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GALLIUM

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Gallium

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Globally, primary (crude, unrefined) gallium is recovered as a byproduct of processing bauxite and zinc ores. No domestic primary gallium was recovered in 2012, and imports of gallium metal and gallium arsenide (GaAs) wafers continued to account for most of U.S. gallium consumption. Metal imports were 32% lower than those in 2011. The leading sources of imported gallium, in descending order of imports by gallium content, were Germany, China, the United Kingdom, and Ukraine. Doped GaAs wafer (a wafer with intentionally modified electrical properties) imports were about the same as those in 2011—Germany and Japan were the principal sources. Undoped GaAs wafer imports were substantially lower than those in 2011—Austria, Canada, and Japan were the principal sources. Almost all gallium consumed in the United States was for the production of GaAs and gallium nitride (GaN), which along with imported wafers, were used in integrated circuits (ICs) and optoelectronic devices [laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells]. Gallium consumption decreased slightly from that in 2011. In 2012, the quantity of gallium consumed in the United States was less than the quantity imported because a significant portion of imports was estimated to be low-purity gallium that was refined in the United States and shipped to other countries. Data on refined gallium exports were not available.

In 2012, estimated world primary gallium production was 383 metric tons (t). Principal producers were China, Germany, Japan, Kazakhstan, Russia, and Ukraine. Plants in Hungary and the Republic of Korea also recovered gallium. Refined gallium production was estimated to be about 250 t, which may include some refined from new scrap. Refined gallium was produced in China, Japan, the United Kingdom, and the United States.

Legislation and Government Programs

TriQuint Semiconductor, Inc. (Hillsboro, OR) continued work on phase 2 of the Defense Advanced Research Projects Agency (DARPA) multiyear Nitride Electronic NeXt-Generation Technology (NEXT) program. The NEXT program was established to create digital GaN circuits for defense and aerospace applications. Phase 1 concentrated on fabricating very-high-frequency devices and meeting defined yield metrics. Phase 2 was to concentrate on process development in the pursuit of increased yields while doubling the current operating frequency to 400 gigahertz. The devices developed under the NEXT program were expected to advance applications for lower voltage GaN-based products, which achieve power densities four times higher than GaAs devices (Compound Semiconductor, 2012c; TriQuint Semiconductor, Inc., 2013, p. 6–7).

Production

No domestic production of primary gallium was reported in 2012 (table 1). In June, Molycorp Inc. (Greenwood Village, CO) acquired Neo Material Technologies Inc. (Toronto, Ontario, Canada), the largest gallium refiner/recycler in Canada and the United States. Molycorp recovered gallium from scrap materials, predominantly those generated during the production of GaAs. Molycorp's Blanding, UT, facility had the capability to produce about 50 metric tons per year (t/yr) of high-purity gallium. The company produced high-purity gallium from its customers' scrap and purchased scrap and low-purity gallium. Molycorp's other gallium operations included a gallium trichloride production facility in Quapaw, OK; a 50% interest in a primary gallium facility in Stade, Germany; a gallium recycling facility in Peterborough, Ontario, Canada; and an 80% interest in a new gallium trichloride production facility in the Hyeongok Industrial Zone in the Republic of Korea. Gallium trichloride is a precursor for many gallium compounds, including the organic gallium compounds used in epitaxial growth (Molycorp Inc, 2013, p. 6, 43, 89).

Consumption

Gallium consumption data were collected by the U.S. Geological Survey from a voluntary survey of U.S. operations. In 2012, 65% of the canvassed respondents replied to the gallium consumption survey. Data in tables 2 and 3 were adjusted by incorporating estimates to reflect full industry coverage. Many of these estimates were based on company reports submitted to the U.S. Securities and Exchange Commission.

More than 99% of the contained gallium consumed in the United States was in the form of GaAs or GaN. GaAs was used to manufacture optoelectronic devices (laser diodes, LEDs, photodetectors, and solar cells) and ICs. ICs accounted for 68% of domestic consumption and optoelectronic devices accounted for 32% (table 2). GaN principally was used to manufacture LEDs and laser diodes.

