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Germanium

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In 2009, germanium-bearing concentrates were produced at two zinc mines in Alaska and Washington (placed on care-and-maintenance status in early 2009) 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 (NDS) in 1984. Sales of germanium metal were significantly lower in 2009 compared with those in previous years. The Defense National Stockpile Center (DNSC) reported that germanium metal sales in 2009 were 68 kilograms (kg) compared with 102 kg in 2008. Germanium was last sold in February 2009 at an average price of $1,331 per kilogram. As of December 31, 2009, the total inventory of germanium metal held by the NDS was 16,365 kg valued at $16.3 million.

During fiscal year 2009 (October 1, 2008, through September 30, 2009), the DNSC sold 170 kg of germanium metal at an average value of $1,392 per kilogram. The Annual Materials Plan for fiscal year 2010 (October 1, 2009, through September 30, 2010) allowed for the sale of up to 8,000 kg of germanium metal (Defense National Stockpile Center, 2009a, b).

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 2009, 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 from imported primary material, germanium compounds, and new scrap was 4,600 kg in 2009.

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 Resources' 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 and other byproduct metals. Teck Resources reported that zinc and lead concentrate production at Red Dog in 2009 was greater than that of 2008 owing to increased mill operating rates and online time resulting from a number of performance improvement initiatives.

In February, Teck Resources temporarily placed its underground Pend Oreille zinc-lead mine in northeastern Washington on care-and-maintenance status owing to reduced metal demand and the decline in zinc prices. Teck Resources indicated that, during the unspecified-duration closure at Pend Oreille, the company would continue to produce germanium and other byproduct metals at Trail from an existing residue stockpile at Pend Oreille. In 2009, Teck Resources produced 4,800 metric tons (t) of zinc concentrate at Pend Oreille compared with 35,000 t of zinc concentrate in 2008 (Teck Resources Ltd., 2010, p. 44–45).

In 2009, 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 produced germanium from fly ash, germanium concentrates, scrap generated internally or by the fiber-optics industry, and imported germanium compounds. The Quapaw facility refined the raw 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 2009, construction work continued 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 per year. The construction of the plant began in mid-October 2008 and was completed by yearend 2009. Umicore planned to start qualifying germanium substrates manufactured at the plant with customers during the first half of 2010. The company stated that the production capacity was added in anticipation of rapid growth in the terrestrial concentrator solar (or photovoltaic) cell market during the next 12 years (Umicore s.a., 2010b, p. 14).

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 January, Strategic Resource Acquisition Corp. (SRA) (Toronto, Ontario, Canada), owner of the Middle Tennessee zinc mining complex near Gordonsville, TN, filed for bankruptcy under Chapter 11 of the Federal Bankruptcy Code in Nashville, TN. The company had depleted its available funding and listed assets of about $1 million against debts of $100 million. In 2007, SRA had announced plans to restart operations at the idled mining complex, which consisted of zinc mines in Cumberland, Elmwood, and Gordonsville, TN, and had anticipated that the mines would be able to produce significant amounts of byproduct germanium and gallium. In October 2008, the company placed the mines on care-and-maintenance status owing to the state of the credit market and declining zinc prices. In May 2009, Nyrstar N.V. (Balen, Belgium), a leading global zinc and lead producer, announced that it had acquired the mine complex from Mid-Tennessee Zinc Corp. for about $13.3 million. 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 would be an important source of concentrate for the Clarksville zinc smelter. Nyrstar kept the mines on care-and-maintenance status for the remainder of 2009 but planned to commence production at the mine complex by yearend 2010. Once the mines were operational, the company stated that it intended to capture the value contained in the germanium- and gallium-rich zinc concentrates (Metal-Pages, 2009c; Nyrstar N.V., 2009).

