



2010 Minerals Yearbook

DIAMOND, INDUSTRIAL

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In 2010, U.S. synthetic diamond production was estimated to be 93.0 million carats (Mct) with an estimated value of \$66.4 million. U.S. imports of all forms of industrial diamond totaled about 597 Mct valued at almost \$119 million, while exports totaled more than 113 Mct valued at almost \$52.8 million. The estimated U.S. apparent consumption of all forms of industrial diamond was 612 Mct with an estimated value of \$150 million. Total industrial diamond output worldwide was estimated by the U.S. Geological Survey (USGS) to be about 4.45 billion carats valued between \$1.65 and \$2.50 billion. This was the combination of more than 63.8 Mct natural industrial diamond and about 4.38 billion carats synthetic industrial diamond.

Diamond is best known as a gemstone, but some of its unique properties make it ideal for many industrial and research applications as well. Current information on gem-grade diamond can be found in the USGS Minerals Yearbook, volume I, Metals and Minerals, chapter on gemstones. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Production and consumption quantities and values reported are estimated to avoid disclosing company proprietary data and still provide useful data on the overall market. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using unrounded data. The USGS does not conduct surveys of either domestic polycrystalline diamond (PCD) producers or domestic chemical vapor deposition (CVD) diamond producers for quantity or value of annual production. Also, trade and consumption quantity or value data are not available for PCD or for CVD diamond.

Production

The USGS conducts an annual survey of domestic industrial diamond producers and U.S. firms that recover diamond wastes. Although most of these companies responded to the 2010 survey, one of the three industrial diamond recycling firms did not report data that they deemed to be proprietary. To protect the proprietary data of other producers and recyclers, only estimates of U.S. primary and secondary output are provided in this review.

As one of the world's leading producers of synthetic industrial diamond, the United States accounted for an estimated output of 93 Mct valued at more than \$66.4 million in 2010. Only two U.S. companies produced synthetic industrial diamond during the year—Diamond Innovations, Inc. (Worthington, OH) and Mypodiamond, Inc. (Smithfield, PA).

In 2010, at least eight U.S. companies also manufactured PCD from synthetic diamond grit and powder. These companies were Dennis Tool Co. (Houston, TX), Diamond Innovations, Novatek Inc. (Provo, UT), Precorp Inc. (Provo), Sii MegaDiamond Inc. (Provo), Tempo Technology Corp. (Somerset, NJ), US Synthetic

Corp. (Orem, UT), and Western Diamond Products LLC (Salt Lake City, UT).

During 2010, an estimated 33.8 Mct of used industrial diamond worth about \$17.3 million was recycled in the United States. Recycling firms recovered most of this material from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD; most of this material was recovered from within the production operations of the PCD-producing companies.

The recovery and sale of industrial diamond was the principal business of three U.S. companies in 2010—Industrial Diamond Laboratory, Inc. (Bronx, NY), International Diamond Services Inc. (Houston, TX), and National Research Co. (Fraser, MI). In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

There were no commercially operated diamond mines in the United States during 2010. The last commercially operated diamond mine in the United States closed in 2002 and was fully reclaimed.

Consumption

Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature. Diamond is more than twice as hard as its nearest competitors, cubic boron nitride and silicon nitride. Because it is the hardest substance known, diamond has been used for centuries as an abrasive in cutting, drilling, grinding, and polishing. Industrial-grade diamond continues to be used as an abrasive for many applications. Even though it has a higher unit cost, diamond has proven to be more cost-effective in many industrial processes because it cuts faster and lasts longer than alternative abrasive materials (Boucher, 1997, p. 26.6). Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, computing, and other advanced technologies.

Both synthetic and natural diamonds have industrial uses. Synthetic industrial diamond is superior to its natural diamond counterpart because its properties can be tailored to specific applications, and it can be produced in large quantities (Boucher, 1996). For these reasons, synthetic diamond accounts for about 94% of the industrial diamond used in the United States and about 99% of the industrial diamond used in the world.

The United States remained the world's leading market for industrial diamond in 2010. Based on production estimates and trade data, U.S. apparent consumption of industrial diamond during the year increased 100% to an estimated 612 Mct valued at \$150 million compared with 305 Mct valued at \$109 million in 2009. This apparent consumption was the combination of

556 Mct of diamond bort, grit, dust, and powder valued at \$63.2 million and 55.9 Mct of diamond stone valued at \$86.5 million. These large increases were owing to industrial sectors that consume industrial diamond beginning to recover from the negative impacts of the economic recession.

The major consuming industries of industrial diamond in the United States during 2010 were construction, machinery manufacturing, mining services (exploration drilling for minerals, natural gas, and oil), stone cutting/polishing, and transportation systems (infrastructure and vehicles). Within these sectors, stone cutting and highway building/repair together made up the largest demand for industrial diamond. Research and high-technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks in electronic circuits, lenses for laser radiation equipment, polishing of silicon wafers and disk drives, and other applications in the computer industry.

