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GALLIUM [ADVANCE RELEASE]

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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 2022. Imports of gallium metal and powders, gallium arsenide (GaAs) wafers, gallium nitride (GaN) wafers, and domestically refined and recycled gallium continued to account for all U.S. gallium consumption. In 2022, the quantity of gallium metal imports increased by 28% from that in 2021 (tables 1, 4), owing primarily to increases in gallium metal and powder imports from Canada, China, Estonia, Luxembourg, and Slovakia. The value of all gallium metal and powder imports was 100% greater than that in 2021 (table 4). The leading sources of imported gallium metal and powders were, in descending order, China, Japan, and Canada. Some of the imports were estimated 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 increased by 38% from those in 2021 (table 5). Finland was the leading source, followed by Taiwan, Germany, and China, in descending order of quantity. Undoped GaAs wafer imports were more than seven times greater than those in 2021. However, the quantity of undoped wafers imported was negligible compared with that of doped wafers. Almost all gallium consumed in the United States was for the production of GaAs, gallium arsenide phosphide (GaAsP), GaN, and gallium phosphide (GaP) which, along with imported wafers, were used in integrated circuits (ICs) and optoelectronic devices [laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells]. In 2022, U.S. gallium consumption for the production of analog and digital ICs and the production of laser diodes and LEDs increased by 15% and 8%, respectively (table 2). Gallium consumed domestically for the production of photodetectors and solar cells increased by 58%. Refined gallium metal consumption increased by 9% (table 3). In total, U.S. gallium consumption increased by 15% from that in 2021 (table 1). The 28% increase in gallium metal imports and 38% increase in doped GaAs wafer imports suggest that the U.S.-based stockpile of imported gallium metal and GaAs wafers, created in 2018 following the establishment of high import tariffs on gallium from China, was becoming depleted. In 2022, 100% of gallium metal consumed was at a purity level of 99.99999% to 99.999999% (table 3).

In 2022, the U.S. Geological Survey (USGS) estimated world low-grade primary gallium production to be 610 metric tons (t), an increase of 41% from 434 t in 2021 (table 7). China produced 98% of total global low-grade primary gallium. Japan, the Republic of Korea, and Russia accounted for the remaining production in 2022. The estimated worldwide low-grade primary gallium production capacity in 2022 was 1,120 t, and China accounted for 89% of that capacity (fig. 1, table 6). The estimated worldwide compound annual growth rate (CAGR) of low-grade primary gallium production was 4% from 2012 through 2022, primarily owing to China's large annual increases in production beginning in 2010. Worldwide, the USGS estimated that 310 t of low-grade primary gallium was processed into high-grade refined gallium; the remaining low-grade primary gallium produced in 2022 most likely was consumed for producing magnetic materials, liquid metals and alloys, petrochemicals, pharmaceuticals and radiopharmaceuticals, and other industrial applications. Some also may have been stockpiled. High-grade primary refined gallium was produced in Canada, China, Japan, Slovakia, and the United States. The United Kingdom stopped domestic production of high-grade primary refined gallium in 2018, and its refining capacity was thought to have been moved to China. The worldwide CAGR of high-grade primary refined gallium production was 7% from 2012 through 2022. Worldwide, the USGS estimated that 260 t of gallium was recycled from new scrap in 2022. Worldwide production of recycled gallium increased at a CAGR of 10% from 2012 through 2022. Worldwide gallium consumption, which increased at a CAGR of 12% from 2012 through 2022, was estimated by the USGS to be 780 t in 2022, an increase of 20% from the worldwide gallium consumption estimate of 650 t in 2021 (fig. 2).