In 2012, U.S. consumption of gallium for use in ICs decreased by 7% from that in 2011 owing to a decreased rate of growth of GaAs-rich "smartphones" (cellular telephones with advanced personal computer-like functionality) and reduced demand for other wireless communication devices. Gallium use in LEDs and laser diodes increased by 10% from that in 2011 owing to increased demand for LEDs in general lighting applications. Gallium supplied to the photodetector and solar cell industry decreased by 9% from that in 2011 owing to decreased prices of silicon-based solar cells slowing demand for the more expensive copper-indium-gallium-diselenide (CIGS) technology. A complicated manufacturing process also impeded commercial mass production of CIGS panels. GaAs applications comprised about 80% of the worldwide gallium market in 2012, while GaN applications comprised about 7%, and CIGS comprised about 5% (Spicer, 2013).

Gallium Arsenide.—The value of worldwide GaAs devices consumed increased to $5.3 billion in 2012, from $5.2 billion in 2011. The GaAs device market rate of growth slowed in 2012 owing primarily to a decreased rate of growth of third-generation (3G) and fourth-generation (4G) smartphones, as well as reduced demand for radio frequency (RF) circuits and wired and wireless networks. With the exception of 2009, when GaAs device consumption remained flat owing to the global economic downturn, the rate of growth in 2012 was the lowest since 2004. Developments in cellular telephone technology, particularly sophisticated 3G and 4G smartphones, continued to drive the GaAs device industry, accounting for more than 50% of the GaAs device market in 2012. Fourth-generation smartphones use up to 10 times the amount of GaAs that a standard cellular telephone does. The rate of growth of global smartphone shipments slowed to 43% in 2012 from 64% in 2011 as penetration of smartphones began to mature in developed regions such as North America and Western Europe. The proportion of smartphones shipped worldwide increased to 38% of total handset shipments in 2012 from 32% in 2011 (Higham, 2013a; IQE plc, 2013, p. 18; Semiconductor Today, 2013b, e).

The value of worldwide GaAs bulk substrate consumption decreased by 10% to $193 million in 2012 owing to a combination of slow growth in the GaAs device market, the conversion of cellular telephone switches from GaAs to silicon-on-insulator technology, and the economic slowdown in Europe. The GaAs substrate market was also affected by cellular radio architecture migrating towards a less GaAs-intensive single multi-band power amplifier from multiple single-band power amplifiers. Japan, the world's largest producer of GaAs bulk substrates, reported that the value of GaAs substrate shipments was down 22% from that in 2011. North America was the world's largest consumer of GaAs bulk substrates, comprising 60% of the market (Higham, 2013a, b; Roskill's Letters from Japan, 2013a).

Gallium Nitride.—Increased demand for GaN devices, namely laser diodes, power electronics, and RF electronics, provided significant growth for advanced GaN-based products. The key drivers of GaN-based technology have been military and defense applications, but the technology also was being used in automotive, industrial, medical, and commercial applications such as cable television and wireless infrastructure. The value of the worldwide GaN device market was estimated to be approximately $100 million in 2012 (Compound Semiconductor, 2013d).

Owing to increased development of advanced power applications in information and communications technology and industrial power markets worldwide, the value of the worldwide GaN power semiconductor market increased to an estimated $12.6 million in 2012, a fivefold increase from $2.5 million in 2011. GaN power transistors operated at higher voltages and with a higher power density than existing GaAs devices. The major application segments for GaN power semiconductors were inverters, motor drives, power supply modules, and RF devices. The value of the GaN power semiconductor market was forecast to reach $1.75 billion by 2022 (Semiconductor Today, 2012f).