In 2009, Australian exploration company PacMag Metals Ltd. reported that a resource drill program at the Church deposit in the company's Sentinel project in southwestern North Dakota had led to an initial inferred resource estimate of germanium, molybdenum, and uranium contained in lignite coal seams. The flat-lying mineralization of the coal seams in the region has been compared to lignite coal deposits found in China that produce germanium. The drilling program established that mineralization at the Church deposit was continuous in sufficient widths and lengths to accommodate mining. Metallurgical testing demonstrated successful leach recoveries of germanium, molybdenum, and uranium mineralization using acid or alkaline solutions. By yearend, the company was looking to secure a development partner that could help fund further assessment and possible future development of the Sentinel project (PacMag Metals Ltd., 2009, p. 2, 8–10).

Consumption

The USGS estimated that domestic consumption of germanium decreased to about 44,000 kg in 2009 from 54,500 kg in 2008 owing to the economic slowdown that affected sales of germanium for use in infrared optic, fiber-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.

Electronic Components.—Germanium substrate consumption for production of high-brightness light-emitting diodes (LEDs) used in such devices as automobile taillights, cameras, flashlights, mobile telephone display screens, televisions, and traffic signals increased in 2009 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. 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).

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. Demand for fiber-optic cable in North America declined slightly in 2009 compared with that of 2008, reflective of an overall reduction in business activity owing to the global financial slowdown. Producers of germanium tetrachloride for fiber optics and fiber-optic cable producers indicated that sales volumes in 2009 were reduced from those in 2008, especially in North America and Europe. Fiber-optic cable manufacturers indicated that their customers were more cautious about making new investments in private networks and fiber-to-the-home (FTTH) technologies in 2009. This was not the case in China and other emerging Asian economies that continued to expand their telecommunications infrastructures in 2009. In 2009, the Fiber-to-the-Home Council estimated that 17.2 million homes in North America had FTTH available at their premises as of September 2009, an increase of about 13% from that in September 2008. The council reported that the growth rate of new fiber-optic runs had slowed considerably during the last half of 2009 owing to the deteriorating economic conditions (Corning Inc., 2010, p. 3, 30; Fiber-to-the-Home Council, 2010, p. 6–7).

The American Recovery and Reinvestment Act of 2009 included funding for a broadband initiative that led to the creation of a national broadband plan that could increase demand for fiber-optic cable in the future. The plan, created by the Federal Communications Commission (FCC), was intended to accelerate broadband deployment in underserved and rural areas and to strategic institutions that were likely to use broadband access to create jobs or provide public benefit. The term broadband referred specifically to high-speed internet access, such as that provided by fiber-optic cable, which is always on and faster than the traditional dialup access. The U.S. Congress directed the FCC to develop a plan that would ensure every American had "access to broadband capability." According to the initiative, widespread broadband infrastructure was considered a foundation for better quality of life, economic growth, global competiveness, and job creation. A long-term goal set forth in the plan specified the improvement of the existing broadband infrastructure in the United States to provide at least 100 million U.S. homes with access to affordable broadband connections by 2020. In addition to the national broadband plan, there were other broadband programs ongoing at the FCC, the National Telecommunications and Information Administration, the U.S. Department of Agriculture, and other Federal agencies (Federal Communications Commission, 2009, p. 12–15).

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.

In 2009, the sales value of the global infrared thermal imaging market was estimated to be about $6.6 billion. Military applications represented 80% of this market, with commercial applications accounting for the remaining 20%. 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. 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. The military continued to invest in thermal weapon sight technology in 2009, which helped fuel domestic consumption of germanium optical products. In March, the U.S. Army Research, Development and Engineering Command Contacting Center at Aberdeen Proving Ground, MD, ordered more than 40,000 thermal weapons sights for small-arms, surveillance, and fire-control applications valued at more than $350 million from three manufacturers. This type of spending on thermal imaging devices was expected to continue in the near future to support troops currently engaged in ongoing military operations. In fiscal year 2010, the U.S. Department of Defense proposed to spend slightly less for procurement and research in military communications, electronics, intelligence, and telecommunications than it had in the previous year. The Army's technology procurement request for fiscal year 2010 included $235 million for purchasing common remotely operated weapons stations, $460 million for acquiring new night-vision devices, and $338 million for new thermal weapons sights. The U.S. Air Force requested $513 million to develop a new space-based infrared system (Keller, 2009).