Production

No domestic production of low-grade primary gallium was reported in 2022. Indium Corp. (Clinton, NY) refined high-grade gallium from low-grade primary gallium and recycled gallium from new scrap at its facilities in Rome and Utica, NY (Indium Corp., 2022). Neo Performance Materials Inc. (Canada) purchased low-grade primary gallium and recovered gallium from new scrap materials, predominantly those generated during the production of GaAs ingots and wafers. In 2020, Neo closed its facility in Blanding, UT. It previously had the capacity to refine 50 metric tons per year (t/yr) of high-grade gallium from low-grade primary gallium, recycle 30 t/yr of new scrap, and refine it into high-grade gallium. Neo's other gallium recycling facility in Peterborough, Ontario, Canada, may have acquired some of Blanding's refining and recycling capacity. The Peterborough facility also began producing GaN from recycled gallium in 2020. Neo's other gallium facilities included a gallium trichloride production facility in Quapaw, OK (80% ownership), and a gallium trichloride production facility in the Hyeongok Industrial Zone in the Republic of Korea (80% ownership). Gallium trichloride is a precursor for many gallium compounds, including the organic gallium compounds used in epitaxial layering (Neo Performance Materials Inc., 2020, p. 20; 2023, p. 26–28).

Consumption

U.S. Consumption

Gallium consumption data were collected by the USGS from a voluntary survey of U.S. operations. In 2022, 20 operations were canvassed, and 45% 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, GaAsP, GaN, and GaP were used to manufacture ICs and optoelectronic devices. ICs accounted for 74% of domestic gallium consumption in 2022, optoelectronic devices accounted for 25%, and research and development accounted for the remainder. About 79% of the gallium consumed in the United States was contained in GaAs, GaAsP, GaN, and GaP wafers and epiwafers. Gallium metal, trimethylgallium (TMG), and triethylgallium used in the epitaxial layering process to fabricate epiwafers in the production of LEDs and ICs accounted for most of the remainder (table 2).

In 2022, reported gallium consumption in the United States was 19.7 t, a 15% increase from 17.1 t in 2021 (table 1), owing to a 14% increase in gallium consumption in producing laser diodes, LEDs, photodetectors, and solar cells, and a 15% increase in gallium consumption for the production of analog and digital ICs (table 2). Refined gallium metal consumption increased by 9% to 586 kilograms (kg) from 538 kg in 2021 (table 3). All gallium metal consumed was at a purity level of 99.99999% to 99.999999%. Although reported U.S. gallium consumption increased by 15% in 2022 from that in 2021, U.S. gallium consumption since 2013 has declined by 48%. U.S. gallium consumers utilizing GaAs wafer production facilities in Asia to be closer to the Asian-dominated optoelectronics industry were estimated to be a leading cause for the continued decrease in U.S. gallium consumption and gallium wafer imports.

Global Consumption

Gallium Arsenide.—In 2022, owing to global economic uncertainty, inflation, ongoing supply chain issues, and trade sanctions, the value of radio frequency (RF) GaAs devices consumed worldwide was reported to be about $8 billion, a 12% decrease from the USGS-estimated value of $9.1 billion in 2021. Despite the reduced value, wireless applications continued to drive the RF GaAs device market. Wide deployment of fifth-generation (5G) networks and devices with high RF content was estimated to be the most significant factor (everything RF, 2022; Tech Insights Inc., 2024).

In 2022, worldwide shipments of smartphones from device vendors decreased by 11% to 1.21 billion units from 1.35 billion units shipped in 2021, owing to reduced global demand, high inventory, and economic uncertainty (IDC Corp. USA, 2023). Emerging markets in Asia and the Pacific (excluding China and Japan), Central and Eastern Europe, and China fared the worst, with shipment volumes in Asia and the Pacific (excluding China and Japan) forecast to be down by 5%; Central and Eastern Europe forecast to be down by 17%; and China forecast to be down by 13%. Developed markets in North America (United States and Canada) and Western Europe fared better, with shipment volumes in Canada forecast to increase 3%; and the United States and Western Europe forecast to remain essentially unchanged (Semiconductor Today, 2022).

Gallium Nitride.—GaN substrates, where GaN is grown epitaxially on sapphire, silicon, silicon carbide, or GaN wafers, were produced and consumed mostly in Asia and the Pacific and in North America. Prominent GaN technology companies occupied both regions, and significant investments were made in the research and development of innovative GaN technologies. In 2022, Asia and the Pacific (including Australia, China, India, Indonesia, Japan, and the Republic of Korea) was the leading market for GaN substrates in terms of revenue share. North America (the United States and Canada) was the second largest market for GaN substrates but was expected to increase significantly owing to the increased use of the substrates in the aerospace, automotive, and defense industries and the increased adoption of electric vehicles. The European GaN substrate market was expected to increase moderately (Reports and Data, 2023).

