DIAMOND, INDUSTRIAL

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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 U.S. Geological Survey (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 in order 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.

In 2004, U.S. synthetic diamond production was estimated to be 252 million carats with an estimated value of $256 million. U.S. imports of all forms of industrial diamond totaled about 242 million carats valued at about $75 million, while exports totaled more than 86 million carats valued at almost $47 million. The estimated U.S. apparent consumption of all forms of industrial diamond was 413 million carats with an estimated value of $288 million.

At the end of December 2003, Littlejohn & Co., LLC announced the completion of its acquisition of the GE Superabrasives division from General Electric Co. The new company is called Diamond Innovations, Inc., and it will continue to be led by GE Superabrasives' management team (Diamond Innovations, Inc., 2003).

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 (Ravi, 1994, p. 537). 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 diamond 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). It is for these reasons that synthetic diamond accounts for about 98% of the industrial diamond used in the United States and nearly 90% of the industrial diamond used in the world.

Legislation and Government Programs

Congress has authorized the sale of all diamond in the National Defense Stockpile (NDS), which is managed by the U.S. Department of Defense (DOD). A portion of the stockpiled diamond stones was scheduled for sale in the NDS 2004 annual plan. During 2004, the Defense National Stockpile Center (DNSC) sold 381,000 carats of industrial diamond stone, valued at approximately $1 per carat. At yearend 2004, the DNSC reported an NDS remaining inventory of about 520,000 carats of industrial diamond stone with a market value of $5.2 million (Jenkins, 2004; Ringquist, 2004). The DOD planned to conduct additional sales until all NDS diamond stone stocks are sold.

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 2004 survey, one of the two U.S. primary producers of industrial diamond and one of the four industrial diamond recycling firms withheld data from the survey that they deemed proprietary. Thus, 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 252 million carats in 2004. Only two U.S. companies produced synthetic industrial diamond during the year—Diamond Innovations, Worthington, OH, and Mypodiamond, Inc., Smithfield, PA.

In 2004, nine firms also manufactured polycrystalline diamond (PCD) from synthetic diamond grit and powder. These companies were Dennis Tool Co., Houston, TX; Diamond Innovations; Novatek Inc., Provo, UT; Phoenix Crystal Corp., Ann Arbor, MI; Precorp Inc., Provo; SII Megadiamond Industries Inc., Provo; Tempo Technology Corp., Somerset, NJ; U.S. Synthetics Corp., Orem, UT; and Western Diamond Products, Salt Lake City, UT.

It is estimated that about 5 million carats of used industrial diamond was recycled in the United States during 2004. 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 four U.S. companies in 2004—Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston; and National Research Co., Fraser, MI. In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

Consumption

The United States remained the world's leading market for industrial diamond in 2004. Based on production estimates, trade data, and adjustments for Government stockpile sales, the apparent U.S. consumption of industrial diamond during the year decreased slightly to an estimated 413 million carats valued at $288 million. The major consuming industries of industrial diamond in the United States during 2004 were construction, machinery manufacturing, mining services (drilling for mineral, oil, and gas exploration), 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. The manufacture of every automobile made in the United States consumes about 1.5 carats of 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, and polishing silicon wafers and disks drives in the computer industry (Bailey and Bex, 1995).

Diamond tools have numerous industrial functions. Diamond drilling bits and reaming shells are used principally for gas, mineral, and oil exploration. 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 microns) and diamond bort (smaller, fragmented material). Diamond stone is used mainly in drilling 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 drilling 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 much 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.

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

Prices

Natural and synthetic industrial diamonds differ significantly in price (Boucher, 1997, p. 26.6). Natural industrial diamond normally has a more limited range of values. Its price varies from about $0.30 per carat for bort size material to about $7 to $10 per carat for most stones, with some larger stones selling for up to $200 per carat.

