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SILICON

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In 2005, overall domestic silicon production decreased from that of 2004. At 270,000 metric tons (t) of contained silicon, production was 2% lower than that of 2004 (table 1). On a gross-weight basis, production decreased by 1% from that in 2004 (table 2). On the basis of contained silicon, U.S. exports of silicon products increased by 24%, and imports increased by 4%. The increase in exports was associated with increases in the "more than 55% silicon" ferrosilicon and "more than 99.99% silicon" and "other" silicon metal trade categories (table 5). The increase in imports was primarily attributable to increases in the "55% to 80% silicon" ferrosilicon and the "other" ferrosilicon metal trade categories (table 6). Apparent consumption for ferrosilicon increased by 7% and for silicon metal decreased by 5% compared with that in 2004 (revised). Year-average import prices for silicon metal decreased by 7%, and those for the 50% and 75% ferrosilicon grades decreased by 5% and 13%, respectively, compared with those in 2004 (table 1).

Silicon is a light chemical element with metallic and nonmetallic characteristics. Silicon is not found free in nature. Silicon combines with oxygen and other elements to form silicates, which comprise more than 25% of the Earth's crust. Silica (SiO_2) as quartz or quartzite is used to produce silicon ferroalloys for the iron and steel industries and silicon metal for the aluminum and chemical industries. Silicon metal that is refined into semiconductor-grade metal for use in making computer chips is crucial to modern technology, but the quantity is less than 5% of total silicon metal demand (Roskill's Letter from Japan, 2000). Silicon metal may also be refined into wafers used to power solar batteries. The U.S. Geological Survey (USGS) does not survey the high-purity silicon industry for production and related data; therefore, the only information that this report contains about these high-purity grades is as it appears in the foreign trade statistics and from published sources.

Legislation and Government Programs

The General and Plastic Surgery Devices Advisory Panel for the U.S. Food and Drug Administration (FDA) met April 11-13 to give advice and recommendations to the FDA on the premarket approval applications for silicone-filled breast implants submitted by Inamed Corporation and Mentor Corporation. After reviewing company data and FDA and public comments, the panel voted five to four against approving Inamed's application and seven to two in favor of approving Mentor's application with conditions. In the case of Inamed, the panel felt the performance of the implant device was inadequate and that additional patient followup data were needed (U.S. Food and Drug Administration, 2005§[1]).

Production

Silicon Ferroalloys[2] and Metal.—Domestic production data for silicon are derived from monthly and annual voluntary surveys and estimates for nonrespondents by the USGS. The data in table 2 were obtained from all operations listed in table 3 that are canvassed by means of the USGS "Silicon Alloys" survey. In terms of gross weight and compared with those of 2004, overall domestic gross production, net shipments, and stocks of silicon products decreased by 1%, 2%, and 15%, respectively. The most pronounced year-to-year changes were in the 75% ferrosilicon category, for which production and shipments decreased by 7% and 4%, respectively. Production of 50% ferrosilicon increased by 2%, and shipments and stocks decreased by 2% and 12%, respectively. Data for ferrosilicon reflected adjustments in inventory and in-plant consumption of ferrosilicon to produce magnesium ferrosilicon and other miscellaneous alloys. Silicon metal production and shipments both fell by 1% (table 2).

Elkem ASA (a subsidiary of Orkla ASA) announced late in the year that it would sell its silicon plant and associated hydroelectric plant located in Alloy, WV, to U.S. ferroalloys producer Globe Metallurgical, Inc. for $130 million (Orkla ASA, 2005§). The sale would double Globe's silicon metal production capacity to 135,000 metric tons per year (t/yr) from 65,000 t/yr and would make the company the leading U.S. silicon metal producer (Ryan's Notes, 2005a). The sale would also reduce the number of companies that produce silicon metal in the United States to two from three.

Semiconductor- and Solar-Battery-Grade Silicon.—U.S. production of polycrystalline silicon used in semiconductor-grade silicon was reported to be 10,100 t in 2005; solar-battery-grade production was 5,400 t. Total domestic polycrystalline production capacity in 2005 was 16,800 t, as follows: Hemlock Semiconductor Corporation, 7,700 t; REC Advanced Silicon Materials LLC, 3,000 t; MEMC Electronic Materials, 2,700 t; REC Solar Grade Silicon LLC, 2,200 t; and Mitsubishi Materials Group, 1,200 t (Roskill's Letters from Japan, 2006).

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

[2]There are two standard grades of ferrosilicon—50% and 75%. A more detailed explanation of these grades is found in table 2.

Consumption

Silicon Ferroalloys and Metal.—The majority of ferrosilicon (including miscellaneous silicon alloys) was used to produce steel (65%) and cast irons (32%) (table 4). Silicon metal was used mainly to produce chemicals—silanes, silicones, and others—and silica fume (76%). Metallurgical-grade silicon carbide can substitute for ferrosilicon, especially in iron foundries. Data on North American production and U.S. imports of silicon carbide are reported in the Manufactured Abrasives chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals.