Increased demand for GaN RF devices provided significant growth for advanced GaN-based products. In 2022, the value of GaN RF devices consumed worldwide was estimated to be $1.3 billion, an 18% increase from $1.1 billion in 2021. GaN RF technology was developed originally for military use, and expanded to cable television, communications base station transceivers, radar, and very small aperture terminal satellites, among other end uses. In 2022, telecommunications infrastructure accounted for an estimated 57% of sales; military applications, 35%; satellite communications, 7%; and other uses, 1% (Yole Intelligence, 2019; Chiu and Dogmus, 2021; Chiu and Ghorbel, 2023).

GaN power devices operate at higher voltages, power densities, and switching frequencies and offer greater power efficiency than existing GaAs and silicon devices. In 2022, the value of GaN power devices consumed worldwide was estimated to be $185 million, a 47% increase from $126 million in 2021, owing to the rapid penetration of GaN devices into smartphone fast-charger applications. Yole Intelligence reported that fast charging was likely the leading end use for the GaN power device market. In 2022, consumer electronics applications accounted for 79% of sales; defense and aerospace applications and telecommunication and infrastructure applications, 5% each; industrial applications, 4%; automotive and mobility applications, 3%; energy applications, 2%; and other applications, 2% (Yole Intelligence, 2021, 2022; Ayari, 2023, p. 2).

Laser Diodes and Light-Emitting Diodes.—Gallium is a primary component of many laser diodes and LEDs. Various gallium compounds, including aluminum gallium indium phosphide, GaAs, GaAsP, GaN, and GaP, produce variously colored light when exposed to an electric current.

According to a U.S. Department of Energy report on the worldwide LED manufacturing supply chain in 2020, the Asia and the Pacific region has historically been the leading consumer of LED material, followed distantly by Europe and North America. 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, Malaysia, Taiwan, and Vietnam. The

Asia and the Pacific region accounted for more than 90% of global LED-chip production capacity in 2019, with most of the capacity located in China (Lee and others, 2021, p. 4–5).

Worldwide LED consumption decreased in 2022 owing to a decline in worldwide LED demand. Reduced demand led to an LED chip surplus, resulting in a continuous drop in prices throughout the year. According to TrendForce Corp., LED chip sales revenue was valued at $2.78 billion in 2022, a decrease of 23% from $3.61 billion in 2021. Owing to a combination of heightened industry competition forcing some companies to exit the LED chip market and Chinese LED chip manufacturers decreasing their focus on the chip sector, the chip manufacturers who have remained in the market have reported consistent losses over an extended period (Yu, 2023).

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 reactor and heated, a GaN layer is formed on the epiwafer. TMG's purity and quality determine an LED's brightness and reliability. As of 2021 there were five major TMG producers worldwide. 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 Inc. (a subsidiary of Sigma Aldrich Corp., St. Louis, MO) manufactured TMG in Taiwan and the United Kingdom (QY Research, 2021).

Neodymium-Iron-Boron Magnets.—According to some analysts, in 2022, China accounted for more than 90% of all rare-earth magnet production (Yao, 2022). To influence the magnetic properties of neodymium-iron-boron (NdFeB) magnets, the magnet is doped with different concentrations of gallium ranging from 0.15% to 0.45% of the magnet weight (Zhong and others, 2023).

Gallium consumed in China's magnet industry increased considerably in the previous several years. According to Beijing JiYa Semiconductor Material Co., Ltd., consumption of gallium in China for the production of NdFeB magnets reached an estimated 100 t in 2020, a 50% increase from that in 2019 (Asian Metal Ltd., 2021). In 2021, the USGS estimated that almost 120 t of gallium was consumed in the production of NdFeB magnets based on reported data that China's NdFeB magnet production increased by 16.4% from that in 2020 (Shanghai Metals Market Information and Technology Co., Ltd., 2022). In 2022, according to gallium consumption data from the China Nonferrous Metals Industry Association (CNMA), the USGS estimated that China's NdFeB magnet industry consumed approximately 180 t of gallium in 2022 (Argus Media group, 2023), an 80% increase from the estimated 100 t of gallium consumed in 2020 (Asian Metal Ltd., 2021).