Light-Emitting Diodes.—The worldwide high-brightness light-emitting diode (HB-LED) market increased to $13.7 billion in 2012, a 10% increase from $12.5 billion in 2011. Owing to significant LED capacity expansion in 2011 and the resulting LED surplus, prices for HB-LEDs decreased in 2012. The lower prices, however, proved beneficial to the HB-LED lighting sector, where LED consumption more than doubled from that of 2011 and helped offset the decline in LED revenue from the backlighting sector. As a result of its increased consumption in 2012, LEDs for general lighting applications became the largest segment of the market. Research and consulting firm Strategies Unlimited reported that the general lighting segment comprised 23% of the HB-LED market, while the television and monitor backlighting segment comprised 22%. Mobile display applications (such as cellular telephones, computer notebooks and tablets, eBooks, and MP3 players) had a 19% share. Additional HB-LED market segments in 2012 included signage and automotive, with respective market shares of 13% and 10%. Various smaller market segments comprised the remaining 13% of the overall HB-LED market (Strategies Unlimited, 2013).

Japan and the Republic of Korea supplied 30% and 28%, respectively, of the 2012 worldwide HB-LED market, followed by the United States and Europe, 19%; Taiwan and Southeast Asia, 15%; and China, 8%. China's HB-LED market share quadrupled from 2% in 2010 owing to the large investments the country made in its domestic solid-state lighting industry (Strategies Unlimited, 2013).

In 2012, an estimated total of 142 LED fabrication plants were in operation worldwide, up from 64 plants in 2006. Taiwan's LED fabrication plants accounted for 28% of global capacity, followed by Japan (22%), China (21%), the Republic of Korea (19%), North America and South America (6%), Southeast Asia (3%), and Europe and the Mideast (1%) (Peters, 2012).

As HB-LED demand increased throughout 2010 and the first half of 2011, materials suppliers began adding more capacity for trimethylgallium (TMG), the metal-organic chemical used to fabricate LED epiwafers. When TMG and nitrogen gas are fed into the metal-organic chemical vapor deposition (MOCVD) reactor and heated, a GaN layer is formed on the epiwafer. TMG's purity and quality determine an LED's brightness and reliability. In 2012, an estimated 30 t of TMG was consumed worldwide, with 80% consumed by China, the Republic of Korea, and Taiwan (Compound Semiconductor, 2013a). Albermarle Corp. (Baton Rouge, LA) continued the construction of its TMG and triethylgallium (TEG) production facility in the Republic of Korea (Semiconductor Today, 2012b). SAFC Hitech, a subsidiary of Sigma-Aldrich Co. LLC (St. Louis, MO), began the expansion of its TMG and TEG production facility in Kaohsiung, Taiwan (Sigma-Aldrich Co. LLC, 2012). AkzoNobel N.V. (Amsterdam, The Netherlands) announced it was to build a new TMG plant in Deer Park, TX, which was expected to be operational by 2014 (Semiconductor Today, 2012a).

GaN devices were estimated to account for 85% of total revenues in the LED industry, and dominated key LED applications such as televisions, computer monitors, notebook computers, and tablet computers (Semiconductor Today, 2013c).

Solar Cells.—In 2012, the solar cell market continued to be dominated by crystalline silicon solar cells, which account for approximately 90% of the market. Industry experts had thought that CIGS would eventually be able to compete with conventional silicon-based photovoltaic technology. CIGS technology, however, has been slow to enter the commercial market owing to a decline in prices of silicon-based solar cells and a complicated manufacturing process that has impeded commercial mass production of CIGS panels. These two factors resulted in a large oversupply of CIGS modules that caused prices to decrease on average by 40% from 2010 to 2011, with further price decreases expected by yearend 2012 (Osborne, 2012). World production of CIGS solar cells decreased to 770 megawatts (MW) in 2012, a 5% decrease from 813 MW produced in 2011. World production of CIGS solar cells in 2011, however, had increased by 91% from that in 2010 (Roskill's Letters from Japan, 2013b).

Nevertheless, consulting firm Lux Research, Inc., (Boston, MA) reported that CIGS manufacturers trimmed production costs, increased production capacities, improved module conversion efficiencies, and increased CIGS adoption in commercial rooftops. Strategic partnerships and consolidation of the industry were considered key in keeping CIGS technology viable and competitive (Lux Research, Inc., 2012).