Diamond tools have numerous industrial functions. Diamond drilling bits and reaming shells are used principally for minerals, natural gas, and oil. Other applications of diamond bits and reaming shells include foundation testing, masonry drilling, and inspecting concrete. The primary uses of point diamond tools are for dressing and truing grinding wheels and for boring, cutting, finishing, and machining applications. Beveling glass for automobile windows is another application. Cutting dimension stone and cutting/grooving concrete in highway reconditioning are the main uses of diamond saws; other applications include cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws are used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels include edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond are used by industry—diamond stone (generally larger than 60 mesh/250 micrometers) and diamond bort (smaller, fragmented material). Diamond stone is used mainly in drill bits and reaming shells used by mining companies; it also is incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort is used for drill bits and as a loose grain abrasive for polishing. Other tools that incorporate natural diamond include bearings, engraving points, glass cutters, and surgical instruments.

Synthetic diamond grit and powder are used in diamond grinding wheels, saws, impregnated bits and tools, and as a loose abrasive for polishing. Diamond grinding wheels can be as large as 1 meter in diameter.

Loose powders made with synthetic diamond for polishing are used primarily to finish cutting tools, gemstones, jewel bearings, optical surfaces, silicon wafers, and wire-drawing dies for computer chips. Hundreds of other products made from ceramics, glass, metals, and plastics also are finished with diamond powders.

Two types of PCDs used by industry are polycrystalline diamond compacts (PDCs) and polycrystalline diamond shapes

(PDSs). The use of PDCs and PDSs continues to increase for many of the applications cited above, including some of those that employ natural diamond. The use of PDCs, PDSs, and matrix-set synthetic diamond grit for drilling bits and reaming shells has increased in recent years. PDCs and PDSs are used in the manufacture of single- and multiple-point tools, and PDCs are used in a majority of the diamond wire-drawing dies.

Since its introduction in the mid-1980s, CVD diamond has seen strong growth and is presently being accepted by multiple industries as an enhanced material of choice owing to its properties of exceptional strength, durability, stiffness, high thermal conductivity, and electrical isolation. The global market value of industrial diamond and diamond-like films and coatings was estimated to have been \$905 million in 2010, and is expected to increase to more than \$1.7 billion in 2015.

Early applications for CVD diamond focused largely around thin- and thick-film PCD for cutting tools and dressing applications because of the mechanical properties of diamond. Newer applications that take advantage of CVD diamond's mechanical properties include wear parts, such as watch gears and chemical mechanical polishing pad conditioners. Diamond has tremendous potential for electronics applications because it significantly improves upon current strategies for thermal management while remaining highly cost-competitive with other approaches. CVD diamond is used in microelectronic components, such as high-speed processors, medical devices, wide bandgap radio frequency (RF) devices, power conversion devices, and opto-electronic devices (light emitting diodes, laser diodes) that generate exceptionally high heat densities requiring innovative approaches to thermal management. In the manufacture of semiconductors, wafer scale diamond offers enhanced mechanical properties, such as significantly higher stiffness, strength, hardness, thermal conductivity, and chemical inertness than silicon and most other thin-film materials, which are commonly used. Diamond coatings are finding increasing use in electronic applications because of the high thermal conductivity of diamond (10 times that of silicon). Micro-electro-mechanical systems (MEMS), such as RF MEMS resonators, have design needs that offer a compelling case for the use of diamond as a base material as a result of superior properties (high Young's Modulus and its durability in harsh environments). Researchers are investigating the use of boron-doped diamond (BDD) electrodes for water treatment owing to diamond's potential as an environmentally friendly, high performance electrode material. BDD electrodes have many characteristics that make them ideal for eliminating organic contaminants from water (Zimmer, 2011).

Historically, diamond has been perceived as an expensive material. Advances in CVD diamond manufacturing like the development of microwave carbon plasma technology and the development of higher-throughput hot filament (HF) CVD diamond reactors have significantly reduced diamond costs. This led many industries to revisit development activities and actively pursue the use of CVD diamond for a growing number of applications (Zimmer, 2011).

Prices

Pricing of natural diamond was driven up by strong demand at auctions held in all of the global diamond centers. This has affected prices of industrial diamond as well as gemstone diamond. These price increases were a reflection of strong demand for the whole range of rough diamonds for industrial markets (Roffman, 2011).

