2017 Minerals Yearbook

GALLIUM [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

April 2020

Gallium

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Low-grade primary gallium was recovered globally as a byproduct of processing bauxite and zinc ores. No domestic low-grade primary gallium was recovered in 2017. Imports of gallium metal and gallium arsenide (GaAs) wafers plus domestically refined and recycled gallium continued to account for all U.S. gallium consumption (metal and gallium in GaAs). Metal imports were 93% higher than those in 2016 (table 1). The leading sources of imported gallium metal were, in descending order, China (including Hong Kong), the United Kingdom, France, Ukraine, Russia, and the Republic of Korea (table 4). A significant portion of imports was thought to be low-grade gallium that was refined in the United States and shipped to other countries. Data on refined gallium exports, however, were not available. Doped GaAs wafer (a wafer with intentionally modified electrical properties) imports decreased by 36% from those of 2016. China was the leading source, followed by Taiwan, Japan, Germany, France, and the Republic of Korea in descending order of quantity (table 5). The U.S. Census Bureau ceased reporting undoped GaAs wafer imports in 2017. 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]. U.S. gallium consumption decreased slightly from that in 2016 owing to a decline in gallium consumed for the production of analog and digital ICs, laser diodes and LEDs, and photodetectors and solar cells (table 2), as well as a decrease in doped GaAs wafer imports. Although gallium metal imports increased by 93% in 2017, most likely owing to consumer restocking, refined gallium metal consumption decreased by 8% (table 3). About 97% of the gallium metal consumed was at a purity level of 99.99999% to 99.999999%.

In 2017, estimated world low-grade primary gallium production was 317 metric tons (t), an increase of approximately 20% from estimated production of 265 t in 2016 (table 6). China, which accounted for 83% of global low-grade primary gallium capacity (fig. 1, table 7), was the leading producer. Japan, the Republic of Korea, Russia, and Ukraine accounted for the remaining production. Germany ceased primary gallium production in 2016 owing to a prolonged period of low prices. The estimated worldwide compound annual growth rate (CAGR) of low-grade primary gallium production was 13% from 2007 through 2017 (fig. 2), primarily owing to China's large annual increases in production beginning in 2010. About 192 t of low-grade primary gallium was processed to high-grade refined gallium; the remaining low-grade primary gallium produced in 2017 was most likely stockpiled. High-grade primary refined gallium was produced in China, Japan, the United Kingdom, the United States, and possibly Slovakia. The worldwide CAGR of high-grade primary refined gallium production was 5% from 2007 through 2017. World high-grade secondary refined gallium production increased at a CAGR of 7%. World gallium consumption, which increased at a CAGR of 6% from 2007 through 2017, was estimated to have been 355 t in 2017.

Production

No domestic production of low-grade primary gallium was reported in 2017. Neo Performance Materials Inc. (Canada) recovered gallium from new scrap materials, predominantly those generated during the production of GaAs ingots and wafers. Neo's facility in Blanding, UT, had the capability to produce about 50 metric tons per year of high-grade gallium. The company purchased new scrap and low-grade primary gallium to refine into high-grade gallium. It also refined its customers' scrap into high-grade gallium. Neo's other gallium investments included an 80% interest in a gallium trichloride production facility in Quapaw, OK; a gallium recycling facility in Peterborough, Ontario, Canada; and an 80% interest in a 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 layering (Neo Performance Materials Inc., 2018, p. 5, 7, 19, 20).

Consumption

U.S. Consumption

Gallium consumption data were collected by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations. In 2017, 65% of those canvassed responded to the gallium consumption survey. Data in tables 2 and 3 incorporated estimates for the nonrespondents to reflect full-industry coverage. Many of these estimates were based on company reports submitted to the U.S. Securities and Exchange Commission.

GaAs was used to manufacture ICs and optoelectronic devices. GaN principally was used to manufacture LEDs and laser diodes. ICs accounted for 68% of domestic gallium consumption, optoelectronic devices accounted for 30%, and research and development accounted for the remainder (table 2). Approximately 75% of the gallium consumed in the United States was contained in GaAs and GaN wafers. Gallium metal, trimethylgallium (TMG), and triethylgallium (TEG) used in the epitaxial layering process to fabricate epiwafers for the production of LEDs and ICs accounted for most of the remainder.