At yearend 2012, scientists at Empa, the Swiss Federal Laboratories for Materials Science and Technology in Dübendorf, Switzerland, achieved a record 20.4% efficiency for their CIGS solar cell on a flexible polymer substrate in a laboratory setting (Empa, 2013).

Prices

Since 2002, producer prices for gallium have not been quoted in trade journals. Data in table 4 represent the average customs value of gallium imported into the United States. Reports in Metal-Pages indicated volatile gallium prices during 2012. At the beginning of the year, the low-grade gallium price was reported to be about $520 per kilogram (a decrease of 18% from that in January 2011) as the market for LED backlighting in televisions did not increase as forecast and newly expanded primary gallium capacity in China greatly exceeded demand. By May, the price had decreased to about $360 per kilogram, and by December, the price decreased to about $280 per kilogram.

From U.S. Census Bureau import data, the annual average value for low-grade (≤99.99%-pure) gallium in 2012 was estimated to be $349 per kilogram, about 7% less than that in 2011. For high-grade (≥99.9999%-pure) gallium, the annual average estimated value decreased by 23% to $529 per kilogram. Import data reported by the U.S. Census Bureau do not specify purity, so the values listed in table 4 were estimated based on the average value of the material imported and the country of origin.

Foreign Trade

In 2012, U.S. gallium imports were 32% less than those in 2011 (table 5). Germany (41%), China (39%), United Kingdom (11%), and Ukraine (4%) were the leading sources of imported gallium.

In addition to gallium metal, GaAs wafers were imported into the United States (table 6). In 2012, 218,000 kilograms (kg) of doped GaAs wafers and 3,610 kg of undoped GaAs wafers were imported. Imports of doped GaAs wafers were about the same as those in 2011, while imports of undoped GaAs wafers were 96% less than those in 2011. The large reduction in undoped GaAs wafer imports was most likely due to a combination of a reduced rate of growth in the GaAs device market, migration of multiple GaAs-intensive single-band power amplifiers toward a less GaAs-intensive single multi-band power amplifier in cellular radio architecture, and disruption of the GaAs substrate supply chain caused by the earthquake and tsunami in Japan in 2011. The data listed in table 6 may include some packaging material weight and, as a result, quantities may be higher than the actual total weight of imported wafers.

World Review

Imports of gallium into Japan and the United States, two leading consuming countries, and an updated gallium production estimate for China, were used as the basis for estimating world gallium production. In addition, Metal Bulletin reported China's production increased considerably as a result of substantial capacity increases of Chinese gallium operations. Estimated worldwide primary gallium production was 383 t in 2012. Principal world producers were China, Germany, Japan, Kazakhstan, Russia, and Ukraine. Gallium also was recovered in Hungary and the Republic of Korea. Refined gallium production in 2012 was estimated to be about 250 t, 35% lower than the year's primary production. China, Japan, the United Kingdom, and the United States refined gallium. Updated refined gallium production figures for 2010 and 2011 were estimated to be 268 t and 242 t, respectively.

Roskill Information Services estimated worldwide gallium consumption to be 234 t in 2012, 50 percent of which was estimated to have come from recycled material (Seeley, 2011; Roskill's Letters from Japan, 2012). German recycler PPM Pure Metals GmbH estimated 2012 worldwide gallium consumption to be slightly higher, at 250 t, with 40% to 45% of consumption coming from recycled material (Spicer, 2013). Gallium was recycled from new scrap in Canada, Germany, Japan, the United Kingdom, and the United States.

Canada.—In 2012, minor metals refiner 5N Plus Inc. (Montreal, Quebec) acquired the remaining 50% ownership interest in the joint-venture company MCP Metals (Shenzhen) Co., Ltd. from Hong Kong based Golden Harvest Investments Ltd. MCP Metals operates a gallium refining facility in Shenzhen, China. Additionally, 5N Plus announced its new solar cell recycling facility in Malaysia was operational (Liu, 2012).