Natural and synthetic industrial diamonds differ significantly in price. Natural industrial diamond normally has a more limited range of values, from about \$0.49 per carat for bort size material to about \$2.50 to \$10 per carat for most stones, with some larger stones selling for \$200 per carat or more. Prices of synthetic diamond vary according to size, shape, crystallinity, and the absence or presence of metal coatings. In general, prices for synthetic diamond for grinding and polishing range from as low as \$0.26 per carat to \$2.50 per carat. Strong and blocky material for sawing and drilling sells for \$2.50 to \$4.00 per carat. Large, synthetic crystals with excellent structure for specific applications sell for several hundred dollars per carat. During 2010, U.S. imports of all types of industrial diamond had an average value of \$0.20 per carat. These imports were a combination of imports of diamond bort, grit, and dust and powder (natural and synthetic) that had an average value of \$0.15 per carat and imports of diamond stone (natural and synthetic) that had an average value of \$18.80 per carat.

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2010; imports were received from 33 countries and exports and reexports were sent to 35 countries (tables 1–4). Although the United States has been a major producer of synthetic diamond for decades, expanding domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond have always been dependent on imports and secondary recovery operations because there has been no domestic production of natural diamond.

During 2010, U.S. imports of industrial-quality diamond stones (natural and synthetic) increased by 23% from those of 2009 to about 1.72 Mct valued at about \$32.3 million (table 1). The average value of these industrial-quality diamond stone imports was \$18.80 per carat. Imports of diamond dust, grit, and powder (natural and synthetic) more than doubled from those of 2009 to 596 Mct valued at about \$86.5 million (table 2). The average value of these industrial diamond dust, grit, and powder imports was \$0.15 per carat.

Reexports account for a significant portion of total exports/reexports; therefore, exports and reexports are listed separately in tables 3 and 4 so that U.S. trade and consumption can be calculated more accurately. During 2010, the United States did not export industrial diamond stones, unchanged from 2009. U.S. reexports of industrial diamond stone increased by 14% from those of 2009 to 1.08 Mct valued at \$23.4 million and an average value of \$21.60 per carat (table 3). U.S. exports of industrial diamond dust, grit, and powder (natural and synthetic) increased by 68% from those of 2009 to 113 Mct valued at \$52.8 million and an average value of \$0.47 per carat. Reexports of industrial

diamond dust, grit, and powder (natural and synthetic) increased by 85% from those of 2009 to 18.2 Mct valued at \$8.73 million and an average value of \$0.48 per carat (table 4).

World Industry Structure

In 2010, industrial diamond was produced in 28 countries (tables 5, 6). Total industrial diamond output worldwide was estimated by the USGS to be about 4.45 billion carats valued between \$1.65 and \$2.50 billion. Natural industrial diamond production worldwide was estimated to be more than 63.8 Mct, a 15% increase compared with that of 2009. Congo (Kinshasa) was the leading producing country, followed by Russia and Australia, in descending order of quantity. These three countries produced more than 74% of the world's natural industrial diamond (table 5). Synthetic industrial diamond production worldwide was estimated to be more than 4.38 billion carats, a slight increase compared with that of 2009. China was the leading producing country, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 98% of the world's synthetic industrial diamond (table 6).

In addition to the countries listed in table 6, Germany and the Republic of Korea produced synthetic diamond, but specific data on their output could not be confirmed. In 2010, 97% of the total global natural and synthetic industrial diamond output was produced in China, Ireland, Russia, South Africa, and the United States. Synthetic diamond accounted for more than 99% of global diamond production and consumption.

World Review

Global diamond production increased 10% during 2010 to 144 Mct. The world's leading rough diamond producers, in decreasing order of quantity produced, were: Russia, producing 32.8 Mct or 23% of total world production; Botswana, with 32.0 Mct (22%); Congo (Kinshasa), with 27.7 Mct (19%); Angola, with 13.8 Mct (10%); Canada, with 11.8 Mct (8%); Australia, with 10.0 Mct (7%); South Africa, with 8.9 Mct (6%); and other countries, with 6.76 Mct (5%) (table 5).

Worldwide diamond exploration allocations decreased 9% in 2010, to \$357 million spent by 99 companies compared with \$393 million by 113 companies during the previous year. This lowered the diamond share of overall worldwide exploration spending to 3% during 2010. Planned diamond exploration spending in 2010 was the least budgeted since 2003. Africa was the most popular diamond exploration location for the seventh year in a row, although Africa's share of overall exploration spending decreased to 35% in 2010 from almost 50% in 2009. Canada's share of total diamond exploration budgets increased to 29% in 2010 from 18% in 2009. De Beers Group dropped from the position of top diamond explorer that it had held for well over a decade, and was replaced by ALROSA Co. Ltd. ALROSA, De Beers Group, and Rio Tinto plc were the three leading diamond exploring companies, accounting for 57% of the estimated \$357 million total global diamond exploration budget in 2010 (Metals Economics Group, 2010, p. 8–9; 2011, p. 13).