Total U.S. apparent consumption of silicon ferroalloys and metal in 2005 increased by 1% to 592,000 t from the revised estimate of 588,000 t in 2004 (contained silicon). Apparent consumption increased by 7% to 317,000 t for ferrosilicon and miscellaneous silicon alloys and decreased by 5% to 275,000 t for silicon metal. Increases in net imports for consumption contributed to the rise in ferrosilicon apparent consumption. Decreases in net imports for consumption led to the decline in silicon metal apparent consumption. Ferrosilicon and miscellaneous silicon alloys accounted for 54% of the total demand.

The ratio of reported to apparent consumption on a content basis was 66:34 for ferrosilicon, which includes miscellaneous silicon alloys, and 85:15 for silicon metal. These ratios were derived based on the typical silicon content of the materials noted in table 4.

Consumption of ferrosilicon and silicon metal was estimated by CRU International Ltd. to have decreased in 2005 throughout the Western World. In terms of contained silicon, ferrosilicon consumption decreased to 1.97 million metric tons (Mt) from 2.08 Mt (revised) in 2004, and silicon metal consumption decreased to about 1.28 Mt from 1.29 Mt. Areas with the largest year-to-year decrease in consumption were, for ferrosilicon, Japan, Europe, and Asian countries (excluding China, Japan, and North Korea), and for silicon metal, Japan and the United States. In decreasing order of consumption, Europe, Japan, and other Asian countries accounted for 70% of the ferrosilicon consumption in 2005. Also in decreasing order of consumption, Western Europe, the United States, and Japan accounted for 77% of the silicon metal consumed in 2005 (CRU Bulk Ferroalloys Monitor, 2006a, b).

Semiconductor- and Solar-Battery-Grade Silicon.—Global demand for silicon wafers made from polycrystalline silicon increased by 6% as shipments rose to 6,640 million square inches from 6,260 million square inches in 2004. The value of the shipments increased by 8% to $7.9 billion from $7.3 billion in 2004 (Roskill's Letters from Japan, 2006).

Prices

Ferrosilicon and silicon metal prices (excluding those of high-purity silicon) tend to vary in response to changes in demand and supply by the steel, ferrous foundry, aluminum, and chemical industries. Year-average import prices given by Platts Metals Week were 48.0 cents per pound for 75% ferrosilicon and 76.2 cents per pound for silicon metal; these prices were 13% and 7% lower, respectively, than those of 2004. The year-average North American transaction price for 50% ferrosilicon as calculated from Ryan's Notes listings was 55.0 cents per pound, a 5% decrease from that of 2004. Prices for both standard grades of ferrosilicon fell based on decreased crude steel production and higher import levels from those of 2004 (Metal Bulletin Ferro-Alloys Monthly, 2005a). Lower silicon metal prices in the United States were attributed to a decrease in demand by the secondary aluminum sector (Metal Bulletin Ferro-Alloys Monthly, 2005b).

Annual polycrystalline contract prices were estimated to be $50 to $55 per kilogram for semiconductor-grade silicon and $40 to $45 per kilogram for solar-battery-grade material (Roskill's Letters from Japan, 2006).

Foreign Trade

Trade volumes discussed below are based on gross weight. U.S. ferrosilicon exports increased by 17% to 23,400 t, and their value increased by 15% to $13.4 million from that of 2004. In decreasing order of quantity, Canada and Mexico accounted for 97% of the total 2005 ferrosilicon exports (table 5). Exports of silicon metal increased by 25%, and their value increased by 73% to $847 million from that of 2004. In decreasing order of quantity, Japan, Canada, and China accounted for 57% of silicon metal exports. Shipments of high-purity silicon containing more than 99.99% silicon accounted for 63% of total silicon metal exported and 96% of the total value of combined ferrosilicon and silicon metal exports.

U.S. ferrosilicon imports increased by 17% to 290,000 t, but increased in value only by 7% to $215 million compared with that in 2004. The rise in ferrosilicon imports was primarily attributable to increases in the "55% to 80%, other" and "other" ferrosilicon trade categories. Imports of standard 75% ferrosilicon (ferrosilicon category of "55% to 80% silicon, other") accounted for 81% of total ferrosilicon imports by gross weight and value (table 6). China was the leading source of ferrosilicon imports at 45%, followed by Venezuela at 16%.

Silicon metal imports decreased by 6% to 157,000 t from 167,000 t in 2004, but increased by 17% in value to $366 million from $314 million. Imports fell because of decreases in the "99.00% to 99.99% silicon" category. Brazil was the leading source of the "99.00% to 99.99% silicon" import category at 42%, followed by South Africa at 28%. This category accounted for 51% of the total value for silicon metal imports and showed an increase of 8% from that in 2004.

The estimated U.S. net import reliance for ferrosilicon in 2005 increased to 61% from 57% in 2004 (revised), and that for silicon metal decreased to 47% from 50%. The overall import reliance for silicon was estimated to be 54%, about the same as that of the revised level (53%) in 2004.