In 2017, U.S. gallium consumption was 17.9 t, a slight decrease from 18.1 t in 2016 owing to a slight decline in gallium consumed for the production of analog and digital ICs, laser diodes and LEDs, and photodetectors and solar cells, as well as a 36% decrease in doped GaAs wafer imports (tables 2, 5). Refined gallium metal consumption decreased by 8% from that of 2016 (table 3). About 97% of the gallium metal consumed was at a purity level of 99.99999% to 99.999999%. U.S. gallium consumers opening new GaAs wafer production facilities in Asia to be closer to the Asian-dominated optoelectronics industry were thought to be a leading cause for the decrease in U.S. gallium consumption and gallium wafer imports.

Global Consumption

Gallium Arsenide.—Wireless applications continued to drive the radio frequency (RF) GaAs device market in 2017. The value of RF GaAs devices consumed worldwide increased by 7% to approximately $8.8 billion from $8.2 billion in 2016 (Strategy Analytics Inc., 2018).

Worldwide shipments of smartphones from device vendors in 2017 totaled more than 1.49 billion units, a slight increase from 1.47 billion units shipped in 2016. China, Europe, North America, and India were the principal regions and (or) countries of smartphone growth in 2017, with China accounting for 30% of smartphone sales, Europe accounting for 14% of sales, North America accounting for 12% of sales, and India accounting for 9% of sales. India, which has become one of the fastest growing smartphone markets in the world, was projected to overtake North America in sales by 2020 and account for 13% of the smartphone market (Scarsella and Stofega, 2017; Statista Inc., undated).

The value of GaAs wafers consumed worldwide increased by an estimated 13% in 2017, to $790 million from $700 million in 2016. Countries within the Asia and the Pacific region dominated the GaAs wafer market, with cellular, optoelectronics, and regional wireless manufacturers consuming an estimated 61% of the GaAs wafers. The three largest GaAs wafer manufacturers in the world—WIN Semiconductors Corp. (Taiwan), Advanced Wireless Semiconductor Company (Taiwan), and Global Communication Semiconductors, LLC (Torrance, CA), in order of market share—have wafer foundries in Taiwan. Wireless and cellular manufacturers within North America consumed an estimated 26% of GaAs wafers. Device manufacturers in Europe and the rest of the world consumed about 4% and 9%, respectively, of the remaining GaAs wafers (Technavio, 2016a, p. 21, 33–40). Globally, by volume, wireless and cellular manufacturers consumed approximately 58% of GaAs wafers in 2017, and optoelectronics manufacturers consumed the remaining 42% (QYR Electronics Research Center, 2018, p. 44).

Gallium Nitride.—Increased demand for GaN devices, such as opto semiconductors (LEDs and laser diodes) and power semiconductors (pure power devices and RF devices), provided significant growth for advanced GaN-based products. In 2017, worldwide bulk GaN substrate production was estimated to be approximately 75,000 wafers (2-inch equivalent), an increase of 25% from 60,000 wafers produced in 2016 (Yole Développement, 2017a).

Prior to construction of the GaN devices, GaN substrates, where GaN is grown epitaxially on sapphire, silicon, or silicon carbide wafers, or to a lesser extent, on GaN wafers, were mostly produced and consumed in the Asia and the Pacific region. China, Japan, and the Republic of Korea accounted for more than 80% of world production. It was reported that the costs of the gallium material and fabrication were lower in China than elsewhere, and the country has attracted an increasing number of GaN substrate manufacturers (Semiconductor Today, 2015; Transparency Market Research, 2016).

GaN RF device sales increased by an estimated 12% to approximately $380 million owing to an increase in wireless infrastructure applications. Telecommunications, which accounted for 40% of sales, and defense use, which accounted for 38% of sales, were the two dominant applications for GaN RF devices. Cable TV, civil radar and avionics, and satellite communications were also significant applications (Yole Développement, 2018).

In 2017, GaN power device sales were approximately $22 million, a 57% increase from $14 million in 2016 (Yole Développement, 2017b). GaN power devices operate at higher voltages, power densities, and switching frequencies, and offer greater power efficiency than existing GaAs and silicon devices. Increased demand from the military for enhanced battlefield performance stimulated demand for GaN power devices. The main application of GaN in the military was in discrete high electron mobility transistors (HEMT), which allow for high-frequency operations used in radar and electronic warfare systems (Transparency Market Research, 2015).