Worldwide in 2010, diamond prices recovered strongly from the downturn caused by the global recession. The recovery was

led by an upturn in the U.S. markets; this was demonstrated by increasing quantity and value of diamond imports in 2010 and improved sales in North America overall (Metals Economics Group, 2011, p. 10).

Worldwide in 2010, three diamond mines started up, including one mine reopening. One of the startups was in Botswana, one in Brazil, and the reopening was in South Africa (Metals Economics Group, 2011, p. 15).

Botswana.—Firestone Diamonds plc received a license for mining the BK11 Mine in July 2010, and began operating phase I of the production plant. Work on phase 2 was completed in the third quarter of 2010, increasing the ore production rate to 1.5 million tons per year. The mine reached full production of 150,000 carats per year in the fourth quarter 2010. The BK11 Mine is an open pit operation, which is 90% owned by Firestone Diamonds plc and 10% by a local company. Firestone estimated the BK11 mine's reserves to be 18.0 million tons (Mt) at start up (Metals Economics Group, 2011, p. 15).

Brazil.—During the third quarter 2010, Vaaldiam Mining Inc. started production at its Duas Barras alluvial mining operation. Diamond recovery during the quarter was 643 carats from ore grading 0.03 carats per cubic meter. The ore grade improved after September with the opening of a second mining front that exposed large amounts of better quality gravels. The recovered diamond grade was approximately 0.16 carats per cubic meter. Vaaldiam estimated the reserves to be 2.3 Mt for Duas Barras (Metals Economics Group, 2011, p. 15).

Canada.—Canadian diamond production was about 11.8 Mct during 2010, an increase of about 8% compared with that of 2009. Diamond exploration continued in Canada, with several commercial diamond projects and additional discoveries in Alberta, British Columbia, the Northwest Territories, the Nunavut Territory, Ontario, and Quebec. In 2010, Canada produced 8.2% of the world's combined natural gemstone and industrial diamond output.

The Ekati Diamond Mine, Canada's first operating commercial diamond mine, completed its twelfth full year of production in 2010. Ekati produced 2.89 Mct of diamond from 4.85 Mt of ore. BHP Billiton Ltd. has an 80% controlling ownership in Ekati, which is in the Northwest Territories. Ekati has estimated remaining reserves of 38.5 Mt of ore in kimberlite pipes that contain 18.3 Mct of diamond. BHP Billiton projected the remaining mine life to be 12 years. Approximately 21% of the Ekati 2010 diamond production is industrial-grade material (BHP Billiton Ltd., 2011, p. 10; Perron, 2011, p. 1).

The Diavik Diamond Mine, Canada's second diamond mine, also located in the Northwest Territories, completed its eighth full year of production. In 2010, Diavik produced 6.5 Mct of diamond, an increase of 16% from the previous year's production. At yearend 2010, Diavik estimated the mine's remaining proven and probable reserves to be 18 Mt of ore in kimberlite pipes containing 52.2 Mct of diamond and projected the total mine life to be 16 to 22 years. Diavik began developing an underground mine and substantially completed construction on the project during 2009. The first ore was produced from the underground mine during the first quarter of 2010, with full production expected in 2013. The mine is an unincorporated joint venture between Diavik Diamond Mine Inc. (60%) and Harry Winston

Diamond Mines Ltd. (40%) (Diavik Diamond Mine Inc., 2011; Perron, 2011, p. 2).

Canada's third diamond mine, the Jericho Diamond Mine, is located in Nunavut and was originally owned by Tahera Diamond Corp. Tahera estimated the Jericho Diamond Mine's reserves to be about 5.5 Mt of ore grading 0.85 carats per ton. The Jericho Diamond Mine experienced startup problems related to ore mining and processing. The mine also suffered financial problems owing to the cost of transporting supplies to the mine site, high operational costs, high oil prices, and appreciation of the Canadian dollar versus the U.S. dollar. All of these problems combined to force the company to enter into protection under Canada's "Companies' Creditors Arrangement Act" on January 16, 2008, and the mine suspended production on February 6, 2008. At yearend 2009, Tahera was finalizing arrangements to sell all of its Jericho Mine assets (Perron, 2011, p. 2). In July 2010, Shear Minerals Ltd. (now known as Shear Diamonds Ltd.) announced that it had entered into a purchase agreement with Tahera and Benachee Resources Inc. to acquire a 100% interest in the Jericho Diamond Mine, the mine's processing facilities, and all supporting exploration assets in the Kitikmeot region of Nunavut (Shear Minerals Ltd., 2010). Shear Minerals completed the acquisition of the Jericho Diamond Mine in August 2010 with the intention of bringing the mine back into production (Shear Minerals Ltd., 2011).