The general rates of duty that applied to U.S. imports during 2005 were the same as in 2004. These were, on an ad valorem basis, 5.8% for ferrosilicon containing more than 90% silicon; 5.3% or 5.5% for metal exclusive of the high-purity grade, which is free; 1.9% for ferrosilicon containing 80% to 90% silicon; 1.5% for standard 75% ferrosilicon; 1.1% for nominal 75% ferrosilicon that contains more than 3% calcium; and

free for magnesium ferrosilicon and other ferrosilicon (U.S. International Trade Commission, 2006).

Silicon Metal Imports from Brazil (July 1, 1998, through June 30, 1999).—On October 6, the U.S. Court of International Trade (CIT) affirmed the revised antidumping duty margins for silicon metal imports from Companhia Brasileira Carbureto de Calcio (CBCC) and Eletrosilex, S.A., which were zero and 61.58%, respectively, that were calculated by the International Trade Administration (ITA) of the U.S. Department of Commerce on July 14, 2004 (Elkem Metals Company v. United States, Consol. Court No. 01-00098, CIT Slip Opinion 05-134). Although the CIT agreed with the revised duties, the ITA suspended liquidation of the imports until a conclusive decision[3] could be made in the case (International Trade Administration, 2005e).

Silicon Metal Imports from Russia (July 2001 through December 2001).—On January 5, upon remand by the CIT, the ITA recalculated the dumping margin rates for silicon metal imported from Russia by Bratsk Aluminum Smelter to 87.08% from 79.42%, and by ZAO Kremny/Sual-Kremny-Ural Ltd. (ZAO Kremny) to 56.2% from 56.11% . On July 25, the CIT affirmed the revised antidumping duty margin rate for Bratsk, but remanded that of ZAO Kremny back to the ITA for further evaluation (Globe Metallurgical Inc. v. United States, Consol. Court No. 03-00202, CIT Slip Opinion 05-90). The ITA submitted its revised antidumping duty rate of 61.61% for ZAO Kremny on October 25, which the CIT affirmed on November 28 (Globe Metallurgical Inc. v. United States, Consol. Court No. 03-00202, CIT Slip Opinion 05-150) (Platts Metals Week, 2005). Although the CIT agreed with the revised duties, the ITA suspended liquidation of the imports until a conclusive decision could be made in the case (International Trade Administration, 2005b).

Silicon Metal Imports from Brazil (July 1, 1999, through June 30, 2000).—On August 26, the CIT upheld the 0.48% duty margin rate on silicon metal imported from Brazil by Rima Industrial S.A. that the ITA had recalculated on remand on March 16 (Elkem Metals Company v. United States, Consol. Court No. 02-00232, CIT Slip Opinion 05-109). Although the CIT agreed with the revised duty, the ITA suspended liquidation of the imports until a conclusive decision could be made in the case (International Trade Administration, 2005d).

Pending U.S.-Southern African Customs Union Free Trade Agreement.—Representatives from the Office of the United States Trade Representative (USTR) and member nations of the Southern African Customs Union (Botswana, Lesotho, Namibia, South Africa, and Swaziland) continued negotiations on the pending U.S.-Southern African Customs Union Free Trade Agreement (FTA). In April 2006, the parties agreed to establish a framework for pursuing the FTA over the longer term (Office of the United States Trade Representative, 2006§). The USTR launched negotiations for the FTA on June 2, 2003 (Office of the United States Trade Representative, 2003§). The FTA could result in the elimination of the 5.5% ad valorem duty on imports of less than 99.00% silicon metal from South Africa.

Antidumping Duty Administrative Reviews.—On August 8, the ITA preliminarily determined that Brazilian producer Camargo Correa Metais, S.A. (CCM) did not sell silicon metal at less than the normal value during the period of July 1, 2003, through June 30, 2004 (International Trade Administration, 2005g). In late November, the ITA extended the deadline for making a final determination until February 4, 2006 (International Trade Administration, 2005c).

The ITA also began an antidumping duty administrative review of silicon metal imports during the period of July 1, 2004, through June 30, 2005, from Brazilian producers CCM, Companhia Ferroligas de Minas Gerais-Minasligas (Minasligas), and Ligas de Aluminio S.A. (LIASA) on August 29 (International Trade Administration, 2005a). On November 28, the ITA rescinded the administrative review for the companies because none had sales or exports of the subject merchandise during the period of review (International Trade Administration, 2005f).