Synthetic industrial diamond has a much larger price range than natural diamond. Prices of synthetic diamond vary according to particle strength, size, shape, crystallinity, and the absence or presence of metal coatings. In general, synthetic diamond prices for grinding and polishing range from as low as $0.40 to $1.50 per carat. Strong and blocky material for sawing and drilling sells for $1.50 to $3.50 per carat. Large synthetic crystals with excellent structure for specific applications sell for many hundreds of dollars per carat (Law-West, 2002, p. 23.8).

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2004; imports were received from 37 countries, exports were sent to 48 countries, and reexports were sent to 52 countries (tables 1-4). Although the United States has been a major producer of synthetic diamond for decades, growing domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond always have been dependent on imports and secondary recovery operations because there has been no domestic production of natural diamond.

During 2004, U.S. imports of industrial-quality diamond stones (natural and synthetic) decreased slightly from 2003 to about 1.78 million carats valued at more than $13.8 million (table 1). Imports of diamond powder, dust, and grit (natural and synthetic) decreased slightly from 2003 to 240 million carats valued at almost $61.2 million (table 2).

Reexports may 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 2004, U.S. exports of industrial diamond stones increased by almost 56% from 2003 to 0.52 million carats valued at $0.44 million, and U.S. reexports of industrial diamond stone decreased by approximately 23%

from 2003 to 1.82 million carats valued at $21.2 million (table 3). U.S. exports of industrial diamond powder, dust, and grit (natural and synthetic) increased by 16% from 2003 to 85.7 million carats valued at $46.4 million, and reexports of industrial diamond powder, dust, and grit (natural and synthetic) increased by 68% from 2003 to 12.2 million carats valued at $5.14 million (table 4).

World Review

Total 2004 industrial diamond output worldwide was estimated by the USGS to be in excess of 626 million carats valued between $626 million and $1 billion. Natural industrial diamond production worldwide was estimated to be more than 66.6 million carats, a 5% decrease compared with the previous year. Congo (Kinshasa) was the leading producing country, followed by Russia and Australia, in order of descending quantity. These three countries produced more than 71% of the world's natural industrial diamond (table 5). Synthetic industrial diamond production worldwide was estimated to be more than 559 million carats, an increase of almost 3% compared with the previous year. The United States was the lead producing country, followed by Russia, Ireland, and South Africa, in order of descending quantity. These four countries produced about 81% of the world's synthetic industrial diamond (table 6).

In 2004, industrial diamond was produced in 25 countries (tables 5-6). 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. China may have produced more than the output listed in the table (Wilson Born, National Research Co., oral commun., 2004).

In 2004, more than 81% of the total global natural and synthetic industrial diamond output was produced in Ireland, Japan, Russia, South Africa, and the United States. The dominance of synthetic diamond over natural diamond was even more pronounced, as synthetic diamond accounted for more than 89% of global production and consumption.

The Ekati Diamond Mine, Canada's first operating commercial diamond mine, completed its sixth full year of production. In 2004, Ekati produced 4.08 million carats of diamond from 4.54 million metric tons (Mt) of ore (BHP Billiton Ltd., 2005). BHP Billiton has an 80% controlling ownership of the Ekati, which is located in the Northwest Territories in Canada. Ekati has estimated reserves of 60.3 Mt of ore in kimberlite pipes that contain 54.3 million carats of diamond, and the company projected the mine life to be 25 years. The Ekati mine is now producing from the Koala, Panda, and Misery kimberlite pipes. In November 2002, BHP Billiton began using underground mining techniques to recover diamonds from deeper portions of the Koala kimberlite pipe, which was first open pit mined (Diamond Registry Bulletin, 2002). Plans have now been approved for underground mining of deeper portions of the adjacent Panda kimberlite pipe, and initial production is expected in early 2005 (BHP Billiton Ltd., 2004). Approximately one-third of the Ekati diamond production is industrial-grade material (Darren Dyck, senior project geologist, BHP Diamonds, Inc., oral commun., May 27, 2001).