Prices

According to Argus Media group (2022c), the low-grade gallium price in China increased from $370 per kilogram in January to $578 per kilogram in May. The increase in China's low-grade gallium price resulted from several reasons. Environmental restrictions placed on Chinese bauxite production in 2019 compelled the country's alumina refineries to import bauxite with lower gallium content from abroad, which increased gallium extraction costs. When the global coronavirus disease 2019 (COVID-19) pandemic reduced gallium demand in early to mid-2020, Chinese gallium producers slowed or shut down operations. Chinese gallium supply was scarce when gallium demand resumed in the second half of 2020, and gallium prices increased significantly beginning in the last quarter of 2020 and continued through May 2022. The price rise also was driven by China's increased gallium consumption in the production of NdFeB magnets for use in the electric vehicle industry (Messecar, 2021; Stratton, 2021). China's low-grade gallium price decreased from June to November 2022 owing to high gallium inventory, decreased demand from China's NdFeB magnet manufacturing sector, and China's resurgence of the COVID-19 pandemic. At the end of December 2022, the low-grade gallium price in China increased to $290 per kilogram from $200 per kilogram in November owing to an upturn in demand for gallium from China's magnet manufacturing sector (Argus Media group, 2022a, b).

According to U.S. Census Bureau data, the average unit value for imported low-grade gallium in 2022 was estimated to be $394 per kilogram, an increase of 55% from that in 2021 (table 1). The estimated average unit value for imported high-grade (≥99.999%-pure) gallium decreased by 10% to $560 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.

Foreign Trade

In 2022, gallium metal imports increased by 28% from those in 2021 (table 4), owing primarily to a 560% increase in gallium metal and powder imports from China. China (38%), Japan (21%), and Canada (15%) were the leading sources of imported gallium metal in 2022. U.S. gallium export data were not available.

In addition to gallium metal, doped and undoped GaAs wafers were imported into the United States in 2022 (table 5). Doped GaAs wafer imports increased by 38% from that in 2021. Finland was the leading source, accounting for 57% of imports. Taiwan (16%), Germany (11%), and China (6%) were the other leading sources of doped GaAs wafers. Undoped GaAs wafer imports were more than seven times greater than those in 2021, however the quantity of undoped wafers imported was negligible compared with that of doped wafers.

World Review

Reported gallium production for China and imports of gallium into Germany, Japan, and the United States were used initially as the basis for estimating world gallium production. The USGS estimated that China increased its production of low-grade primary gallium in 2022 by 42% and accounted for 98% of worldwide low-grade primary gallium production (table 7). The USGS estimated worldwide low-grade primary gallium

production to be 610 t in 2022, an increase of 41% from that in 2021 (table 7). Principal world producers, in descending order of production, were China, Russia, Japan, and the Republic of Korea. The USGS estimated production of high-grade primary refined gallium (sourced from current and stockpiled low-grade primary gallium) in 2022 to be 310 t, 51% of low-grade primary production. Canada, China, Japan, Slovakia, and the United States refined high-grade gallium from low-grade primary material.

The USGS estimated worldwide gallium consumption to be 780 t in 2022, an increase of 20% from the worldwide gallium consumption estimate of 650 t in 2021. Based on historical low- and high-grade gallium consumption patterns, approximately 45% to 50% of high-grade gallium consumed was from recycled material (Spicer, 2013). Therefore, about 520 t of low-grade primary gallium, of which 310 t was refined into high-grade primary gallium, and 260 t of high-grade recycled gallium were estimated by the USGS to have been consumed in 2022. The remaining 210 t of low-grade primary gallium was thought to have been consumed directly in industry. Gallium was recycled from new scrap in Canada, China, Japan, Slovakia, and the United States.

China.—In 2022, the USGS estimated that China produced 600 t of low-grade primary gallium (table 7), and the CNMA reported that China recycled 131 t of gallium. The CNMA also reported that China consumed a total of 540 t of gallium in 2022, of which 48% was consumed in the semiconductor, LED, and laser diode industries; 33% in the NdFeB magnet production industry; 10% in the solar cell industry; and 9% in other industries (Argus Media group, 2023). China was the world's leading gallium consumer, accounting for approximately 70% of worldwide consumption according to USGS estimates.