World Review

Data on annual world production of ferrosilicon and silicon metal by country during 2001 through 2005 are provided in the Ferroalloys chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals. World production of ferrosilicon was estimated to have been 5.43 Mt in 2005 compared with 5.66 Mt (revised) in 2004. The major ferrosilicon producers in 2005 were, in decreasing order, China, Russia, Norway, Ukraine, the United States, Brazil, South Africa, Iceland, and Kazakhstan; they accounted for 87% of total production as listed in table 1. World production of silicon metal, excluding that from China, was estimated to have been 662,000 t in 2005 compared with 658,000 t (revised) in 2004. Firm data on China's production of silicon metal are lacking, although one source reported it to be 520,000 t/yr (Ryan's Notes, 2004). At this rate, China is by far the leading producer of silicon metal in the world. Other major producers of silicon metal in 2005 were, in decreasing order, the United States, Brazil, Norway, France, South Africa, and Russia; they accounted for about 84% of total production as listed in table 1.

Bhutan.—Bhutan Ferro Alloys Limited reported that it had the capacity to produce ferrosilicon (about 21,000 t/yr), silica fume (4,200 t/yr), and magnesium ferrosilicon (2,400 t/yr). The company also mentioned it would be commissioning a new 18-megavoltampere (MVA) furnace for silicon and manganese alloys by yearend (Bhutan Ferro Alloys Limited, 2006§). The new furnace would have the capacity to produce about 12,000 t/yr of ferrosilicon (Metal-Pages, 2005a§).

Bosnia and Herzegovina.—In May 2004, Italian ferroalloy producer Metalleghe Spa acquired the Elecktrobosma silicon plant located in Jajce, Bosnia. The plant has three 7.5 megawatt furnaces with a combined capacity of about 15,000 t/yr. Most of the silicon metal produced at the plant is sold in Italy (Ryan's Notes, 2005d).

China.—China's exports of ferrosilicon containing more than 55% silicon rose slightly to an alltime high of 916,911 t from

[3]The ITA determines a "conclusive" decision is made when either a trade case is not appealed or it is affirmed by the Court of Appeals for the Federal Circuit on appeal. When such a decision is reached, the ITA will instruct the U.S. Customs and Border Protection to liquidate the subject merchandise.

that of 2004, and those containing 55% or less silicon increased by 6% to 24,094 t. China exported 536,130 t of silicon metal in 2005, a decrease of 2% from 545,034 t in 2004 (TEX Report, 2006a, b).

To reduce ferroalloy and metal exports, China's Ministry of Finance revoked the 8% export tax rebate on ferrosilicon starting January 1. On April 29, the Government also repealed the 13% export tax rebate on silicon metal effective May 1, 2005, and imposed a 5% export tax on ferrosilicon effective June 1, 2005 (TEX Report, 2005a, b).

The Central Government of China, through the National Development and Reform Commission (NDRC), estimated the number of ferroalloy producers in the country to be 1,570; total installed production capacity was about 22 million metric tons per year (Mt/yr) (twice that of 2000). In 2005, 1.16 Mt of ferroalloy capacity was under construction, with an additional 1.23 Mt planned. Ferroalloy production during the year was 10.67 Mt, and the amounts consumed, exported, and imported were 9.30 Mt, 1.74 Mt, and 370,000 t, respectively. China accounted for 40% of global ferroalloy production and 30% each of global consumption and exports (TEX Report, 2006d, f).

Because of overcapacity, the NRDC issued a bulletin on July 5 that established a national system for approving state-owned ferroalloy companies. The new system would also reduce energy consumption and increase environmental protection by the ferroalloys industry. The NDRC also set a limit for energy consumption at 8,500 kilowatts per metric ton of 75% ferrosilicon produced (TEX Report, 2005b, c).

As part of the approval process, state-owned ferroalloy producers were required to report the following information: total capital, profit, number of production facilities, the amount of energy consumed, and environmental protection controls at plant operations. Plant inspections would be conducted to verify compliance with regulations instituted in 2004 as described in the Silicon chapter of the 2004 Minerals Yearbook, volume I, Metals and Minerals. The NDRC announced the names of 25 ferrosilicon and 3 silicon metal producers that met environmental standards as of December 31 (TEX Report, 2006d, e).

France.—On April 5, Spanish ferroalloy producer Ferroatlantica S.L. purchased Pechiney Électrométallurgie (PEM) from Alcan Inc. for €140 million ($180 million) (Yahoo!Finance France, 2005§). The sale was completed by June (Alcan Inc., 2005§). PEM's ferroalloy division includes ferrosilicon and silicon metal producer Invesil with four plants in France and one in South Africa.

Japan.—The Japanese aluminum industry consumed 63,205 t of silicon metal, a 4% increase compared with that in 2004 because of greater demand by the automotive manufacturing sector (TEX Report, 2006h). The Japanese steel industry consumed 383,182 t of ferrosilicon, a 3% increase from that in 2004 (TEX Report, 2006g). Ferrosilicon imports containing at least 55% silicon were 466,364 t at an annual average price of $743.70 per metric ton, down from 538,668 t at $816.97 per ton in 2004. Other ferrosilicon imports were 20,324 t at an average annual price of $769.26 per ton, down from 24,172 t at $787.23 per ton. Silicon metal imports were 222,851 t at an annual average price of $1,204.35 per ton, down from 242,439 t at $1,221.18 per ton in 2004 (TEX Report, 2006c).