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 has grown at a compound annual rate of 25% since 2005 (FLIR Systems, Inc., 2010, p. 1).

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 20 t in 2009, down from about 30 t in 2008. 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 (Mikolajczak, 2010).

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 during the 2007 through 2009 period 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-base solar cells (Umicore s.a., 2010a, p. 52). 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 2009, Emcore Corp. (Albuquerque, NM), a manufacturer of compound semiconductor-based components and subsystems for the fiber-optic and solar power markets, was in the final stages of qualifying a next-generation, high-efficiency multijunction solar cell for satellites that had an average energy conversion efficiency of 30%. Another leading solar cell producer, Spectrolab Inc. (a subsidiary of The Boeing Co.) planned to produce germanium-substrate-based multijunction cells with conversion efficiencies greater than 33% in 2009. In comparison, the conversion efficiency of a standard silicon solar cell ranged from 13% to 15%. Umicore, a leading producer of germanium substrates, reported that sales volumes of germanium substrates in 2009 were slightly lower than those in 2008, reflective of a decline in orders from solar panel manufacturers owing to the global economic slowdown.

While satellites have traditionally used energy generated by solar panels to operate onboard systems and transmit data to Earth, there are other potential uses for the energy created by the high-efficiency solar cells. The use of solar energy, collected by space-based, high-efficiency multijunction cells, as a source of power for spacecraft was being developed. In 2009, an industry team led by Boeing received a contract from the Defense Advanced Research Projects Agency to design a new ultralightweight high-power generation system (HPGS) capable of generating up to 175 kilowatts of power (more than currently available to the International Space Station) for spacecraft. The team, comprising several leading satellite and solar cell manufacturers (including Emcore and Spectrolab), using high-efficiency, germanium-based, multijunction solar cells and sun tracking systems, developed a preliminary system that was one-half the weight and one-sixth the size of an existing orbital solar power system. Eventually, an HPGS was expected be able to provide power for a new generation of compact spacecraft that self-deploy from a low-Earth orbit and then reach a final orbit using electric propulsion systems to perform communications, satellite transfer and servicing, and space radar missions. A power system like this could be a cost-effective means for spacecraft to travel to the outer solar system without the need for radioisotope power (Umicore s.a., 2008, p. 14; The Boeing Co., 2009; Emcore Corp., 2010, p. 9).

Several manufacturers of germanium substrates, multijunction solar cells, and solar systems have focused capital investment and research efforts on the emerging terrestrial solar market. In 2009, Umicore completed construction of a new germanium substrate manufacturing facility in Quapaw in anticipation of increased future demand for terrestrial-based solar applications. 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 were generating about 24.5 megawatts (MW) of electrical power. By yearend 2009, new CPV projects under development in the United States were expected to produce about 17 MW of additional electrical power. It was estimated that, in current CPV installations, 1 MW of solar power generation 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. In August, Spectrolab announced that it had set a new world record for terrestrial concentrator solar efficiency with a new cell that converted 41.6% of concentrated sunlight into electricity. The Federal Government has also been actively involved in advancing solar energy technologies, including CPV systems. In October, the U.S. Department of Energy (DOE) announced that up to $87 million in funding would be made available to support the development of new solar technologies, including funding for 15 projects at DOE laboratories to improve devices, processes, and technologies for the concentrating solar power industry (Spectrolab Inc., 2009; U.S. Department of Energy, 2009; Umicore s.a, 2010c, p. 5).

Prices

The downturn in the global economy that began during the second half of 2008 continued in 2009, and the market price of germanium declined throughout the year owing to weakened global demand. Free market prices for germanium dioxide in 2009, published by Metal-Pages, began the year at about $920 per kilogram and declined by 37% to $580 per kilogram by yearend. The free market prices for germanium metal began the year at $1,425 per kilogram and declined by 34% to $940 per kilogram by yearend 2009.