Gallium demand in China for the production of NdFeB magnets increased considerably in 2022, driven by heightened consumption from the electric vehicle industry. Based on gallium consumption data from the CNMA, the USGS estimated that China's NdFeB magnet industry consumed 180 t of gallium in 2022 (Argus Media group, 2023), an 80% increase from the estimated 100 t of gallium consumed in 2020 (Asian Metal Ltd., 2021). Approximately 95% of China's gallium was sourced as a byproduct from bauxite during alumina production. The remaining 5% was sourced from the refining of lead and zinc ores (Juncong, 2017, p. 6).

China's major 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 Co., Ltd. (Hejin, Shanxi Province); Shanxi Zhaofeng Gallium Industry Co. (Shanxi Province); Vital Materials Co., Ltd. (Guangzhou, Guangdong Province); Xiaoyi Xingan Gallium Co., Ltd. (Guangxi Province); and Zhuhai SEZ Fangyuan Inc. (Guangdong Province) (Huy and Liedtke, 2016, p. 34; Roskill Information Services Ltd., 2020, p. 57). China's high-grade primary refined gallium producers included 5N Plus Inc. (Shenzhen, Guangdong Province); Nanjing Jingmei Gallium Co., Ltd. (Nanjing, Jiangsu Province); Shanxi Jiahua Tianhe (Hejin, Shanxi Province); Vital Materials (Guangzhou, Guangdong Province); and Zhuzhou Keneng New Material Co., Ltd. (Zhuzhou, Hunan Province) (Shen, 2015; Roskill Information Services Ltd., 2020, p. 58).

Japan.—Japan reported 150 t of gallium consumption in 2021, approximately 23% of worldwide consumption (Japan Organization for Energy and Metals Security, 2022, p. 5–6). For 2022, the USGS estimated that Japan consumed about 160 t of gallium, approximately 21% of worldwide consumption, and that 58% of Japan's imported gallium came from China.

Japan's high-grade primary and secondary refined gallium producers included Dowa Electronics Materials Co., Ltd. (Tokyo); Furukawa Denshi Co., Ltd. (Yoshima-machi Iwaki-city); Nichia Corp. (Tokushima); Nippon Rare Metal Inc. (Yokohama); Rasa Industries Ltd. (Tokyo); and Sumitomo Chemical Co., Ltd. (Tokyo) (Roskill Information Services Ltd., 2020, p. 62). Production of GaN wafers was concentrated in Japan, with more than 85% of sales held by three Japan-based companies: Mitsubishi Chemical Corp. (Tokyo, Tokyo-to Prefecture); Sciocs Co. Ltd. (Hitachi, Ibaraki Prefecture); and Sumitomo Electric Industries, Ltd. (Osaka, Osaka Prefecture) (Yole Intelligence, 2017).

Outlook

Gallium consumption is expected to increase in the implementation of new 5G networks and as the use of GaN technology in defense applications and wireless infrastructure increases. High-frequency RF applications greater than 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. The consumption of GaAs wafers for laser diode applications is expected to increase, driven by devices with three-dimensional (3D) sensing functions.

According to Yole Intelligence, compound semiconductor substrate sales for GaN power applications and GaN RF applications are expected to increase by a CAGR of 58% and 11%, respectively, by 2027. Compound semiconductor substrate sales for GaAs photonics applications are expected to increase by a CAGR of 8% by 2027, and sales for GaAs RF applications and GaAs LED applications are each expected to increase by a CAGR of 2% by 2027 (Chiu and others, 2023).

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

(Kilograms, gallium content, unless otherwise specified)

	2018	2019	2020	2021	2022
Production, primary crude	--	--	--	--	--
Imports for consumption:					
Metal	32,000	5,740	4,430	8,890	11,400
Gallium arsenide wafers, gross weight[2]	446,000 [r]	289,000 [r]	208,000 [r]	306,000	424,000
Consumption, reported	15,000	14,900	15,700	17,100	19,700
Price,[3] dollars per kilogram:[e]					
Purity ≥99.999%	508	573	596	625	560
Purity ≤99.99%	185	153	163	254	394

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through August 30, 2023. Data are rounded to no more than three significant digits.
[2]Includes doped and undoped gallium arsenide wafers.
[3]Source: U.S. Census Bureau. Estimated based on average value of U.S. imports of gallium metal.