The Snap Lake Mine, which is wholly owned by De Beers Canada Inc., is in the Northwest Territories. The Snap Lake deposit is a tabular-shaped kimberlite dyke rather than the typical kimberlite pipe. The dyke is 2.5 meters thick and dips at an angle of 12° to 15°. The deposit was mined using a modified room and pillar underground mining method in 2010. The Snap Lake Mine started mining operations in October 2007, reached commercial production levels in the first quarter of 2008, and officially opened June 25, 2008. The mine was expected to produce 1.4 Mct per year of diamond, and the mine life was expected to be about 20 years. The mine's production for 2010 amounted to 926,000 carats for a recovered grade of 1.2 carats per ton (De Beers Canada Inc., 2011; Perron, 2011, p. 2–3).

The Victor Mine, which also is wholly owned by De Beers Canada, is in northern Ontario on the James Bay coast. The Victor kimberlite consists of two pipes with surface area of 15 hectares (37.1 acres). The Victor Mine initiated mining operations at the end of December 2007 and was officially opened on July 26, 2008. The Victor reportedly has 27.4 Mt of ore with average ore grade of 0.23 carats per ton estimated minable reserves. At full capacity, the open pit mine was expected to produce 600,000 carats per year, and the mine life was expected to be about 12 years. In 2010, the mine's production was 826,000 carats recovered from 2.67 Mt of ore (De Beers Canada Inc., [undated]; Perron, 2011, p. 3).

South Africa.—In 2007, Petra Diamonds Ltd. bought the Kimberley diamond operations from De Beers for \$11 million. After completing the mine rehabilitation, Petra reopened the underground mine in September 2010. Petra had been producing from tailings and stockpile for the previous few years. During the fourth quarter 2010, Kimberley produced 25,000 carats grading 0.14 carats per ton, and sold 17,300 carats for an average price of \$285 per carat. The Kimberley Mine is 74%

owned by Petra Diamonds Ltd. and 26% by Sedibeng. Petra estimated the Kimberley Mine's reserves to be 57.0 million tons. Kimberley's production was expected to be 100,000 carats from the processing of 1 million tons per year of ore (Metals Economics Group, 2011, p. 15).

Outlook

China is expected to remain the world's leading producer of synthetic industrial diamond, with annual production exceeding 4 billion carats. The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and likely will remain a significant producer and exporter of synthetic industrial diamond as well. U.S. industrial diamond production, imports, and apparent consumption is expected to continue to increase as manufacturing sectors that use industrial diamond recover from the negative impact of the economic recession that started in mid-2008. U.S. demand for industrial diamond is likely to continue in the construction sector as the United States continues building and repairing the Nation's highway system.

Diamond offers many advantages for precision machining and longer tool life. In fact, even the use of wear-resistant diamond coatings to increase the life of materials that compete with diamond is a rapidly growing application. Increased tool life not only leads to lower costs per unit of output but also means fewer tool changes and longer production runs (Advanced Materials & Processes, 1998). In view of the many advantages that come from increased tool life and reports that diamond film surfaces can increase durability by a factor of 50, much wider use of diamond as an engineering material is expected.

PCD for abrasive tools and wear parts are likely to continue to replace competing materials in many industrial applications by providing closer tolerances as well as extending tool life. For example, PDCs and PDSs will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries.

CVD technology can produce extremely pure diamond crystals that have great potential in computer technology in the production of diamond computer chips when their cost becomes competitive. These diamond computer chips will work at a much higher frequency or faster speed and can be placed in a higher-temperature environment than the silicon chips currently used in computers. Eventually, they may replace silicon chips in computers. CVD diamonds annealed using the low-pressure/high-temperature microwave plasma process may have applications such as using the diamond crystals in high-pressure research, optical applications that take advantage of the outstanding transparency of diamond, or using them in quantum computing to store quantum information in vacancy centers in the diamond's crystal lattice.

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. Stones for these applications have not yet been manufactured economically. No shortage of the stone is anticipated, however, because new mines and more producers selling in the rough diamond market will maintain ample supplies. More competition introduced by the additional sources also may temper price increases.

Demand for synthetic diamond bort, grit, and dust and powder is expected to remain greater than for natural diamond material. Constant-dollar prices of synthetic diamond products probably will continue to decline as production technology becomes more cost effective; the decline is even more likely if competition from low-cost producers in China and Russia continues to increase.