Mexico.—Hascor Metals S.A. de C.V. started full production of magnesium ferrosilicon at a rate of 200 to 250 metric tons per month at its plant in Tamos, Tampico (Ryan's Notes, 2005e).

Norway.—In March, Alcoa Inc. agreed to sell its 46.5% stake in silicon producer Elkem to Orkla for $870 million. With this sale, Orkla acquired about 98% ownership in Elkem (Alcoa Inc., 2005§). In April, Orkla made an offer for the remaining Elkem shares (American Metal Market, 2005§). Elkem's ownership in Norwegian-based Renewable Energy Corporation AS (REC) increased to 27.5% from 25% in 2004. REC produces silicon raw materials and wafers for the solar cell industry (Elkem ASA, 2006a§). In January 2006, Elkem announced it would close its silicon metal plant in Meraker, Norway, by midyear 2006 in response to tougher international competition (particularly from China) (Elkem ASA, 2006b§).

Fesil ASA reported that its Lilleby Metall ferrosilicon and silicon metal plant remained shut down during 2005, although necessary maintenance was performed for a possible future restart (Fesil ASA, 2006§).

Finnfjord Smelteverk ASA closed its Finnsnes, Norway, ferrosilicon plant indefinitely in October. The plant has an operating capacity of 100,000 t/yr (Ryan's Notes, 2005b).

Russia.—Chelyabinsk Electrometallurgical Integrated Plant planned to produce 600,000 t of ferrosilicon containing 45% silicon during 2005 (TEX Report, 2005d). The company's ferroalloy production mix was about 39% ferrosilicon, 25.5% ferrochrome, 19.6% silicomanganese, and 13.5% ferrochromium silicon (Interfax Metals & Mining Weekly, 2006a).

Kuznetsk Ferroalloy Works (KFZ) increased production of ferrosilicon containing 45% silicon by 11% to 439,922 t during 2005. KFZ also raised production of microsilica (fume silica) by 4% to 15,528 t. KFZ invested Rub195 million (approximately $6.79 million) in 2005 to construct a new ferrosilicon line at the former Yurga abrasives plant in the Kemerovo region of Russia; production was expected to start in May 2006 (Interfax Metals & Mining Weekly, 2006b). Production capacity at the Yurga plant was planned to be up to 70,000 t/yr of 75% ferrosilicon (Interfax Mining & Metals Report, 2004).

Taiwan.—Taiwan imported 73,653 t of standard ferrosilicon (more than 55% silicon content) during 2005, a 17% decrease from that of 2004. Of that amount, 76% came from China, 14% from Russia, and 6% from Brazil (TEX Report, 2006i).

Ukraine.—SUAL Group acquired 69% ownership in Zaporozhye Aluminum Combine in 2004 (Ryan's Notes, 2005c). Stakhanov Ferroalloy Plant, the country's sole ferrosilicon producer, announced plans to invest about $16 million in plant improvements during 2005. Capital expenditures would include the continued reconstruction of its furnaces and installation of a new gas purification system (Metal-Pages, 2005b§).

Current Research and Technology

Metal Powder.—Metalysis Ltd., United Kingdom, used the Fray-Farthing-Chen (FFC) Cambridge process to produce silicon metal powder directly from silicon oxide powder. The FFC Cambridge process uses a molten salt to electrolytically extract silicon from the metal powder. Other metals can also be produced this way. The company believes there is potential to produce metal alloys directly from mixed metal oxides without the need for smelting (Metalysis Ltd., 2005§).

Nanotechnology.—NanoDynamics, Inc., Buffalo, NY, developed a new high-rate, low-cost method for anisotropically etching silicon wafers by an electrochemical process. The new process yields more silicon wafers than traditional processes; a higher yield would reduce the overall cost of fuel cells. The new wafers might also increase energy efficiency, thereby reducing the fuel-cell size (larger cells and more fuel are required for less efficient fuel cells) (Advanced Materials & Processes, 2005).

Silicon Chemicals.—GE Advanced Materials (a consolidated affiliate of General Electric Company) announced two new silanes, the NXT LowV™ and NXT Ultra-LowV™, for use in the production of silica-base tire tread compounds. The new products can be made in one step rather than the multistep process required to mix silica with rubber when using traditional polysulfide silanes. The new materials can also lower ethanol emissions by up to 90% because they do not react with rubber like traditional polysulfide silanes do. While silica tires help reduce automobile fuel consumption by up to 5% and improve traction and handling, they have been difficult to manufacture (GE Advanced Materials, 2005b§). GE Advanced Materials also introduced its Silbreak™ line of silicone demulsifiers for crude oil separation. Silbreak™ may allow the development of crude oil resources currently considered "economically unattractive" (GE Advanced Materials, 2005a§).