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

(Kilograms, gallium content)

End use	2021	2022
Optoelectronic devices:		
Laser diodes and light-emitting diodes	3,740	4,060
Photodetectors and solar cells	498	786
Integrated circuits:		
Analog	11,500	13,800
Digital	1,150	821
Research and development	247	263
Total	17,100	19,700

[1]Table includes data available through August 30, 2023. 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, gallium content)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2021:				
99.99% to 99.999%	1,870	--	--	1,870
99.9999%	595	--	--	595
99.99999% to 99.999999%	452	434	538	348
Total	2,920	434	538	2,810
2022:				
99.99% to 99.999%	1,870	--	--	1,870
99.9999%	595	--	--	595
99.99999% to 99.999999%	348	552	586	314
Total	2,810	552	586	2,780

-- Zero.
[1]Table includes data available through August 30, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Consumers only.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF UNWROUGHT GALLIUM AND GALLIUM POWDERS, BY COUNTRY OR LOCALITY[1, 2]

	2021		2022	
Country or locality	Quantity (kilograms)	Value[3]	Quantity (kilograms)	Value[3]
Belgium	86	$36,700	--	--
Canada	792	164,000	1,720	$567,000
China	648	170,000	4,300	1,870,000
Estonia	--	--	357	195,000
Germany	1,140	279,000	202	91,800
Japan	4,510	1,450,000	2,380	1,200,000
Luxembourg	--	--	400	177,000
Russia	500	130,000	300	142,000
Singapore	689	48,200	--	--
Slovakia	--	--	992	444,000
Taiwan	500	168,000	700	210,000
United Kingdom	15	14,600	4	5,660
Total	8,890	2,460,000	11,400	4,910,000

-- Zero.
[1]Table includes data available through June 13, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States code 8112.92.1000.
[3]Customs value.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF
GALLIUM ARSENIDE WAFERS, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2021 Quantity (kilograms)	2021 Value[3]	2022 Quantity (kilograms)	2022 Value[3]
Doped:				
Austria	9	$20,000	8	$23,100
Belgium	90	334,000	224	338,000
Canada	100	39,000	21	50,800
China	15,900	8,530,000 r	24,600	11,500,000
Denmark	56	259,000	126	232,000
Finland	123,000	5,760,000	240,000	4,390,000
France	14,300	28,400,000	4,500	14,700,000
Germany	27,100	25,000,000	45,300	25,000,000
Israel	31	24,100	32	5,130
Italy	22,300	4,640,000	3,920	2,510,000
Japan	14,200	27,900,000	12,300	22,300,000
Korea, Republic of	14,000	9,220,000	18,700	11,800,000
Malaysia	200	563,000	1,440	919,000
Mexico	76	3,190	5	3,840
Netherlands	73	67,800	184	44,100
Poland	19	21,400	8	7,690
Russia	9	15,700	--	--
Singapore	420	314,000	761	138,000
Sweden	2	9,040	9	91,700
Switzerland	504	83,600	2	13,000
Taiwan	71,200	93,800,000	68,400	103,000,000
Ukraine	37	8,390	--	--
United Kingdom	2,840	2,450,000	1,840	2,180,000
Other	3 r	29,000 r	15	68,800
Total	306,000	207,000,000	422,000	199,000,000
Undoped:				
Canada	--	--	400	2,030
China	--	--	1,540	14,200
Japan	132	35,000	--	--
Taiwan	115	42,200	--	--
Total	247	77,200	1,940	16,300

rRevised. -- Zero.
[1]Table includes data available through October 10, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States code 8112.92.1000.
[3]Customs value.

Source: U.S. Census Bureau.