References Cited

- Advanced Materials & Processes, 1998, Diamond coating increases carbide tool life by 50x: *Advanced Materials & Processes*, v. 154, no. 2, August, p. 20.
- BHP Billiton Ltd., 2011, BHP Billiton production report for the half year ended 31 December 2010: Melbourne, Australia, BHP Billiton Ltd. news release, January 20, 15 p.
- Boucher, Michel, 1996, Overview of the diamond industry, *in* *Industrial Minerals '96*, Toronto, Ontario, Canada, October 22–23, 1996, Proceedings: Toronto, Ontario, Canada, Blendon Information Services, [unpaginated].
- Boucher, Michel, 1997, Diamonds, *in* *Canadian minerals yearbook 1996*: Ottawa, Ontario, Canada, Natural Resources Canada, p. 26.1–26.19.
- De Beers Canada Inc., 2011, Snap Lake Mine fast facts: Yellowknife, Northwest Territories, Canada, De Beers Canada Inc. fact sheet, September, 1 p. (Accessed December 9, 2011, at http://www.debeerscanada.com/files_3/pdf_documents/Snap-Lake-Mine_Fast-Facts.pdf.)
- De Beers Canada Inc., [undated], Victor Mine fast facts: Timmins, Ontario, Canada, De Beers Canada Inc. fact sheet, 1 p. (Accessed December 9, 2011, at http://www.debeerscanada.com/files_3/pdf_documents/fast_facts_vm.pdf.)
- Diavik Diamond Mine Inc., 2011, 2010 sustainable development report: Yellowknife, Northwest Territories, Canada, Diavik Diamond Mine Inc. media release, July 8. (Accessed December 9, 2011, at http://www.diavik.ca/documents/2010_Sustainable_Development_Report.pdf.)
- Metals Economics Group, 2010, Trends in worldwide exploration budgets, 2010: Metals Economics Group Strategic Report, v. 23, no. 6, November/December, p. 1–10.
- Metals Economics Group, 2011, Diamond pipeline, 2011: Metals Economics Group Strategic Report, v. 24, no. 1, January/February, p. 10–19.
- Perron, Louis, 2011, Diamonds, *in* *Canadian minerals yearbook 2009*: Ottawa, Ontario, Canada, Natural Resources Canada, March 11, 27 p. (Accessed March 17, 2011, at <http://www.nrcan.gc.ca/mms-smm/busi-indu/cmy-amc/2009cmy-eng.htm>.)
- Roffman, Steve, 2011, Natural industrial diamonds—update 2011: *Finer Points*, winter, p. 22.
- Shear Minerals Ltd., 2010, Shear Minerals Ltd. to acquire Jericho Diamond Mine, Nunavut: Edmonton, Alberta, Canada, Shear Minerals Ltd. press release, July 19, 5 p.
- Shear Minerals Ltd., 2011, Jericho Diamond Mine, Nunavut: Edmonton, Alberta, Canada, Shear Minerals Ltd. project fact sheet. (Accessed December 16, 2011, at <http://www.shearminerals.com/jericho.html>.)
- Zimmer, Jerry, 2011, CVD diamond comes into its own: *Finer Points*, winter, p. 23.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Abrasives. Ch. in *United States Mineral Resources*, Professional Paper 820, 1973.
- Diamond (Industrial). Ch. in *Mineral Commodity Summaries*, annual.

Other

- De Beers Consolidated Mines Ltd. annual reports, 1998–2001.
- Diamond, Industrial. Ch. in *Mineral Facts and Problems*, U.S. Bureau of Mines Bulletin 675, 1985.
- Finer Points*, quarterly.
- Industrial Diamond Review*, quarterly.
- World Diamond Industry Directory & Yearbook*, 1998–99.

TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Natural industrial diamond stones ²				Miners' diamond, natural and synthetic ³			
	2009		2010		2009		2010	
	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴	Quantity	Value ⁴
Australia	52	390	42	288	(5)	40	9	74
Belgium	9	164	23	321	(5)	30	(5)	21
Botswana	678	10,400	835	19,800	3	13	11	47
Congo (Kinshasa)	10	209	7	111	--	--	2	7
Ghana	(5)	5	(5)	11	--	--	(5)	3
India	40	39	77	218	11	146	3	350
Namibia	129	856	219	1,340	1	6	--	--
Russia	137	2,140	210	4,540	--	--	(5)	5
South Africa	295	3,540	234	4,140	7	118	26	266
Other	30	466	13	663	(5)	71	10	133
Total	1,380	18,200	1,660	31,400	22	424 ^r	61	906

^rRevised. -- Zero.

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

²Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000.

³HTS codes 7102.21.1010 and 7102.21.1020.

⁴Customs value.

⁵Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF DIAMOND DUST, GRIT, AND POWDER, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Synthetic ²				Natural ²			
	2009		2010		2009		2010	
	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³
Belgium	709	297	1,540	353	20	12	121	79
China	174,000	13,500	461,000	35,800	142	65	1,050	430
Germany	64	34	53	39	--	--	24	22
Hong Kong	504	157	638	218	--	--	10	5
India	759	384	854	439	744	442	1,470	818
Ireland	44,900	17,900	66,200	28,800	637	359	688	399
Israel	--	--	445	423	--	--	--	--
Italy	9	2	14	14	--	--	--	--
Japan	1,670	922	2,540	1,970	16	46	--	--
Korea, Republic of	7,850	1,790	22,700	7,600	4	7	25	6
Macau	13	9	--	--	--	--	--	--
Mexico	--	--	--	--	--	--	89	59
Romania	1,240	265	13,200	1,540	--	--	--	--
Russia	7,700	1,470	15,500	2,700	15	17	--	--
Switzerland	1,000	1,360	3,130	2,770	231	135	548	180
Taiwan	61	15	55	15	--	--	--	--
Ukraine	327	29	176	29	--	--	--	--
United Arab Emirates	--	--	243	170	--	--	--	--
United Kingdom	1,790	761	1,710	636	886	478	559	384
Other	170	140	451	169	147	401 ^r	163	384
Total	243,000	39,100	591,000	83,700	2,840	1,960 ^r	4,750	2,770