Orbite Aluminae Inc. (Montreal, Quebec) (formerly known as Exploration Orbite V.S.P.A. Inc.) announced that construction of its high-purity alumina plant, located in Cap-Chat, Quebec, was near completion. A separation facility was to be built at the alumina plant to recover 4N purity (99.99%) gallium and other rare metals and rare-earth elements. Production capacity was reported to be 90 t/yr of primary gallium (Orbite Aluminae Inc., 2012).

China.—China invested substantially in its LED manufacturing infrastructure, which was valued at $6.6 billion in 2012, an increase of 25% from $5.3 billion in 2011 (Gu, 2012). Subsidies from local governments were instrumental in helping ramp up LED production capacity. In 2012, the Chinese Government passed a series of domestic policies to stimulate LED lighting demand and strengthen the business momentum within the LED lighting market. The country was reported to have produced 300 t of primary gallium in 2012, and increased its primary gallium manufacturing capacity to 350 t in 2012 from 280 t in 2011 (Metal-Pages Ltd, 2012; Metal Bulletin, 2013; Semiconductor Today, 2013a).

China's primary gallium producers were Aluminum Corporation of China, Ltd.; Beijing JiYa Semiconductor Material Co., Ltd.; China Crystal Technologies, Ltd.; East Hope Mianchi Gallium Industry Co.; and Zhuhai Fangyuan (Roskill Information Services, Ltd., 2011, p. 21–26).

Japan.—The Japan Oil, Gas, and Metals National Corp. (JOGMEC) estimated that Japan consumed 85 t of gallium in 2012, with the LED market accounting for approximately 60% of consumption. About 55% of Japan's gallium supply was sourced from imports, while 40% was from reprocessed scrap. The remaining 5% was primary gallium produced by Japan as a by-product of its zinc refining process (Kamiki Takashi and Yamamoto Koji, Rare Metals Stockpile Department, Japan Oil, Gas, and Metals National Corp., written commun., February 13, 2013).

Following the 2011 earthquake and the resulting tsunami that devastated northeast Japan, several Japanese compound semiconductor-related manufacturing plants were destroyed, which reduced Japanese production of GaAs substrates (Compound Semiconductor, 2012a). In addition, Japan's shipments of GaAs decreased by 22% in value in 2012 compared with those of 2011 owing to the economic slowdown in Europe and competition from overseas producers. Japan's shipments of gallium phosphide decreased by 15% in value from 2011 due to competition from lower cost Chinese LED producers (Roskill's Letters from Japan, 2013a).

Korea, Republic of.—Molycorp began commercial operation of its gallium trichloride production facility in the Hyeongok Industrial Zone, which was regarded as the center of the country's LED industry. The new facility was built to supply gallium trichloride to Asian markets as well as to serve as a backup for Molycorp's gallium trichloride facility in Quapaw, OK (Molycorp, Inc., 2013).

United Kingdom.—In 2012, IQE plc (Cardiff, Wales) acquired the molecular beam epitaxy (MBE) epiwafer manufacturing unit of RF Micro Devices Inc. (Greensboro, NC). The transferred assets include a 8,400 square meter cleanroom and 16 MBE manufacturing systems and equipment in Greensboro. The value of the transferred assets was about $27 million (Semiconductor Today, 2012g).

In January 2013, IQE completed the acquisition of the Kopin Wireless compound semiconductor epiwafer manufacturing division of Kopin Corp. (Taunton, MA), plus its 90.2% controlling interest in subsidiary Kopin Taiwan Corp. in Hsinchu, Taiwan. Kopin Wireless was a global manufacturer of heterojunction bipolar transistors, which are used in power amplifiers, a key wireless component in mobile devices. The devices are produced using MOCVD epitaxial wafer technology (Compound Semiconductor, 2013b).