TABLE 6
ESTIMATED WORLD ANNUAL LOW-GRADE PRIMARY GALLIUM PRODUCTION CAPACITY, DECEMBER 31, 2022[1, 2]

(Kilograms, gallium content)

Country or locality	Capacity
China	1,000,000
Germany	40,000
Hungary	8,000
Japan	10,000
Kazakhstan	25,000
Korea, Republic of	16,000
Russia	10,000
Ukraine	15,000
Total	1,120,000

[1]Table includes data available through August 30, 2023. Data are rounded to no more than three significant digits; may not add to total shown.
[2]Includes capacity at operating plants and at plants on standby basis.

TABLE 7
GALLIUM: LOW-GRADE PRIMARY WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Kilograms, gallium content)

Country or locality	2018	2019	2020	2021	2022
China	404,000	338,000	336,400	423,000	600,000
Japan	3,000	3,000	3,000	3,000 [e]	3,000 [e]
Korea, Republic of[e]	3,000	2,000	2,000	2,000	2,000
Russia[e]	6,000	8,000	5,000	5,000	5,000
Ukraine[e]	4,000	--	--	1,000	--
Total	420,000	351,000	346,000	434,000	610,000

[e]Estimated. -- Zero.
[1]Table includes data available through October 20, 2023. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

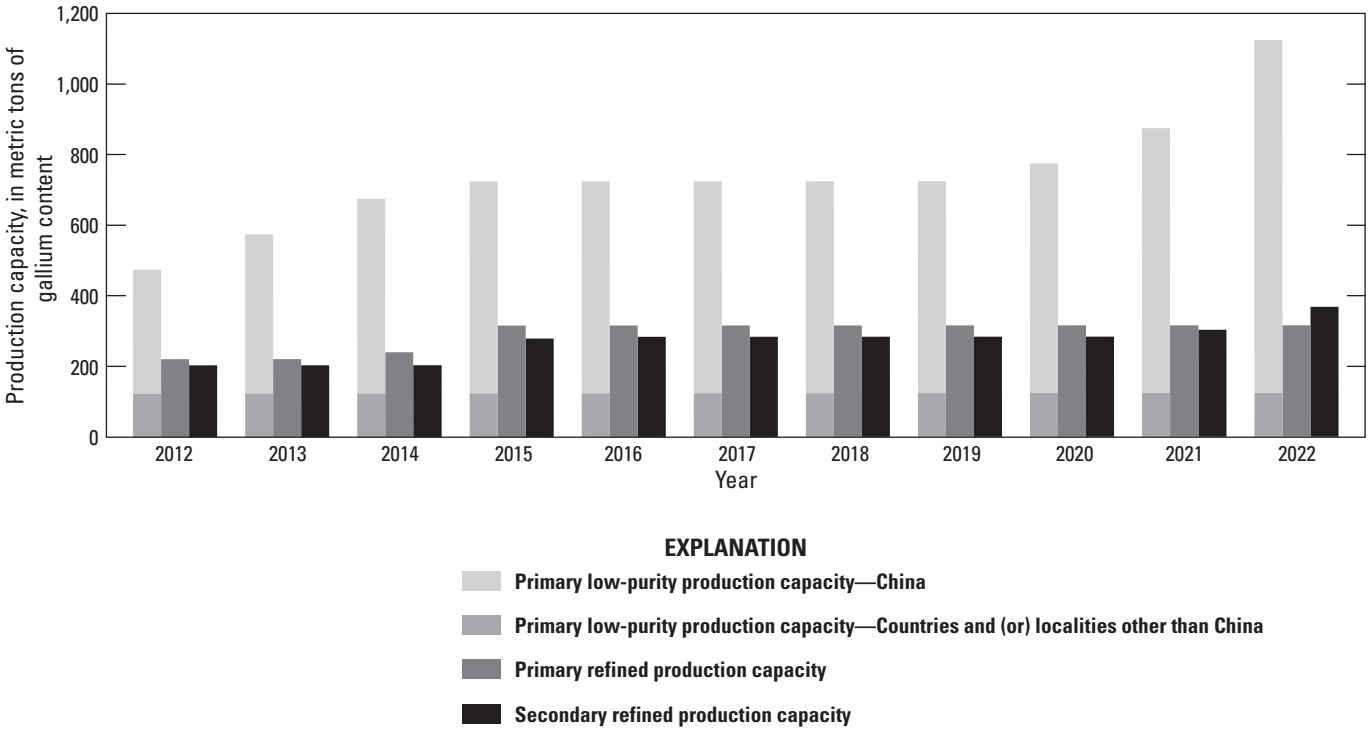

Figure 1. Worldwide gallium production capacity from 2012 through 2022. China's primary low-grade production capacity was reported by Asian Metal Ltd. All other gallium production capacities were estimated by the U.S. Geological Survey.

