, Japanese demand for germanium dioxide, mainly used as a catalyst in PET production, has declined significantly. In 2010, Japan imported 17,200 kg of germanium dioxide, a decrease of 17% from 23,500 kg imported in 2009 and a decrease of 46% from 31,700 kg 2008. Factors that have contributed to the decline in consumption were increased use of less expensive antimony-based catalysts, increased use of recycled catalysts, and reductions in the thickness of PET bottles. Canada has emerged as the primary source of imported germanium dioxide since 2008. In 2010, 81% of the germanium dioxide imported was from Canada. Before 2008, the majority of this material had come from China. Consumers of germanium dioxide reduced imports from China in favor of long-term contacts with Canadian suppliers as Chinese supply tightened and prices increased. Chinese germanium dioxide imports to Japan declined by 88% from 2007 to 2009 (Roskill's Letters from Japan, 2010; 2011).

Namibia.—Emerging Metals Ltd. (Douglas, United Kingdom), a mineral exploration company, was investigating the possibility of extracting germanium from the slag stockpiles near the town of Tsumeb. In January 2008, Emerging Metals had purchased an option to acquire processing and ownership rights to the Tsumeb slag stockpiles from Ongopolo Mining Ltd. [a wholly owned subsidiary of Weatherly International plc (London, United Kingdom)]. In 2009, the company continued studies and test work on the slag stockpiles to determine the viability of extracting the contained metals, principally germanium but also gallium and zinc. In March 2010, the directors of the company decided to exit the Tsumeb slag stockpiles project altogether owing to weak market conditions for the metals of interest (Emerging Metals Ltd., 2010, p. 2).

Outlook

Global germanium consumption is likely to increase during the next several years owing to the growth that is expected in the major end-use sectors. Germanium-based optical blanks and windows that are incorporated in infrared devices were expected to continue to be heavily used by military and law enforcement agencies. New applications for these products in commercial and industrial markets also were expected to become more prevalent and represented a large potential growth area. Global demand for fiber-optic cable, led by the emerging Asian economies, had been forecast to increase at a compound annual growth rate of 8% through 2012. Global support for the increased use of solar energy during the next several years is expected to increase demand for germanium substrates that are used to manufacture high-efficiency multijunction solar cells. New satellites launched for defense and private industry uses were expected to continue to fuel consumption of germanium substrates in solar cells. As energy conversion efficiencies continue to improve, terrestrial-based solar systems will be a more feasible option for large-scale power generation. Owing to the massive size of the installations, growth in the terrestrial-based solar cell market could significantly boost annual germanium substrate consumption (Mikolajczak, 2010).

Germanium substrates used in thermophotovoltaic (TPV) cells that convert heat radiation (instead of sunlight) generated from sources such as furnaces or water boilers into electricity could be a future growth area. Most TPV cells were used almost exclusively for military applications, but this technology could be applied in industrial or residential settings. In an industrial setting, for example, TPV cells could generate electricity from the heat created during the production of materials such as glass or steel.

On the supply side, the redevelopment of existing zinc mines in Tennessee could be a new domestic source of germanium during 2011 though 2013. Several germanium recovery projects in China that were in late stages of development or early production also could bring more germanium to the market if demand continues to increase. In addition to primary germanium production, the availability of recycled germanium recovered from end-of-life products, such as fiber optics, military vehicles, and solar cells, was expected to increase during the next couple of decades as these aging products are taken out of service. Overall, the germanium market is expected to remain tight during the next several years owing to the emerging end uses and limited sources of supply.

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TABLE 1

U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL, BY COUNTRY[1, 2]

Country	2009 Gross weight (kilograms)	2009 Value	2010 Gross weight (kilograms)	2010 Value
Belgium	5,490	$5,960,000	1,560	$2,700,000
Canada	796	425,000	70	15,500
China	14,000	14,800,000	18,100	14,500,000
France	124	91,100	70	70,300
Germany	2,360	4,290,000	2,320	3,310,000
Hong Kong	363	380,000	--	--
Japan	203	185,000	--	--
Russia	5,980	8,900,000	4,620	3,450,000
United Kingdom	53	33,800	--	--
Other	38	4,030,000	312	1,840,000
Total	29,400	39,100,000	27,000	25,900,000

-- Zero.

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

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

Source: U.S. Census Bureau.