The Diavik Diamond Mine, also in the Northwest Territories, completed its second full year of production. In 2004, Diavik produced 7.57 million carats of diamond from its A154 North ore body and the adjacent A154 South pipe. Both pipes are located within the same pit (Diavik Diamond Mines Inc., 2005). The Diavik Diamond Mine has estimated its reserves to be 25.6 Mt of ore in kimberlite pipes, containing 107 million carats of diamond, and the company projected the mine life to be 16 to 22 years. Diavik is an unincorporated joint venture between Diavik Diamond Mines Inc. (60%) and Aber Diamond Mines Ltd. (40%). The mine is expected to produce about 107 million carats of diamond at a rate of 8 million carats per year worth about $63 per carat (Diavik Diamond Mines Inc., 2000, p. 10-12).

Diamond exploration is continuing in Canada, and many new deposits have been found. There are several other commercial diamond projects and additional discoveries located in Alberta, British Columbia, the Northwest Territories, the Nunavut Territory, Ontario, and Quebec. Canada produced about 8% of the world's combined natural gemstone and industrial diamond production in 2004.

Near the end of 2003, De Beers Centenary AG and the U.S. Department of Justice began work toward settlement of its long-running dispute over alleged illegal price fixing. On July 13, De Beers Centenary AG pled guilty in Federal court in Ohio to conspiring to fix the price of industrial diamond in the United States and elsewhere, resolving a 1994 case. De Beers was sentenced to pay a $10 million fine. With this settlement, De Beers is now free to enter the U.S. market (Diamond Registry Bulletin, 2004a, b).

The Kelsey Lake diamond mine was a commercially operated diamond mine, located close to the Colorado-Wyoming State line near Fort Collins, CO. Diamond was produced at Kelsey Lake for several years until April 2002, but the mine has been in care-and-maintenance mode since then with no additional production reported. The Kelsey Lake property includes nine known kimberlite pipes, of which three have been tested and have shown that diamonds are present. The remaining six pipes have yet to be fully explored and tested for their diamond potential. Of the diamonds recovered, 35% to 50% was industrial grade. The identified resources are at least 17 Mt grading an average of 4 carats per 100 metric tons (Taylor Hard Money Advisers, 2000§[1]).

Studies by the Wyoming Geological Survey have shown that Wyoming has the potential for a $1 billion diamond mining business. Wyoming has many of the same geologic conditions as Canada, and there is evidence of hundreds of kimberlite pipes in the State. Twenty diamondiferous kimberlite pipes and one diamondiferous mafic breccia pipe have been identified in southern Wyoming. Two of the largest kimberlite fields, State Line and Iron Mountain, and the largest lamproite field in the United States, Leucite Hills, are in Wyoming. There has been slight interest in the southern Wyoming and northern Colorado area by several diamond mining firms, but the only diamond mine developed in the area thus far is the Kelsey Lake Mine (Associated Press, 2002§).

The success of Canadian diamond mines has stimulated interest in whether there are also commercially feasible diamond

[1]References that include a section mark (§) are found in the Internet References Cited section.

deposits in the United States. Currently, there are no operating commercial diamond mines in the United States. Australian and Canadian companies are now conducting diamond exploration in Alaska and Minnesota. Alaska has similar geologic terrain to the Northwest Territories; in addition, garnet and other diamond indicator minerals as well as 17 microscopic diamonds have been found near Anchorage, AK. Two Canadian companies have invested $1 million in an exploration drilling program. Geologists from the University of Minnesota teamed with an Australian mining company and are conducting a soil sampling program in Minnesota for mineral exploration, including diamond. The samples are being analyzed by Australia's WMC Resources Ltd. The scientists believe that there is good chance of success owing to similarities between the geology in Minnesota and Canada (Diamond Registry Bulletin, 2005).

In another exploration venture during the second half of 2004, Delta Mining and Exploration Corp. found a diamond-bearing kimberlite in an 80-acre site known as the Homestead property near Lewistown, MT. Preliminary tests have shown the presence of microscopic diamonds. The firm is now planning a $700,000 soil sampling program, as further exploration. Diamonds have been found in the stream beds and glacial valleys of Montana for years (Associated Press, 2004§).