Light-Emitting Diodes.—Gallium is a main component of many LEDs. Various gallium compounds, including GaAs, GaN, gallium phosphide, aluminum gallium indium phosphide, and gallium arsenide phosphide, produce variously colored light when exposed to an electric current. Worldwide LED consumption continued to increase in 2017. According to research and consulting firm Strategies Unlimited, shipments of LED lamps were on track to increase by approximately 25% from those of 2016, and the packaged LED market sales revenue was expected to be valued near $16 billion (U.S. Department of Energy, 2017, p. 12, 14). LED prices in 2017, however, decreased by about 10% from those of 2016, which were already about 25% lower than those of 2015. Significant LED capacity expansion began in 2011, mostly brought about by the creation of Government-subsidized LED companies in China. The LED market has been in surplus since 2012, and prices for packaged LEDs have decreased continually since then (Wright, 2016, 2018).

The Asia and the Pacific region was the leading consumer of LED material, followed by North America and Europe. The demand for LED material in the Asia and the Pacific region was driven mainly by the large number of LED chip manufacturing facilities located in China, Japan, the Republic of Korea, and Taiwan. China had the largest LED industry in the world and accounted for about 54% of LED chip production capacity in 2017 (Chu, 2017).

In 2017, LEDs for general lighting applications remained the largest segment of the worldwide packaged LED market and was anticipated to account for about 39% of LED sales, according to Strategies Unlimited. General lighting was forecast to continue to be the leading LED market segment by sales volume. LEDs for automotive and signage applications, each expected to account for about 15% of LED sales in 2017, were also forecast to increase substantially (U.S. Department of Energy, 2017, p. 13–14).

Packaged LEDs also accounted for the largest end use of all GaN devices. Key applications for GaN-based LEDs were computer monitors, notebook computers, tablet computers, televisions, and, increasingly, general lighting. In 2017, Technavio ranked the packaged GaN LED applications as general lighting, 48%; other lighting, 21%; televisions, 20%; digital signage, 7%; and cellular telephones, 4%. As of 2015, the Asia and the Pacific region accounted for 76% of the consumption of all packaged GaN LEDs, whereas Europe consumed 14%, and North America consumed the remaining 10% (Technavio, 2016b, p. 17, 22).

As LED demand increased beginning in 2010, producers began expanding capacity for TMG, the metal-organic chemical used to fabricate the GaN epitaxial layer on 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. There were five major TMG producers worldwide in 2017. Akzo Nobel N.V. (Netherlands) manufactured TMG in Texas; Albemarle Corp. (Baton Rouge, LA) manufactured TMG in the Republic of Korea; the Dow Chemical Co. (Midland, MI) manufactured TMG in Massachusetts and the Republic of Korea; Jiangsu Nata Opto-electronic Material Co., Ltd. (China) manufactured TMG in Jiangsu Province, China; and SAFC Hitech (a subsidiary of Sigma Aldrich, St. Louis, MO) manufactured TMG in Taiwan and the United Kingdom (QYR Chemical and Materials Research Center, 2016, p. 22).

Solar Cells.—The solar cell market continued to be dominated by crystalline silicon solar cells, which accounted for about 95% of the market in 2017 (Fraunhofer Institute for Solar Energy Systems, ISE, 2018, p. 5). Industry experts had thought that copper-indium-gallium-selenide (CIGS) technology 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, a complicated manufacturing process that has impeded commercial mass production of CIGS panels, and financial instability among many of the research-based startup CIGS companies. To keep CIGS technology competitive, CIGS manufacturers have trimmed production costs, increased production capacities, improved module conversion efficiencies, and increased CIGS acceptance in commercial rooftops. Several large corporations acquired select small startup companies and increased use of their production capacities. Japan's Solar Frontier K.K. was thought to be the only mass producer of CIGS solar cells. In December, Solar Frontier announced that it had achieved a record 22.9% efficiency for a CIGS solar cell in a laboratory setting (Solar Frontier K.K., 2017).