^rRevised. -- Zero.

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

²Harmonized Tariff Schedule of the United States codes 7105.10.0020, 7105.10.0030, and 7105.10.0050 for synthetic and 7105.10.0011 and 7105.10.0015 for natural.

³Customs value.

Source: U.S. Census Bureau.

TABLE 3
U.S. REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Industrial unworked diamonds ²			
	2009		2010	
	Quantity	Value ³	Quantity	Value ³
Reexports:				
Belgium	341	4,720	417	6,680
Brazil	12	87	39	195
Canada	95	670	152	993
Germany	11	326	11	359
Hong Kong	114	1,690	49	695
Israel	131	1,140	26	131
Japan	92	4,390	145	8,230
Korea, Republic of	17	860	25	1,430
South Africa	14	10	--	--
United Arab Emirates	16	517	(⁴)	10
United Kingdom	67	2,270	72	2,410
Other	38	815 ^r	147	2,270
Total	948 ^r	17,500	1,080	23,400

^rRevised. -- Zero.

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

²Harmonized Tariff Schedule of the United States code 7102.21.0000.

³Customs value.

⁴Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND DUST, GRIT, AND POWDER, BY COUNTRY¹

(Thousand carats and thousand dollars)

Country	Synthetic ²				Natural ²			
	2009		2010		2009		2010	
	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³	Quantity	Value ³
Exports:								
Austria	470	207	1,790	622	--	--	--	--
Belgium	253	61	368	90	15	6	--	--
Brazil	3,260	1,080	5,530	1,660	11	5	2	5
Canada	2,950	1,970	4,010	3,190	191	440	216	681
Germany	1,600	524	3,490	1,200	22	20	9	7
Greece	255	45	--	--	--	--	--	--
Hong Kong	15	11	40	35	36	107	4	10
India	2,410	998	2,790	1,050	59	44	2	7
Ireland	16,000	5,660	25,300	8,780	47	76	25	74
Israel	4	5	50	33	--	--	516	165
Italy	4,010	1,350	3,910	1,290	--	--	--	--
Japan	10,100	4,970	29,000	13,800	23	58	7	9
Korea, Republic of	6,010	3,550	7,240	3,770	20	14	71	13
Mexico	216	76	366	164	259	125	443	208
Singapore	745	1,660	846	2,480	14	42	--	--
Spain	199	44	68	14	--	--	--	--
Switzerland	6,580	4,820	7,460	5,630	205	124	554	290
Taiwan	2,340	982	4,340	1,710	27	17	26	8
Thailand	3,880	1,280	5,100	1,540	4	3	--	--
United Kingdom	2,460	819	3,630	1,250	212	202	401	224
Other	1,810	975	4,850	2,720	369	998	58	80
Total	65,500	31,100	110,000	51,000	1,510	2,280	2,330	1,780
Reexports:								
Belgium	74	33	35	39	81	192	119	228
Brazil	557	117	792	229	--	--	--	--
Canada	2,180	1,220	7,150	4,120	24	81	118	433
Germany	10	22	11	8	11	32	7	24
India	48	15	66	30	--	--	--	--
Ireland	825	467	1,070	421	18	13 ^r	5	5
Italy	--	--	250	73	--	--	--	--
Japan	3,560	1,340	5,830	1,330	--	--	87	77
Korea, Republic of	373	83	1,220	530	--	--	7	9
Mexico	157	56	72	31	20	44 ^r	38	90
United Kingdom	115	73	323	192	7	12 ^r	7	3
Other	1,830	437	1,020	803	4	7 ^r	29	53
Total	9,720	3,860	17,800	7,810	165	381	417	922
Grand total	75,200	34,900	128,000	58,800	1,680	2,660	2,750	2,700

^rRevised. -- Zero.

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

²Harmonized Tariff Schedule of the United States codes 7105.10.0025 for synthetic and 7105.10.0010 for natural.

³Customs value.

Source: U.S. Census Bureau.