Current Research and Technology

Apollo Diamond, Inc., a company near Boston, MA, has developed and patented a method for growing extremely pure, gem-quality diamond with flawless crystal structure by chemical vapor deposition (CVD). The CVD technique transforms carbon into plasma, which then is precipitated onto a substrate as diamond. CVD has been used for more that a decade to cover large surfaces with microscopic diamond crystals, but until this process, no one had discovered the combination of temperature, gas composition, and pressure that resulted in the growth of a single diamond crystal. CVD diamond precipitates as nearly 100% pure, almost flawless diamond, and therefore may not be distinguishable from natural diamond by some tests (Davis, 2003). Apollo Diamond is producing 1-carat stones thus far, but hopes to be making 2-carat stones by 2006. The company is planning to start selling their diamonds in the jewelry market during the last half of 2005 at costs 10% to 30% below those of comparable natural diamonds (Hastings, 2005). The greatest potential for CVD diamond is in computer technology. For diamond to be a practical material for use as a semiconductor, it must be affordably grown in large wafers. After their process and technology are fully developed, Apollo will eventually be able to grow CVD diamond for about $5 per carat. CVD growth is limited only by the size of the seed placed in the Apollo Diamond machine. Starting with a square, wafer-like fragment, the Apollo Diamond process will grow the diamond into a prismatic shape, with the top slightly wider than the base. For the past 7 years, Apollo Diamond has been growing increasingly larger seeds by chopping off the top layer of growth and using that as the starting point for the next batch. At the moment, the company is producing 10-millimeter wafers but predicts it will reach about 10 times that in 5 years (Davis, 2003). Scientists have said that diamond computer chips are more durable because they can work at a temperature of up to 1,000° C, while silicon computer chips stop working at about 150° C. This means that diamond computer chips can work at a much higher frequency or faster speed and can be placed in a high-temperature environment (Diamond Registry Bulletin, 2003§).

In early 2004, scientists at the Carnegie Institution's Geophysical Laboratory published a study that showed researchers grew diamond crystals by a special CVD process at very high growth rates. They were able to grow gem-sized crystals in a day; a growth rate 100 times faster than other methods used to date. This is a new way of producing diamond crystals for such new applications as diamond-based electronic devices and next generation cutting tools (Willis, 2004). By early 2005, the Carnegie Institution's Geophysical Laboratory and the University of Alabama had jointly developed and patented the CVD process and apparatus to produce 10-carat, half-inch thick single diamond crystals at very rapid growth rates (100 micrometers per hour). This faster CVD method uses microwave plasma technology, and it allows multiple crystals to be grown simultaneously. This size is about five times that of commercially available lab-created diamonds produced by high pressures and high temperatures (HPHT) methods and other CVD techniques. Dr. Russell Hemley, a researcher at the Carnegie Institution stated, "High-quality crystals over 3 carats are very difficult to produce using the conventional approach. Several groups have begun to grow diamond single crystals by CVD, but large, colorless, and flawless ones remain a challenge. Our fabrication of 10-carat, half-inch, CVD diamonds is a major breakthrough" (Willis, 2004; Carnegie Institution of Washington, 2005; Science Blog, 2005§). Both Apollo Diamond and the Carnegie Institution have noted that their diamonds produced by the CVD method are harder than natural diamonds and diamonds produced by HPHT methods.

Outlook

The United States will most likely continue to be the world's leading market for industrial diamond well into the next decade. The United States also is expected to remain a significant producer and exporter of industrial diamond. The strength of U.S. demand will depend on the vitality of the Nation's industrial base and on how well the diamond life cycle cost-effectiveness compares with competing materials that initially are less expensive. 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.

The most dramatic increase in U.S. use of industrial diamond is likely to be in the construction sector as the Nation builds and repairs the U.S. highway system in its implementation of the Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2005 (Public Law 109-59), which was passed by the U.S. House of Representatives on March 10, 2005, and by the U.S. Senate on May 17, 2005. This Act authorized appropriations for fiscal years 2005 through 2009 for Federal-aid highway programs out of the Highway Trust Fund (U.S. House of Representatives, 2005§). Demand for saw-grade diamond alone is expected to increase in the coming year if goals mandated by the Act for the repair and replacement of roads, bridges, and other components in the transportation infrastructure of the country are fulfilled.