Prices

Since 2002, producer prices for gallium have not been quoted in trade journals. From U.S. Census Bureau data, the average unit value for imported low-grade gallium in 2017 was estimated to be $124 per kilogram, about the same as that in 2016 (table 1). The estimated average unit value for imported high-grade (≥99.9999%-pure) gallium decreased by 31% to $477 per kilogram. Import data reported by the U.S. Census Bureau do not specify purity, and the estimated price distinction between gallium grades was based on the average customs value of the material and the country of origin.

Gallium prices declined between 2012 and mid-2016 when significant annual increases in China's low-grade (≤99.99%-pure) primary gallium production exceeded increases in worldwide consumption. To stop the price decline, China decreased production of its low-grade primary gallium in 2016 by approximately 49% from that of 2015 (Sparks, 2016). By yearend 2016, China's low-grade primary gallium price increased to about $150 per kilogram, a 30% increase from those of mid-2016. According to Argus Media group—Argus Metals International, the low-grade gallium price in China remained at about $150 per kilogram at the beginning of 2017. By May, after China began to slowly increase its low-grade gallium production, the price had decreased to about $116 per kilogram. By December, the price increased slightly to $125 per kilogram (Metal-Pages, 2017a, b).

Foreign Trade

In 2017, U.S. gallium metal imports were 93% more than those in 2016 (table 4), most likely owing to consumer restocking. China, including Hong Kong (34%), the United Kingdom (30%), France (10%), Ukraine (8%), Russia (7%), and the Republic of Korea (6%) were the leading sources of imported gallium metal. U.S. gallium export data were not available.

In addition to gallium metal, GaAs wafers were imported into the United States (table 5). Doped GaAs wafer imports decreased by 36% from those of 2016, with China as the leading source, accounting for 50% of imports. Taiwan (25%), Japan (8%), and Germany (7%) were the other main sources of doped GaAs wafers. The data listed in table 5 may include some packaging material weight, and as a result, the quantities reported for 2017 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 a gallium production estimate for China were initially used as the basis for estimating world gallium production. China reportedly increased its production of low-grade primary gallium in 2017 by approximately 33% (Metal-Pages, 2017b) and was estimated to account for 95% of worldwide low-grade primary gallium production. Estimated worldwide low-grade primary gallium production was 317 t in 2017, an increase of about 20% from that of 2016. Principal world producers were China, Japan, the Republic of Korea, Russia, and Ukraine. Gallium also may have been recovered in Hungary. Germany ceased primary gallium production during the second quarter of 2016 owing to a prolonged period of low prices (Willing, 2016). Production of high-grade primary refined gallium (sourced from current and stockpiled low-grade primary gallium) in 2017 was estimated to be 192 t, 39% less than low-grade primary production. China, Japan, Slovakia, the United Kingdom, and the United States refined high-grade gallium from low-grade primary material.

Worldwide gallium consumption was estimated to be about 355 t in 2017, an increase of 4% from that of 2016. Approximately 40% to 45% of total consumption was estimated to come from recycled material (Spicer, 2013). Therefore, about 195 t of high-grade primary refined gallium and 160 t of recycled gallium were estimated to have been consumed in 2017. Gallium was recycled from new scrap in Canada, China, Germany, Japan, Slovakia, the United Kingdom, and the United States. Roskill Information Service Ltd. (2014) projected that, by 2020, worldwide gallium consumption would increase to approximately 420 t.

Canada.—Orbite Technologies Inc. (formerly Orbite Aluminae Inc.) announced that construction of the purification section of its high-grade alumina plant in Cap-Chat, Quebec, was complete as of the third quarter of 2017. A separation facility was to be built at the alumina plant to recover 99.99%-purity gallium and rare-earth elements (Orbite Aluminae Inc., 2012; Orbite Technologies Inc., 2017, p. 3, 4).

China.—China produced an estimated 300 t of low-grade primary gallium in 2017 (Metal-Pages, 2017b) and consumed an estimated 104 t of gallium (Juncong, 2017, p. 8), approximately 29% of worldwide consumption. China's share of worldwide consumption was forecast to increase to 35% in 2020 owing to the rapid growth of the country's LED industry (Business Wire, Inc., 2016). Approximately 95% of China's gallium was sourced from bauxite as a byproduct from its alumina production industry. The remaining 5% was sourced from the refining of lead and zinc ores (Juncong, 2017, p. 6).