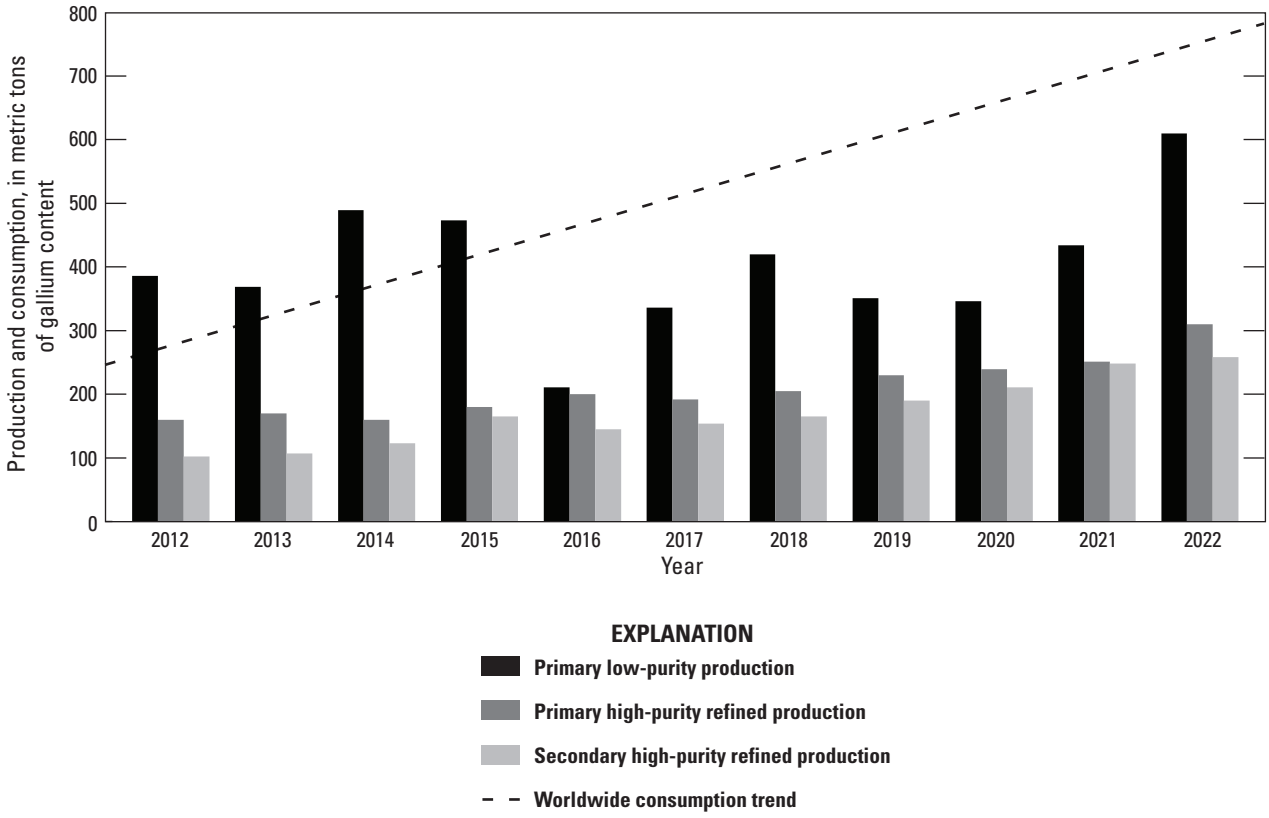

Figure 2. Worldwide gallium production and consumption from 2012 through 2022. China's primary low-grade production was reported by Asian Metal Ltd. and is included in the primary low-grade production columns. All other gallium production and consumption data were estimated by the U.S. Geological Survey.