According to industry sources, PCD for abrasive tools and wear parts will 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 (Wilson Born, National Research Co., written commun., 1998).

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.

World demand for industrial diamond will continue to increase during the next few years. Constant dollar prices of synthetic diamond products, including chemical-vapor-deposition diamond films, will decline as production technologies become more cost effective and as competition increases from low-cost producers in China and Russia.

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TABLE 1

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Natural industrial diamond stones[2]				Miners' diamond, natural and synthetic[3]			
	2003		2004		2003		2004	
Country	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]
Australia	18	240	22	159	(5)	5	7	61
Belgium	126	386	105	590	18	258	94	541
Botswana	2	36	175	3,450	1	44	(5)	23
Canada	--	--	6	162	2	9	(5)	5
China	34	26	--	--	(5)	21	(5)	8
Congo (Kinshasa)	1	4	20	375	--	--	2	12
Ghana	61	209	113	652	21	275	17	158
Guyana	3	11	--	--	(5)	8	--	--
India	37	21	3	65	--	--	--	--
Ireland	227	281	41	55	930	633	572	263
Japan	1	4	--	--	--	--	16	75
Mexico	26	104	3	19	2	25	(5)	22
Namibia	64	255	146	658	26	75	14	65
Russia	(5)	3	98	1,930	--	--	82	348
South Africa	2	19	198	3,460	17	181	2	48
Switzerland	2	28	(5)	13	(5)	22	(5)	36
United Kingdom	139	1,720	37	253	5	24	2	88
Other	20 r	115 r	2	58	38 r	588 r	1	163
Total	763	3,470	969	11,900	1,060	2,170	809	1,920

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 POWDER, DUST AND GRIT, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2003		2004		2003		2004	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Australia	--	--	149	61	3	5	170	56
Belgium	8,400	3,130	13,200	3,770	2,750	1,470	473	274
Brazil	24	20	87	87	35	35	75	75
China	68,400	6,750	85,500	8,930	85	42	259	38
Germany	51	28	474	228	18	9	4	3
India	3,010	638	2,480	662	82	43	1,050	277
Ireland	92,600	34,700	65,200	29,400	1,310	604	1,080	457
Italy	2,130	983	2,750	1,310	--	--	24	29
Japan	5,320	4,870	5,990	5,120	32	46	16	22
Korea, Republic of	7,990	4,080	8,790	3,280	96	40	21	14
Macau	130	135	238	73	--	--	12	13
Namibia	--	--	19	34	33	136	40	171
Romania	419	158	1,150	242	26	28	30	8
Russia	15,200	1,940	15,400	1,550	63	18	30	83
Switzerland	908	564	753	958	284	146	284	281
Ukraine	29,200	2,040	26,100	1,720	--	--	--	--
United Kingdom	4,910	1,030	3,280	981	680	242	534	246
Other	5,750 r	568 r	4,610	680	80 r	59 r	56	43
Total	244,000	61,700	236,000	59,100	5,580	2,920	4,160	2,090

[r]Revised. -- Zero.

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

[2]Harmonized 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.

[3]Customs value.

Source: U.S. Census Bureau.

TABLE 3
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Industrial unworked diamonds[2]			
	2003		2004	
Country	Quantity	Value[3]	Quantity	Value[3]
Exports:				
Australia	2	19	--	--
Belgium	11	111	14	18
Bulgaria	27	38	--	--
Canada	22	81	8	46
Germany	2	24	--	--
Hong Kong	49	487	501	375
Japan	41	412	--	--
Korea, Republic of	9	92	--	--
Malaysia	133	316	--	--
Mexico	8	42	--	--
Poland	(4)	3	--	--
Other	32	299	--	--
Total	336	1,920	523	439
Reexports:				
Belgium	700	6,180	805	8,560
Canada	154	540	69	331
China	25	269	24	135
Germany	27	212	11	113
Hong Kong	266	2,640	83	907
Ireland	66	210	1	8
Israel	7	72	--	--
Japan	620	6,290	410	6,230
Korea, Republic of	157	1,710	109	1,760
Mexico	39	440	13	146
Switzerland	7	71	67	173
United Arab Emirates	45	247	6	13
United Kingdom	160	1,680	150	1,980
Other	96 r	583 r	67	855
Total	2,370	21,100	1,820	21,200
Grand total	2,710	23,100	2,340	21,700