China's low-grade primary gallium producers included Aluminum Corp. of China Ltd. (Beijing); Beijing JiYa Semiconductor Material Co., Ltd. (Beijing); East Hope Mianchi Gallium Industry Co., Ltd. (Shanghai); Shanxi Jiahua Tianhe Electronic Materials (Shanxi Province); Shanxi Zhaofeng Gallium Industry Co. (Shanxi Province); Xiaoyi Xingan Gallium Co., Ltd. (Guangxi Province); and Zhuhai Fangyuan Inc. (Guangdong Province) (Huy and Liedtke, 2016, p. 34). China's high-grade primary refined gallium producers included Beijing JiYa Semiconductor Material Co., Ltd.; 5N Plus Inc. (Shenzhen, Guangdong Province); Nanjing Jingmei Gallium Co., Ltd. (Nanjing, Jiangsu Province); and Zhuzhou Keneng New Material Co., Ltd. (Zhuzhou, Hunan Province) (Shen, 2015).

Japan.—Japan Oil, Gas and Metals National Corp. (JOGMEC) reported that Japan's gallium supply in 2017 totaled 165 t, a 3% increase from 160 t in 2016, with 57% of the gallium supply sourced from imports, 41% from recovered scrap, and 2% from low-grade primary gallium produced in Japan as a byproduct of zinc refining. Of Japan's 94 t of imported gallium, 69% came from China; Japan remained the leading gallium-consuming country and consumed 151 t of gallium in 2017 (Takashi Kamiki, Director, Planning Division and Stockpile Management Division, Rare Metals Stockpile Department, JOGMEC, written commun., October 3, 2018). Japan's share of worldwide consumption was forecast to decrease to 41% by 2020 owing to competition from China's LED industry (Compound Semiconductor, 2014). Production of GaN wafers was concentrated in Japan with more than 85% of sales held by three Japan-based companies: Mitsubishi Chemical Corp., Sciocs Co. Ltd., and Sumitomo Electric Industries, Ltd. (Yole Développement, 2017a).

Outlook

Smartphones are a fundamental structural shift in mobile communications, offering services not available on standard cellular telephones, such as internet access, video streaming, computer program applications ("apps"), and global positioning systems. Smartphones, which use up to 10 times the amount of GaAs-rich RF content than second generation (2G) cellular telephones, are expected to account for 76% of all worldwide handset sales by 2018 and 87% of all worldwide handset sales by 2022 (Scarsella and Stofega, 2018a, b). Installation of third and fourth generation (3G and 4G) mobile networks in India and the Republic of Korea is expected to further increase sales of smartphones. Additional increases in GaAs demand will also result from new Wi-Fi applications, such as point-to-point communications, smart meters, and tablet personal computer technologies. However, although RF compound semiconductor revenue will increase to more than $11 billion in 2021, GaAs devices will not be the primary reason for this revenue growth. A slowdown in the wireless segment is expected to allow other RF compound semiconductor device technologies, including indium phosphide, GaN, and silicon germanium, to drive revenue growth (Higham and Anwar, 2017).

Yole Développement (2018) forecast that the RF GaN device market would increase by a CAGR of 23% between 2017 and 2023 owing to the increased use of GaN technology in defense applications and wireless infrastructure as well as the implementation of new fifth generation (5G) networks beginning around 2019. High-frequency RF applications over 3.5 gigahertz, including cable television applications, commercial wireless telecommunications, and military electronic warfare systems and radar, require the high voltage and high power capabilities of GaN devices. GaAs and silicon devices cannot operate at such high frequencies.

Owing to significant expansion of LED manufacturing capacity, reduced prices, and Government incentives, global LED sales are expected to increase by a CAGR of more than 18% between 2017 and 2021. General lighting is expected to remain the largest segment of the LED market, accounting for 77% by 2021. Sales within the Asia and the Pacific region are projected to increase at a CAGR of about 21% during the forecast period. The region is expected to remain the leading consumer of LED material owing to rapid development in many Asian countries, Government incentives to encourage use of energy-efficient lighting, and the presence of the majority of the LED industry (Semiconductor Today, 2017).

Annual production of TMG was forecast to be 60 t on average from 2018 to 2020 and to increase to 64 t by 2022 (QYR Chemical and Materials Research Center, 2016, p. 91, 95).