TABLE 5
NATURAL DIAMOND: WORLD PRODUCTION, BY COUNTRY AND TYPE^{1,2,3}

(Thousand carats)

Country and type ⁴	2006	2007	2008	2009	2010
Gemstones:					
Angola	8,258	8,732	8,016	12,445	12,500 ^e
Armenia	184	123	101	50	50 ^e
Australia	7,305	231	273	220 ^{r,e}	100 ^e
Botswana ^e	24,000	25,000	25,000	24,000	25,000
Brazil ^e	181	182	182	200 ^{r,5}	200
Canada	13,278	17,144	14,803	10,946	11,773
Central African Republic ^e	340	370	302 ^{r,5}	249 ^{r,5}	250
China ^e	100	100	100	100	100
Congo (Kinshasa)	5,800	5,700	4,200	3,700 ^r	5,500
Côte d'Ivoire ^e	-- ^r	-- ^r	-- ^r	-- ^r	--
Ghana	768	671	478	301 ^r	300 ^e
Guinea	355	815	2,500	557 ^r	550
Guyana	341	269	169	144	144 ^e
Lesotho	231	454	450 ^e	450 ^e	460
Namibia	2,400	2,266	2,435	1,192 ^r	1,200 ^e
Russia ^e	23,400	23,300	21,925 ⁵	17,791 ⁵	17,800
Sierra Leone	362	362	223	241 ^r	240 ^e
South Africa ^e	6,100	6,100	5,200	2,500 ^r	3,500
Tanzania ^e	230	239	202	155 ^r	77
Venezuela ^e	45	45	45	45	45
Zimbabwe ^e	160	100	100	100	50
Other ⁶	70	75 ^r	121 ^r	79 ^r	70
Total	93,900^r	92,300^r	86,800^r	75,500^r	79,900
Industrial:					
Angola ^e	918	970	900	1,383 ^{r,5}	1,300
Australia	21,915	18,960	15,397	10,700	9,900
Botswana ^e	8,000	8,000	8,000	7,000	7,000
Brazil ^e	600	600	600	600	600
Central African Republic ^e	85	93	74 ⁵	62 ^{r,5}	60
China ^e	965	970	1,000	1,000	1,000
Congo (Kinshasa)	23,100	22,600	16,700	14,600 ^r	22,200
Côte d'Ivoire ^e	-- ^r	-- ^r	-- ^r	-- ^r	--
Ghana	192	168	120	75 ^r	75 ^e
Guinea	118	200	600	139 ^r	130
Russia ^e	15,000	15,000	15,000	15,000	15,000
Sierra Leone	241	241	149	160 ^r	160 ^e
South Africa ^e	9,100	9,100	7,700	3,600 ^r	5,400
Tanzania ^e	42	44	36 ^r	27	14
Venezuela ^e	70	70	70	70	70
Zimbabwe ^e	900	600	700	850 ^r	800
Other ⁷	67	84 ^r	145 ^r	115 ^r	118
Total	81,300^r	77,700^r	67,200^r	55,400^r	63,800
Grand total	175,000^r	170,000^r	154,000^r	131,000^r	144,000

^eEstimated. ^rRevised. -- Zero.

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through June 2, 2011.

³In addition to the countries listed, Nigeria and the Republic of Korea produce natural diamond and synthetic diamond, respectively, but information is inadequate to formulate reliable estimates of output levels.

TABLE 5
NATURAL DIAMOND: WORLD PRODUCTION, BY COUNTRY AND TYPE^{1, 2, 3}

⁴Includes near-gem and cheap-gem qualities.

⁵Reported figure.

⁶Includes Cameroon, Congo (Brazzaville), Gabon (unspecified), India, Indonesia, Liberia, and Togo (unspecified).

⁷Includes Congo (Brazzaville), India, Indonesia, and Liberia.

TABLE 6
SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY^{1, 2, 3}

(Thousand carats)

Country	2006	2007	2008	2009	2010
Belarus	25,000	25,000	25,000	25,000	25,000
China	3,900,000	4,000,000	4,000,000	4,000,000	4,000,000
Czech Republic	5	5	5	5	5
France	3,000	3,000	3,000	3,000	3,000
Ireland	60,000	60,000	60,000	60,000	60,000
Japan	34,000	34,000	34,000	34,000	34,000
Russia	80,000	80,000	80,000	80,000	80,000
South Africa	60,000	60,000	60,000	60,000	60,000
Sweden	20,000	20,000	20,000	20,000	20,000
Ukraine	8,000	8,000	8,000	8,000	8,000
United States	128,000	130,000	131,000 ⁴	91,000 ⁴	93,000
Total	4,320,000	4,420,000	4,420,000	4,380,000	4,380,000

¹World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through June 2, 2011.

³In addition to the countries listed, Germany and the Republic of Korea also produces significant amounts of synthetic diamond, but output is not officially reported, and available information is inadequate to formulate reliable estimates of output levels.

⁴Reported figure.