Based on DNSC reports, the unit price of zone-refined germanium metal in inventory that was authorized for disposal as of December 2009 was $998 per kilogram.

Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (wrought, unwrought, and powder) decreased by 27% to 29,400 kg in 2009 from 40,200 kg in 2008. Decreased imports from Belgium accounted for the majority of the overall change. China, Russia, Belgium, and Germany, in descending order of quantity, accounted for 95% of imports into the United States in 2009 (table 1). The estimated germanium content of the germanium dioxide imported in 2009 was about 30,800 kg compared with 27,400 kg in 2008. Canada accounted for 53% of total germanium dioxide imports; Belgium, 29%; and Germany, 15%.

Domestic exports of germanium metal and articles thereof, including waste and scrap, were 21,200 kg in 2009 according to the U.S. Census Bureau. Belgium and Canada accounted for about 90% of germanium exported from the United States in 2009. The estimated germanium content of germanium dioxide exported from the United States in 2009 was less than 100 kg.

World Review

In 2009, the world's total supply of germanium was estimated to be between 100 and 120 t. This comprised germanium recovered from zinc concentrates or fly ash from coal and recycled material. The recycling level remained about the same as that in 2008 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 last 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.

European Union.—In mid-2009, the European Union (EU) supported plans to ensure that industries get better access to critical raw materials as competition for these materials becomes greater. EU industries, particularly aerospace, high-tech, and telecommunications industries, were facing increased competition for natural resources from emerging economies, such as China and India. The European Commission (EC) proposed a strategy that included plans to ensure global access to critical raw materials, improve conditions for raw material extraction in Europe, and to reduce consumption of foreign raw materials by increasing resource efficiency and recycling rates in the EU. The EC planned to finalize a list of raw materials determined to be critical by yearend 2009, but the process extended into 2010. A preliminary list that was based partially on the results of a French study was presented in June, and it indicated that germanium was among a group of metals, the supply of which was considered to be a short- to medium-term supply risk. It was unclear what steps the EU would take upon completion of the critical materials list, but stockpiling some materials was a possibility (Wallop, 2009).

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 2009, Umicore's Advanced Materials Division reported that sales volumes of germanium substrates for space and terrestrial applications and of germanium tetrachloride for fiber optics decreased from those of the previous year. Conversely, sales volumes of germanium materials for infrared optical products and LEDs increased in 2009 from those in 2008 (Umicore s.a., 2010b, p. 22).

Canada.—The metallurgical complex operated by Teck Resources 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 2009. The last time that the company had made germanium production information available was for 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 2009, Teck's production of refined zinc from concentrates at Trail declined by 11% to 240,000 t of refined zinc from 270,000 t of refined zinc produced in 2008. Teck had curtailed zinc production at Trail from November 2008 to September 2009 in response to deteriorating market conditions. 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 40,100 kg of germanium contained in germanium dioxide in 2009 compared with 48,100 kg in 2008. About 89% of the germanium dioxide was exported to Japan and the United States in 2009 (Statistics Canada, 2010; Teck Resources Ltd., 2010, p. 10, 44).

China.—China continued to be the leading global producer of germanium metal and germanium compounds. The germanium reserve base in China was estimated to be about 3,500 t and was spread throughout 11 Provinces and regions. In 2009, 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 in 2009. 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 producers had difficulty selling germanium compounds and metal even at the lower price levels, 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. Partially in response to slumping prices and market conditions, Yunnan Province announced that it was stockpiling about 1 million metric tons of nonferrous metals in 2009, including 8 t of germanium metal, in an attempt to stabilize the domestic markets for these metals and to ensure that production was not adversely affected (Metal-Pages, 2009a, b, d).