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

(Kilograms, unless otherwise specified)

	2013	2014	2015	2016	2017
Production, primary crude	--	--	--	--	--
Imports for consumption:					
Metal	35,400	53,900	28,600	10,500	20,400
Gallium arsenide wafers (gross weight)[2]	714,000	391,000	2,690,000	1,290,000	804,000
Consumption, reported	37,800	35,800	29,700	18,100	17,900
Price,[3] dollars per kilogram:					
Purity ≥ 99.9999%	502	363	317	690	477
Purity ≤ 99.99%	276	239	188	125	124

-- Zero.
[1]Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits.
[2]Data include imports of undoped and doped wafers from 2013 through 2016, but only doped wafers in 2017.
[3]Source: U.S. Census Bureau. Estimate based on average value of U.S. imports of gallium metal.

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

(Kilograms)

End use	2016	2017
Optoelectronic devices:		
Laser diodes and light-emitting diodes	5,140	4,990
Photodetectors and solar cells	329	301
Integrated circuits:		
Analog	10,400	10,300
Digital	2,110	1,940
Research and development	192	370
Total	18,100	17,900

[1]Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes gallium metal and gallium contained in compounds produced domestically.

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

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2016:				
97% to 99.9%	1	--	--	1
99.99% to 99.999%	2,460	-586 [3]	--	1,870
99.9999%	538	111	34	615
99.99999% to 99.999999%	289	457	514	232
Total	3,280	-18 [3]	548	2,720
2017:				
97% to 99.9%	1	1	2	--
99.99% to 99.999%	1,870	--	--	1,870
99.9999%	615	--	11	604
99.99999% to 99.999999%	232	631	493	370
Total	2,720	632	506	2,840

-- Zero.
[1]Table includes data available through August 17, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Consumers only.
[3]Reshipments exceeded receipts.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF UNWROUGHT GALLIUM AND GALLIUM POWDERS, BY COUNTRY OR LOCALITY[1]

Country or locality	2016 Quantity (kilograms)	2016 Value[2]	2017 Quantity (kilograms)	2017 Value[2]
China	4,410	$552,000	4,860	$685,000
Denmark	--	--	28	12,000
France	1,640	1,480,000	1,980	1,610,000
Germany	3,560	484,000	--	--
Hong Kong	--	--	2,000	270,000
Italy	60	24,100	--	--
Japan	131	70,500	540	263,000
Korea, Republic of	--	--	1,270	155,000
Poland	1	9,000	--	--
Russia	--	--	1,360	186,000
Singapore	74	31,400	525	223,000
South Africa	--	--	23	22,100
Ukraine	--	--	1,600	197,000
United Kingdom	676	260,000	6,180	809,000
Total	10,500	2,910,000	20,400	4,430,000

-- Zero.
[1]Table includes data available through August 17, 2018. 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 5
U.S. IMPORTS FOR CONSUMPTION OF
GALLIUM ARSENIDE WAFERS, BY COUNTRY OR LOCALITY[1]

Material and country or locality	2016 Quantity (kilograms)	2016 Value[2]	2017 Quantity (kilograms)	2017 Value[2]
Undoped:				
Austria	77	$27,200	NA	NA
Canada	--	--	NA	NA
China	--	--	NA	NA
Germany	40	10,200	NA	NA
Japan	21	14,300	NA	NA
Taiwan	40,300	106,000	NA	NA
Other	8	30,100	NA	NA
Total	40,400	188,000	NA	NA
Doped:				
Austria	12	11,300	7	$5,140
Belarus	9,400	1,850,000	8,840	1,980,000
Belgium	1,950	2,580,000	618	3,400,000
China	688,000	73,900,000	403,000	43,400,000
Denmark	166	86,200	--	--
Finland	6,620	4,820,000	3,790	3,190,000
France	4,330	3,530,000	36,100	31,600,000
Germany	116,000	16,700,000	55,000	18,500,000
Israel	178	150,000	9	40,000
Italy	462	104,000	1,420	686,000
Japan	59,700	32,500,000	67,000	26,800,000
Korea, Republic of	110,000	9,040,000	21,800	2,560,000
Malaysia	1,950	321,000	1,050	318,000
Netherlands	39	54,400	3	32,200
Poland	526	323,000	226	238,000
Singapore	5,110	658,000	1,140	301,000
Spain	1	2,750	457	19,300
Taiwan	243,000	59,600,000	202,000	67,600,000
United Kingdom	5,860	1,930,000	513	1,700,000
Other	427 r	525,000 r	406	460,000
Total	1,250,000	209,000,000	804,000	203,000,000