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States code 7102.21.0000.
[3]Customs value.
[4]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4

U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST AND GRIT, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2003		2004		2003		2004	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Exports:								
Austria	212	164	196	82	--	--	42	15
Belgium	799	332	582	259	383	266	248	271
Brazil	2,830	1,220	1,730	841	2	6	--	--
Canada	1,860	1,820	2,600	2,330	91	174	84	173
France	113	24	226	60	42	10	77	131
Germany	7,060	3,800	25,400	11,200	277	187	319	357
Greece	343	151	246	78	--	--	--	--
Hong Kong	1,070	335	303	214	66	63	47	95
India	2,000	785	1,470	823	6	8	--	--
Ireland	15,000	10,500	3,490	2,000	500	480	325	261
Israel	998	265	82	34	554	134	--	--
Italy	895	328	2,230	921	94	37	50	35
Japan	14,800	7,710	18,000	8,480	510	673	966	378
Korea, Republic of	12,700	5,330	11,400	4,380	468	148	688	226
Macau	374	168	36	38	--	--	15	15
Malaysia	1,070	736	525	994	20	18	17	52
Mexico	519	245	391	174	169	129	45	115
Netherlands	--	--	43	53	--	--	224	591
Philippines	--	--	51	12	71	57	6	9
Singapore	145	201	600	729	57	93	28	25
Spain	430	111	392	92	115	36	155	42
Switzerland	472	761	1,130	1,630	1,300	2,130	2,150	3,830
Taiwan	2,360	1,060	3,240	1,410	150	107	58	48
Thailand	1,070	410	2,930	1,140	47	51	86	23
United Kingdom	291	179	1,320	429	93	57	186	126
Other	685	474	703	342	756	1,140	522	822
Total	68,200	37,100	79,400	38,800	5,770	6,000	6,330	7,640
Reexports:								
Australia	18	12	29	21	--	--	--	--
Austria	211	94	242	122	194	43	174	26
Belgium	82	23	222	138	111	47	87	95
Brazil	--	--	8	14	15	8	9	8
Canada	512	798	1,020	1,080	37	91	89	54
France	--	--	--	--	68	15	--	--
Germany	350	143	728	232	79	26	596	154
Hong Kong	--	--	--	--	--	--	35	86
India	329	94	241	69	--	--	2	3
Ireland	178	143	184	193	4	3	9	14
Israel	--	--	126	26	--	--	93	23
Italy	519	163	542	132	88	22	327	84
Japan	308	110	898	375	119	99	240	49
Korea, Republic of	1,950	745	1,960	829	543	229	2,290	505
Macau	166	30	80	46	--	--	377	60
Malaysia	--	--	103	25	66	11	--	--
Mexico	71	14	102	34	85	112	96	39
Spain	99	27	92	29	55	20	--	--
Switzerland	62	21	88	53	--	--	163	27
Taiwan	329	269	124	61	48	61	--	--

See footnotes at end of table.

TABLE 4—Continued

U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND POWDER, DUST AND GRIT, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2003		2004		2003		2004	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Reexports—Continued:								
United Kingdom	164	64	204	141	49	26	337	125
Other	236 r	80 r	140	98	86 r	20 r	121	71
Total	5,590	2,830	7,140	3,720	1,650	833	5,050	1,420
Grand total	73,700	39,900	86,500	42,500	7,410	6,840	11,400	9,060

[r]Revised. -- Zero.

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

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

[3]Customs value.

Source: U.S. Census Bureau.