Outlook

According to IQE, smartphones represented a fundamental structural shift in mobile communications. Smartphones, which use up to 10 times the amount of GaAs-rich RF content than standard cellular telephones, were expected to account for 43% of all handset sales by 2014 (IQE plc, 2012, p. 8). Installation of 3G and 4G mobile networks in India and the Republic of Korea was expected to further increase sales of smartphones. Additional increases in GaAs demand will also result from new applications for wireless fidelity (WiFi), such as point-to-point communications, smart meters, and tablet personal computer technologies. Market research firm Yole Développement predicted that the GaAs substrate market would increase nearly 11% per year through 2017 owing primarily to the rise in GaAs content in handsets and increased penetration of LEDs in general lighting and automotive applications (Semiconductor Today, 2012e). Strategy Analytics was more conservative in its growth forecast of the GaAs device market, anticipating 3.6% per year growth through 2016 owing to a slowing rate of growth in the smartphone handset market and an uncertain global economy (Semiconductor Today, 2012d).

Yole Développement reported that emerging companies in the GaN power device market were expected to transition from qualification to production ramp up in 2013, and the increased GaN device capacity would enable the market to expand rapidly. It was thought that the GaN power device market could reach $1 billion in revenue by 2019 if GaN power devices were qualified in the electric vehicle/hybrid electric vehicle sector. Yole Développement also indicated that some LED manufacturers were considering manufacturing GaN power electronics as a means of diversifying their excess LED fabrication capacity (Keller, 2012).

Strategy Analytics forecast the overall GaN device market would increase at nearly 29% per year, to reach $178 million in 2015. The U.S. defense industry was expected to continue to be the major customer of GaN devices. The percentage of total GaN revenue derived from military applications, however, would decrease to 67% in 2015 from 98% in 2010, as GaN's efficiency, power dissipation, and operating temperature advantages increasingly are used in commercial market applications (Compound Semiconductor, 2012b).

Owing to significant expansion of LED manufacturing capacity, reduced prices, government incentives, and a lower rate of adoption of LED television backlighting, the LED industry was expected to expand its general lighting applications for the rest of the decade. The highest growth was forecast to be in LED-based tubes that replace fluorescent tubes used in commercial applications, LED-based street lights, and LED luminaires of varying sizes. Since 2011, Japan has had the largest market for LED lighting applications and was expected to continue leading the market through 2016. China, Europe, and North America also were expected to increase their demand for LED lighting applications (Compound Semiconductor, 2013c).

As the market for general LED lighting increases, global demand for the precursors TMG and TEG was expected to more than double to about 70 t by 2016. China was forecast to consume up to 45% of the precursors in 2016. MOCVD system shipments, however, were predicted to decrease by 46% in 2013 owing to sufficient capacity already established by the LED chipmakers and the decreasing number of LEDs required by LED televisions (Compound Semiconductor, 2013a; Semiconductor Today, 2013d).

More than 100 billion GaN LEDs, valued at more than $10 billion, were forecast to ship in 2013. The revenue in 2013 was expected to be double that of 2009, while unit shipments will have more than tripled (Semiconductor Today, 2013c).

Industry analyst firm NanoMarkets, LC, forecast that the CIGS market could reach $4.4 billion by 2017 provided that CIGS manufacturers adopt new strategies to protect themselves from declining crystalline silicon solar panel prices. NanoMarkets expected CIGS manufacturers to continue reducing prices as a result of increases in production volume and manufacturing efficiencies, as well as aggressive recycling strategies (Semiconductor Today, 2012c).

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TABLE 1
SALIENT U.S. GALLIUM STATISTICS[1]

(Kilograms unless otherwise specified)

		2008	2009	2010	2011	2012
Production		--	--	--	--	--
Imports for consumption		41,100	35,900	59,200	85,700	58,200
Consumption		28,700	24,900	33,500	35,300	34,400
Price[2]	dollars per kilogram	579	449	600	688	529

-- Zero.
[1]Data are rounded to no more than three significant digits.
[2]Estimate based on average value of U.S. imports of high-purity gallium.

TABLE 2
U.S. CONSUMPTION OF GALLIUM, BY END USE[1, 2]

(Kilograms)

End use	2011	2012
Optoelectronic devices:		
Laser diodes and light-emitting diodes	9,500	10,400
Photodetectors and solar cells	705	642
Integrated circuits:		
Analog	22,900	20,600
Digital	2,050	2,730
Research and development	123	32
Total	35,300	34,400

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes gallium metal and gallium compounds.