Researchers at the University of Wisconsin-Madison developed a new type of rechargeable lithium battery that could last up to 12 years. The battery uses current lithium battery technology, except it contains an organosilicon electrolyte. The new batteries will be used in medical implants, such as muscle stimulators used to help patients with Parkinson's disease (Batteries Digest, 2005§).

Silicon in Computer Chips.—Researchers from the University of Illinois fabricated extra-thin ribbons of silicon that can expand and crumple like an accordion's bellows. Unlike silicon on conventional chips, this new form of silicon can flex, bend, and even conform to curved objects like airplane wings and robotic limbs. Flexible silicon could be used in conformal electronics and devices as well as lead to new types of sensors and environmentally sensitive processors (Chemical & Engineering News, 2005).

Scientists at Intel Corporation's Photonics Technology Lab reported the development of a silicon laser that emits a continuous instead of a pulsed beam. As computer processing speeds increase, they are nearing the physical limits of copper to carry more information. Getting silicon to emit a continuous stream of light could resolve this issue by increasing the flow of data transmitted in computers (Savage, 2005).

Outlook

Demand for ferrosilicon follows trends in the iron and steel industries, for which the combined annual growth rates (CAGRs) have been typically in the range of 1% to 2% in the United States. Details of the outlook for the steel industry are discussed in the Outlook section of the Iron and Steel chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals. Raw steel production decreased by 6% in the United States while increasing 7% globally from that in 2004. World apparent consumption of finished steel products increased by 4.1% to 1.013 billion metric tons (Gt) in 2005 from that in 2004 (International Iron and Steel Institute, 2006§). This increase was primarily attributed to steel consumption in Asia, particularly in China. Asia accounted for 55% of steel consumed worldwide in 2005, up by 10.1% to 554.9 Mt from that in 2004. China alone consumed 315 Mt, a 16.7% increase from 2004. Steel consumption in 2005 was also up in Africa, the Commonwealth of Independent States, and the Middle East.

Demand for silicon metal comes primarily from the aluminum and chemical industries. The American Chemistry Council estimated a slight (0.2%) drop in domestic chemical output in 2005, primarily as a result of damage caused to chemical plants along the Gulf Coast by Hurricanes Katrina and Rita (Storck, 2006, p. 12-15). Demand for silicon by the U.S. aluminum castings industry was expected to mirror the 2.7% increase in aluminum casting shipments forecast for 2006 and to rise by 8.3% and 1.6% by 2008 and 2015, respectively (Kirgin, 2006§).

World production of polycrystalline silicon can be used as a rough indicator of high-purity silicon demand. Compared with that of 2004, world production of polycrystalline silicon was forecast to increase by 8% to 29,100 t in 2005, by 20% to 32,500 t in 2006, and by 46% to 39,500 t in 2007 (Roskill's Letter from Japan, 2006, p. 7).

Demand for microsilica comes from the cement industry. Domestic demand for cement through 2009 was forecast to increase by 2.5% from 120 Mt in 2005 (International Cement Review, 2006). Worldwide demand for cement was projected to rise by 4.1% per year through 2006 to 2.1 Gt, although advances were expected to be less robust in more developed areas, such as Japan, the United States, and Western Europe (Mining Engineering, 2002).

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TABLE 1
SALIENT SILICON STATISTICS[1]

		2001	2002	2003	2004	2005
United States production, si content:						
Ferrosilicon	thousand metric tons	148	150	116	128	125
Silicon metal	do.	134	111	137	147	145
Exports:						
Ferrosilicon	do.	10	7	6	6	8
Silicon metal	do.	12	15	20	18	23
Imports for consumption:						
Ferrosilicon	do.	115	140	189	173	197
Silicon metal	do.	116	145	126	165	152
Apparent consumption:						
Ferrosilicon	do.	258	301	304	297 r	317
Silicon metal	do.	244	240	240	291 r	275
Price, average:						
Ferrosilicon, 50% Si[2]	cents per pound	42.80	41.10	47.70	58.20	55.00
Ferrosilicon, 75% Si[3]	do.	31.90	32.90	45.30	55.40	48.00
Silicon metal[4]	do.	50.50	53.20	61.30	81.90	76.20
World production, gross weight:						
Ferrosilicon	thousand metric tons	4,040 r	4,230 r	4,950 r	5,660 r	5,430
Silicon metal[5]	do.	603 r	610 r	641 r	658 r	662

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]Ryan's Notes North American transaction prices based on weekly averages.

[3]Platts Metals Week mean import prices based on monthly averages.

[4]Platts Metals Week dealer import prices based on monthly averages.

[5]Excluding China.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF SILICON ALLOYS AND METAL IN THE UNITED STATES[1, 2]

(Metric tons)

Material	Silicon content (percent)		2004 producers' stocks, December 31 gross weight	2005		
	Range	Typical		Gross production[3] gross weight	Net shipments gross weight	Producers' stocks, December 31 gross weight
Ferrosilicon[4]	25-65 [5]	48	10,400	123,000	86,200	9,130
Do.	56-95	76	13,100	86,100	89,500	10,800
Silicon metal, excluding semiconductor grades	96-99	98	7,530	148,000	140,000	6,380

[1]Data are rounded to no more than three significant digits.