[r]Revised. NA Not available. -- Zero.
[1]Table includes data available through August 17, 2018. 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
GALLIUM: LOW-GRADE PRIMARY WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Kilograms)

Country or locality	2013	2014	2015	2016	2017
China	300,000	450,000	444,000	225,000	300,000
Germany	38,000	16,000	11,000	16,000	--
Hungary	1,713	260 e	-- e	-- e	-- e
Japan	8,000	8,000	5,000	3,000	3,000
Kazakhstan	--	-- e	-- e	-- e	-- e
Korea, Republic of[e]	2,000	1,000	2,500	3,000	3,000
Russia[e]	6,000	1,000	1,000	9,000	7,000
Ukraine	13,000 e	13,000 e	9,400	9,000 e	4,000 e
Total	370,000 r	490,000	473,000	265,000	320,000

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through May 31, 2018. All data are reported unless otherwise noted. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 7
ESTIMATED WORLD ANNUAL LOW-GRADE PRIMARY GALLIUM PRODUCTION CAPACITY, DECEMBER 31, 2017[1, 2]

(Kilograms)

Country or locality	Capacity
China	600,000
Germany	40,000
Hungary	8,000
Japan	10,000
Kazakhstan	25,000
Korea, Republic of	16,000
Russia	10,000
Ukraine	15,000
Total	720,000

[1]Table includes data available through August 17, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes capacity at operating plants as well as at plants on standby basis.