TABLE 5

NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY AND TYPE[1, 2, 3]

(Thousand carats)

Country and type[4]	2000	2001	2002	2003	2004
Gemstones:					
Angola	3,880 r	4,640 r	4,520	4,500 r	5,400
Australia	11,956 5	11,779 5	15,142 5	14,900	9,279 5
Botswana	18,500	19,800	21,300	22,800	23,300
Brazil	1,000	700	500	500	500
Canada	2,534 5	3,716 5	4,937 r, 5	11,200	12,618 p, 5
Central African Republic	348 r	340 r	312 r	250 r	250
China	230	235	235	235	250
Congo (Kinshasa)	3,500	3,640	4,400	5,400	6,000
Cote d'Ivoire	210	207	204	152 r	152
Ghana	792	936	770	760 r	800
Guinea	278	273	368	484 r	468
Guyana	82 5	179 5	248 5	413 r, 5	450
Liberia	100	100	48	36	18
Namibia	1,450	1,487 5	1,562 r, 5	1,481 r, 5	2,000
Russia	17,500 r	17,500 r	17,400 r	20,000 r	21,400
Sierra Leone	58	167	147 5	250 r	309
South Africa	4,320	4,470	4,350	5,070	5,780
Tanzania	301	216	204 r	201 r	305
Venezuela	29 5	14 5	46 5	11 r, 5	40
Zimbabwe	8	--	--	--	16
Other[6]	24	25	25	24	24
Total	67,100 r	70,400 r	76,700 r	88,700 r	89,400
Industrial:					
Angola	431 r	516 r	502	500 r	600
Australia	14,612 5	14,397 5	18,500 5	18,200	11,341 5
Botswana	6,160	6,600	7,100	7,600	7,800
Central African Republic	116 r	113 r	104	83 r	83

See footnotes at end of table.

TABLE 5—Continued

NATURAL DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY AND TYPE[1, 2, 3]

(Thousand carats)

Country and type[4]	2000	2001	2002	2003	2004
Industrial—Continued:					
China	920	950	955	955	960
Congo (Kinshasa)	14,200	14,560 [5]	17,456 [5]	21,600	22,000
Cote d'Ivoire	110	102	102	78 r	78
Ghana	198	234	193	190 r	200
Guinea	91	91	123	161 r	157
Liberia	70	70	32	24	12
Namibia	106	--	--	--	--
Russia	11,700 r	11,700 r	11,600 r	13,000 r	14,200
Sierra Leone	19	56	205 [5]	257 r	304
South Africa	6,470	6,700	6,530	7,600	8,670
Tanzania	53 [5]	38 [5]	36 r, 5	36 r, 5	55
Venezuela	80 [5]	28 [5]	61 [5]	24 r, 5	60
Zimbabwe	15	--	--	--	31
Other[7]	64	66	68	67	66
Total	55,400 r	56,200 r	63,600 r	70,400 r	66,600
Grand total	122,000 r	127,000 r	140,000 r	159,000 r	156,000

pPreliminary. rRevised. -- Zero.

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

[2]Table includes data available through June 3, 2005.

[3]In 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.

[4]Includes near-gem and cheap-gem qualities.

[5]Reported figure.

[6]Includes Gabon, India, and Indonesia.

[7]Includes India and Indonesia.

TABLE 6

SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Thousand carats)

Country	2000	2001	2002	2003	2004
Belarus	25,000	25,000	25,000	25,000	25,000
China	16,800	17,000	17,000	17,000	17,000
France	3,000	3,000	3,000	3,000	3,000
Greece	750	--	--	--	--
Ireland	60,000	60,000	60,000	60,000	60,000
Japan	33,000	33,000	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
Sweden	20,000	20,000	20,000	20,000	20,000
Ukraine	8,000	8,000	8,000	8,000	8,000
United States	182,000	202,000	222,000	236,000	252,000
Total	429,000	508,000	529,000	543,000	559,000

-- Zero.

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

[2]Table includes data available through June 3, 2005.

[3]In addition to the countries listed, 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.