[2]Data for silvery pig iron (less than 25% silicon) withheld to avoid disclosing company proprietary data.

[3]Ferrosilicon production includes material consumed in the production of miscellaneous silicon alloys.

[4]Includes miscellaneous silicon alloys, which were listed separately prior to 1999.

[5]25% to 55% for ferrosilicon; 32% to 65% for miscellaneous silicon alloys.

TABLE 3
PRINCIPAL PRODUCERS OF SILICON ALLOYS AND/OR SILICON METAL IN THE UNITED STATES IN 2005

Producer	Plant location	Product
CC Metals and Alloys, Inc.	Calvert City, KY	Ferrosilicon.
Elkem Metals Co.	Alloy, WV	Ferrosilicon and Silicon metal.
Globe Metallurgical, Inc.[1]	Beverly, OH	Do.
Do.	Selma, AL	Silicon metal.
Oxbow Carbon and Minerals LLC	Bridgeport, AL	Ferrosilicon.
Simcala, Inc.	Mt. Meigs, AL	Silicon metal.

[1]Globe also had a silicon ferroalloys plant in Niagara Falls, NY, but it was idle in 2005.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND STOCKS OF SILICON FERROALLOYS AND METAL IN THE UNITED STATES IN 2005[1, 2]

(Metric tons, gross weight)

End use	Silvery pig iron[3]	Ferrosilicon, 50%[4]	Ferrosilicon, 75%[5]	Silicon metal[6]	Miscellaneous silicon alloys[7]	Silicon carbide[8]
Steel:						
Carbon and high-strength, low-alloy	--	(9)	17,700	(10)	1,270	(9)
Stainless and heat-resisting	--	(9)	48,100	282	(9)	2,600
Full alloy	--	(9)	7,430	(10)	(9)	--
Electric and tool	--	--	29,800	--	(9)	(9)
Unspecified	--	31,100	(10)	(10)	588	4,900
Total	--	31,100	103,000	282	1,850	7,500
Cast irons	3,720	29,000	27,100	(10)	11,300	25,600
Superalloys	--	(11)	(10)	279	--	--
Alloys, excluding superalloys and alloy steel	(11)	3,920	(10)	55,400 [12]	--	--
Miscellaneous and unspecified	--	--	1,350	178,000 [13]	(11)	--
Grand total	3,720	64,000	132,000	234,000	13,200	33,100
Consumers' stocks, December 31	332	2,960	9,060	1,830	697	1,420

-- Zero.

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

[2]Includes U.S. Geological Survey estimates.

[3]Typically 18% silicon content but ranges between 5% to 24% silicon content.

[4]Typically 48% silicon content but ranges between 25% to 55% silicon content; includes briquets.

[5]Typically 76% silicon content but ranges between 56% to 95% silicon content; includes briquets.

[6]Typically 98% silicon content but ranges between 96% to 99% silicon content.

[7]Typically 48% silicon content. Primarily magnesium-ferrosilicon but also includes other silicon alloys.

[8]Typically 64% silicon content but ranges between 63% to 70% silicon content. Does not include silicon carbide for abrasive or refractory uses.

[9]Included with "Steel: Unspecified," to avoid disclosing company proprietary data.

[10]Included with "Miscellaneous and unspecified," to avoid disclosing company proprietary data.

[11]Included with "Cast irons," to avoid disclosing company proprietary data.

[12]Primarily aluminum alloys.

[13]Primarily silicones, silanes, fumed silica, and other chemicals.

TABLE 5

U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Ferrosilicon:			
More than 55% silicon:			
Canada	8,420	5,050	$7,840,000
China	72	60	50,500
Colombia	27	20	37,400
Costa Rica	1	1	2,570
Hong Kong	5	3	3,930
Jamaica	3	2	3,650
Malaysia	22	16	31,200
Mexico	1,190	715	1,470,000
Netherlands	97	75	158,000
Total	9,830	5,940	9,590,000
Other ferrosilicon:			
Australia	10	5	12,800
Canada	2,680	1,340	2,700,000
Colombia	76	36	104,000
Costa Rica	9	5	11,600
Germany	41	18	41,400
Indonesia	2	1	3,050
Italy	33	17	53,300
Mexico	739	371	827,000
Philippines	2	1	9,090
Spain	20	10	22,500
Other	4	2	3,050
Total	3,610	1,800	3,780,000
Grand total ferrosilicon	13,400	7,740	13,400,000
Metal:			
More than 99.99% silicon:			
China	1,390	1,390	72,500,000
Finland	179	179	5,800,000
Germany	2,070	2,070	88,200,000
Italy	118	118	9,570,000
Japan	7,110	7,110	451,000,000
Korea, Republic of	907	907	57,800,000
Malaysia	73	73	12,500,000
Norway	1,790	1,790	66,600,000
Taiwan	407	407	20,700,000
United Kingdom	392	392	23,500,000
Other	376	376	22,200,000
Total	14,800	14,800 [2]	830,000,000
99.00%-99.99% silicon:			
Brazil	867	860	2,270,000
China	120	119	329,000
France	171	170	415,000
Germany	119	118	290,000
India	29	29	78,800
Japan	101	100	232,000
Mexico	30	29	49,800
Spain	32	32	79,300
Sweden	33	32	46,000
United Kingdom	147	145	207,000
Other	131	130	211,000
Total	1,780	1,770	4,210,000

See footnotes at end of table.