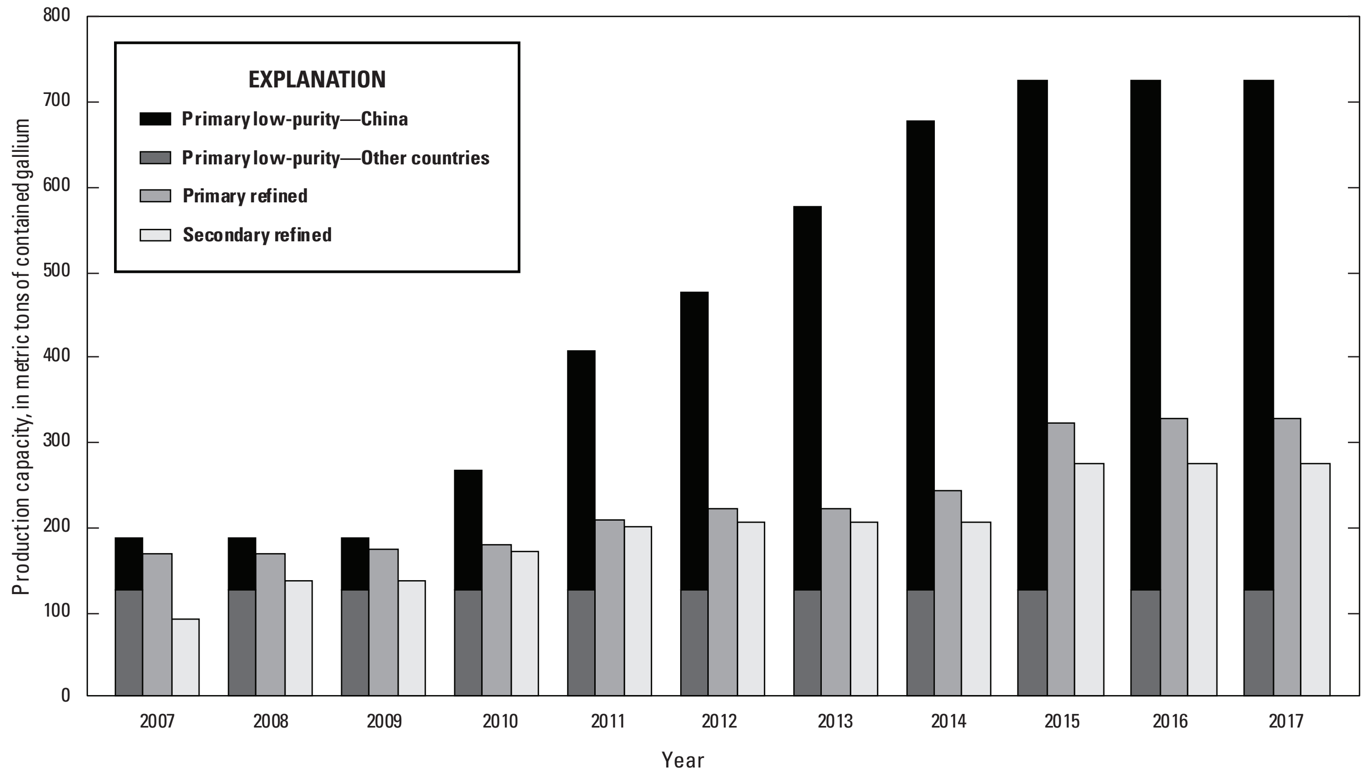

Figure 1. Estimated worldwide gallium production capacity from 2007 through 2017. Source: U.S. Geological Survey.

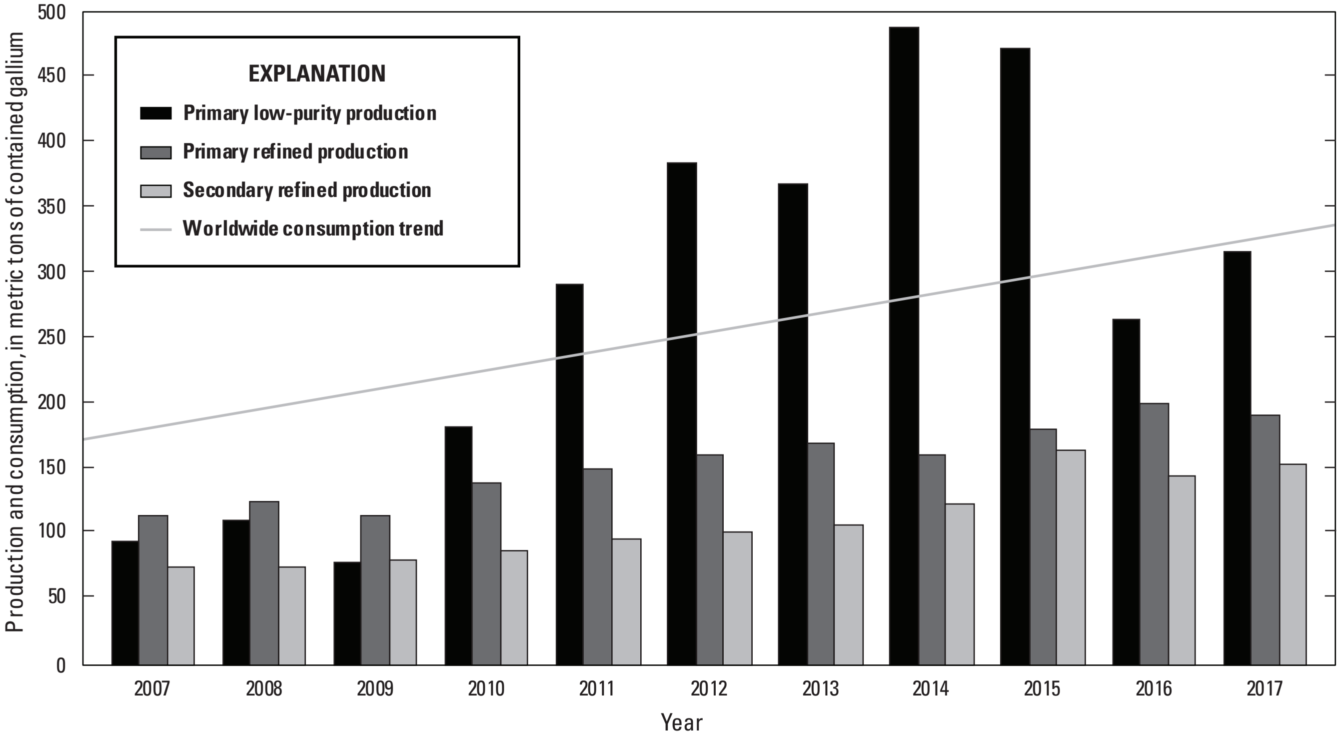

Figure 2. Estimated worldwide gallium production and consumption from 2007 through 2017. Source: U.S. Geological Survey.