TABLE 3
STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM, BY GRADE[1, 2]

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2011:				
99.99% to 99.999%	3,870	1,290	7	5,150
99.9999%	960	679	301	1,340
99.99999% to 99.999999%	144	842	619	367
Total	4,970	2,810	927	6,850
2012:				
99.99% to 99.999%	5,150	-217 [3]	--	4,930
99.9999%	1,340	-242 [3]	2	1,090
99.99999% to 99.999999%	367	655	828	194
Total	6,850	195	829	6,220

-- Zero.
[1]Consumers only.
[2]Data are rounded to no more than three significant digits; may not add to totals shown.
[3]Reshipments exceeded receipts.

TABLE 4
ESTIMATED AVERAGE GALLIUM PRICES

(Dollars per kilogram)

Gallium metal	2011	2012
Purity ≥ 99.9999%; average value of U.S. imports	688	529
Purity ≤ 99.99%; average value of U.S. imports	374	349

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF GALLIUM (UNWROUGHT, WASTE, AND SCRAP), BY COUNTRY[1]

	2011		2012	
Country	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Canada	--	--	199	$55,500
China	8,890	$6,540,000	22,700	9,200,000
France	1,290	667,000	319	163,000
Germany	35,200	13,000,000	23,900	8,230,000
Hungary	268	152,000	--	--
Japan	1,250	844,000	1,130	529,000
Korea, Republic of	1,420	900,000	1,130	231,000
Netherlands	3,100	1,720,000	--	--
Russia	701	607,000	--	--
Singapore	6,050	2,880,000	48	20,500
Ukraine	149	123,000	2,170	632,000
United Kingdom	27,300	16,200,000	6,500	3,610,000
Other	--	--	130	56,000
Total	85,700	43,700,000	58,200	22,700,000

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

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF
GALLIUM ARSENIDE WAFERS, BY COUNTRY[1]

	2011		2012	
Material and country	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Undoped:				
Austria	26	$18,800	117	$78,000
Canada	2,910	23,600	2,980	25,100
China	558	178,000	1	6,000
Germany	11,200	131,000	10	17,600
Japan	12,300	41,700	460	80,600
Taiwan	59,400	304,000	6	19,600
United Kingdom	25	2,360	5	13,600
Other	25	4,730	31	7,720
Total	86,500	704,000	3,610	248,000
Doped:				
Belarus	9,030	1,980,000	6,700	719,000
Belgium	445	588,000	3,390	600,000
China	15,100	22,100,000	20,700	20,200,000
Czech Republic	1,190	1,230,000	199	59,500
Finland	6,490	4,400,000	7,650	5,160,000
France	2,290	3,670,000	8,620	12,000,000
Germany	56,000	31,600,000	44,900	28,600,000
Italy	83	57,200	1,050	431,000
Japan	84,000	96,900,000	71,000	77,300,000
Korea, Republic of	1,830	697,000	12,900	1,290,000
Malaysia	195	27,500	3,240	276,000
Poland	700	644,000	557	453,000
Singapore	6,560	10,700,000	9,200	13,400,000
Taiwan	17,300	45,700,000	24,800	47,400,000
United Kingdom	9,280	3,250,000	1,800	2,500,000
Other	4,120 r	1,950,000 r	1,550	910,000
Total	215,000	225,000,000	218,000	211,000,000

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

Source: U.S. Census Bureau.

TABLE 7
ESTIMATED WORLD ANNUAL PRIMARY GALLIUM
PRODUCTION CAPACITY, DECEMBER 31, 2012[1]

(Metric tons)

Country	Capacity
China	350
Germany	40
Hungary	8
Japan	10
Kazakhstan	25
Korea, Republic of	16
Russia	10
Ukraine	15
Total	474

[1]Includes capacity at operating plants as well as at plants on standby basis.