TABLE 5—Continued

U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Metal—Continued:			
Other silicon:			
Brazil	86	83	$113,000
Canada	3,080	2,990	3,180,000
China	1,060	1,030	1,450,000
Germany	180	174	240,000
Japan	418	406	1,270,000
Korea, Republic of	589	572	1,180,000
Mexico	309	301	903,000
Netherlands	334	321	2,770,000
Philippines	82	79	108,000
Russia	224	218	296,000
Other	407	395	1,150,000
Total	6,760	6,560	12,700,000
Grand total silicon metal	23,300	23,100	847,000,000

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

[2]Contained weight estimated using gross weight.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Ferrosilicon:			
55%-80% silicon, more than 3% Ca:			
Argentina	131	91	$204,000
Belgium	3	2	9,840
China	38	17 [2]	53,000
France	414	252	641,000
Germany	10	5	13,300
United Kingdom	9	6	64,300
Total	606	373	985,000
55%-80% silicon, other:			
Brazil	1,600	1,200	1,380,000
Canada	11,900	8,990	10,800,000
China	108,000	81,700	69,500,000
France	3,870	2,630	7,130,000
Germany	441	345	2,190,000
Kazakhstan	103	15 [2]	69,400
Norway	20,000	15,000	19,200,000
Russia	40,900	30,500	27,300,000
Slovenia	274	191	406,000
Venezuela	47,400	35,900	36,300,000
Other	109	78	305,000
Total	235,000	177,000	175,000,000
Magnesium ferrosilicon:			
Argentina	3,450	1,560	3,540,000
Brazil	2,280	1,020	2,050,000
Canada	6,450	2,980	6,220,000
China	7,130	3,290	5,230,000
France	393	198	368,000
India	119	54	135,000
Japan	350	169	495,000
Netherlands	878	409	719,000
Norway	8,880	4,140	8,020,000
South Africa	76	35	85,500
Other	31	17	69,500
Total	30,000	13,900	26,900,000
Other ferrosilicon:			
Brazil	145	64	273,000
Canada	8,780	2,470	6,880,000
China	13,900	3,230	4,600,000
France	32	19	78,700
Germany	(3) [2]	30	6,990
India	251	149	271,000
Russia	1,520	697	656,000
Slovakia	3	1	5,690
Ukraine	22	11	18,300
United Kingdom	20	3	27,800
Total	24,700	6,670	12,800,000
Grand total ferrosilicon	290,000	197,000	215,000,000

See footnotes at end of table.

TABLE 6—Continued
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Metal:			
More than 99.99% silicon:			
China	27	27	$1,080,000
Denmark	3	3	1,210,000
Germany	849	849	65,600,000
Italy	322	322	13,000,000
Japan	538	538	40,300,000
Korea, Republic of	119	119	8,390,000
Philippines	179	179	253,000
Poland	10	10	29,900
Spain	6	6	52,200
Taiwan	5	5	479,000
Other	12	12	858,000
Total	2,070	2,070 [4]	131,000,000
99.00%-99.99% silicon:			
Australia	8,330	8,290	14,200,000
Brazil	51,500	51,200	71,500,000
Canada	16,800	16,700	27,100,000
France	1,560	1,550	2,140,000
India	114	113	167,000
Norway	7,010	5,760 [2]	15,500,000
Philippines	1,850	1,490 [2]	2,680,000
South Africa	34,800	34,500	52,300,000
Sweden	36	24 [2]	255,000
United Kingdom	189	83 [2]	763,000
Other	40	40	71,600
Total	122,000	120,000	187,000,000
Other silicon:			
Brazil	11,400	11,200	16,800,000
Canada	11,600	10,100	18,300,000
China	2,440	2,390	2,630,000
France	520	513	633,000
Germany	230	221	564,000
Norway	3,560	3,500	5,480,000
South Africa	230	224	274,000
Sweden	444	72	494,000
Ukraine	1,040	1,020	1,320,000
United Kingdom	342	329	553,000
Other	947	688	1,400,000
Total	32,800	30,300	48,500,000
Grand total silicon metal	157,000	152,000	366,000,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]All or part of these data have been referred to the U.S. Census Bureau for verification.
[3]Less than ½ unit.
[4]Contained weight estimated using gross weight.

Source: U.S. Census Bureau.