Xilingol Mengdong Germanium Technology Co., established in 2008, was involved in the development of a new manufacturing facility in Xilingol, Mongolia, that would produce primary germanium and germanium compounds. Mengdong Germanium's parent company owned the mining rights to significant lignite coal resources containing an estimated 3,230 t of recoverable germanium metal. The company planned to use a proprietary technology to extract the germanium from the coal that it recovered through open pit mining. When completed, the new facility was expected to have the capacity to produce 60 metric tons per year (t/yr) of germanium tetrachloride, 20 t/yr of germanium metal, and 10 t/yr of germanium dioxide. The company commenced small-scale production at the facility in the fourth quarter of 2009 and anticipated that the plant would be fully operational by yearend 2010 (Asian Metal Ltd., 2009).

China's consumption of germanium-base products has increased in recent years as the economy has grown and become more developed. Chinese demand for fiber optics, infrared thermal imaging systems, and germanium substrates for solar cells has increased. The growth can be attributed to demand from the military, scientific, and telecommunications industries for these applications. In 2009, demand for germanium in thermal imaging devices was estimated to be about 10 t compared with 8 t in 2008. Demand for fiber-optic cable in Asia, driven primarily by China and India, increased by about 46% in 2009 compared with that of 2008. Chinese production of germanium substrates for satellites was estimated to be 1.4 million substrates in 2009 (of which China consumed 200,000), an increase of about 17% from that in 2008. While most of the germanium substrates produced in China have been exported to other countries for use in the manufacture and assembly of solar cells, several companies were working on plans to begin manufacturing the solar cells domestically (Maozhong, 2010; Qin, 2010).

Mexico.—In February, War Eagle Mining Co. Inc. (Vancouver) announced that it had suspended exploration drilling at the idled Tres Marias zinc and germanium mine in Chihuahua. In 2007, when germanium and zinc prices were elevated, the company began exploring the possibility of restarting the mine and producing germanium-rich zinc concentrates. However, the company decided to suspend all activities in early 2009 to conserve capital and minimize expenditures in light of the state of global financial markets and declining zinc prices. The company planned to focus its efforts on projects that involved the recovery of germanium from fly ash and similar materials owing to lower cost expectations associated with those germanium production processes when compared with mining costs (War Eagle Mining Co. Inc., 2009).

Namibia.—Emerging Metals Ltd. (Douglas, United Kingdom), a mineral exploration company that was incorporated in the British Virgin Islands, 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 response to the weakened market conditions for these metals in 2009, the company emphasized its need to minimize costs associated with evaluating and test work and was reassessing the scope, timing, and feasibility of the project (Emerging Metals Ltd., 2009, p. 2).

Outlook

Global germanium consumption was likely to increase slightly during the next several years owing to the growth that is expected in the major end-use sectors. Germanium-base 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. 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. As energy conversion efficiencies continue to improve, terrestrial-based solar systems will be more feasible options for large-scale power generation. 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, reductions in global zinc production in 2009 could reduce the quantities of byproduct metals, such as germanium, that are available in the near future. The decline in germanium production in 2009 owing to the zinc market decline could tighten global germanium supply from 2010 through 2012, leading to price increases; therefore, producers might find market conditions more favorable to develop new sources of germanium. The redevelopment of existing zinc mines in Tennessee could be a new domestic source of germanium during the 2010 through 2012 period. 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.

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TABLE 1

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

	2008		2009	
Country	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Belgium	18,300	$9,830,000	5,490	$5,960,000
Canada	173	175,000	796	425,000
China	14,000	17,300,000	14,000	14,800,000
France	22	36,700	124	91,100
Germany	1,890	3,830,000	2,360	4,290,000
Hong Kong	503	380,000	363	380,000
Japan	1	5,000	203	185,000
Russia	5,280	7,770,000	5,980	8,900,000
United Kingdom	62	257,000	53	33,800
Other	12 r	27,700 r	38	4,030,000
Total	40,200	39,600,000	29,400	39,100,000

[r]Revised.

[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.