USGS
science for a changing world

2020 Minerals Yearbook

GALLIUM [ADVANCE RELEASE]

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

December 2024

Gallium

By Brian W. Jaskula

Domestic survey data and tables were prepared by Shonta E. Osborne, statistical assistant.

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 2020. Domestically refined and recycled gallium, gallium arsenide (GaAs) wafers, and imports of gallium metal and GaAs wafers continued to account for all U.S. gallium consumption (gallium metal and gallium in GaAs). The quantity of gallium metal imports was 22% lower than that in 2019 (tables 1, 4) owing primarily to the continuation of higher import tariffs on gallium from China. Gallium metal and powder imports from China (including Hong Kong) decreased by 96% from those in 2019. The value of all gallium metal and powder imports was 23% lower than that in 2019 (table 4). The leading sources of imported gallium metal and powders were, in descending order, Germany, Taiwan, and Japan. Some of the imports were 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 34% from those in 2019 (table 5). Germany was the leading source, followed by Taiwan, Italy, Japan, and the Republic of Korea, in descending order of quantity. The U.S. Census Bureau stopped reporting undoped GaAs wafer imports in 2017. Almost all gallium consumed in the United States was for the production of GaAs, gallium arsenide phosphide (GaAsP), gallium nitride (GaN), and gallium phosphide (GaP), which were used in integrated circuits (ICs) and optoelectronic devices [laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells], as were imported wafers. In 2020, U.S. consumption of gallium for the production of analog and digital ICs increased by 12% and consumption for the production of photodetectors and solar cells increased by 20%; whereas U.S. consumption decreased by 16% for the production of laser diodes and LEDs (table 2). Refined gallium metal consumption increased by 28% (table 3). In total, U.S. gallium consumption increased by 6% from that in 2019 (table 1). The 22% decrease in gallium metal imports and 34% decrease in doped GaAs wafer imports suggest that the consumed gallium was sourced from previously stockpiled gallium metal and GaAs wafers. About 98% of the gallium metal consumed in 2020 was at a purity level of 99.99999% to 99.999999% (table 3).

In 2020, estimated world low-grade primary gallium production equaled 327 metric tons (t), a decrease of 7% from the estimated production of 351 t in 2019 (table 6). China, which accounted for 84% of global low-grade primary gallium capacity (fig. 1, table 7), produced 97% of the global low-grade primary gallium (table 6). Japan, the Republic of Korea, and Russia accounted for the remaining production in 2020. Ukraine was thought to have stopped production of low-grade primary gallium in 2019. The estimated worldwide compound annual growth rate (CAGR) of low-grade primary gallium production from 2010 through 2020 was 6%, primarily owing to China's large annual increases in production beginning in 2010. Worldwide, about 239 t of low-grade primary gallium was processed to high-grade refined gallium; the remaining low-grade primary gallium produced in 2020 was most likely consumed in the production of magnetic materials, liquid metals and alloys, and other industrial applications. Some may also have been stockpiled. High-grade primary refined gallium was produced in Canada, China, Japan, the United States, and possibly Slovakia. The United Kingdom stopped production of high-grade primary refined gallium in 2018. The worldwide CAGR of high-grade primary refined gallium production from 2010 through 2020 was 5%. World high-grade secondary refined gallium production from 2010 through 2020 increased at a CAGR of 9%. World gallium consumption, which increased at a CAGR from 2010 through 2020 of 7%, was estimated to be 575 t in 2020, an increase of 21% from the revised worldwide gallium consumption estimate of 475 t in 2019 (fig. 2).

Production

No domestic production of low-grade primary gallium was reported in 2020. 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., undated). 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 and to 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., 2021, p. 22–24).

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 2020, 21 operations were canvassed and

57% 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, and GaP were used to manufacture ICs and optoelectronic devices. GaN was used principally to manufacture LEDs and laser diodes. ICs accounted for 77% of domestic gallium consumption, optoelectronic devices accounted for 21%, and research and development accounted for the remainder (table 2). About 81% of the gallium consumed in the United States was contained in GaAs, GaAsP, GaN, and GaP wafers. 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.

In 2020, reported gallium consumption in the United States was 15.7 t, a 6% increase from 14.9 t in 2019 (table 1), owing to a 12% increase in gallium consumption in the production of analog and digital ICs, offset by a 12% decrease in gallium consumption in the production of laser diodes, LEDs, photodetectors, and solar cells (table 2). Doped GaAs wafer imports decreased by 34% from that in 2019 (table 5). Refined gallium metal consumption increased by 28% to 617 kilograms (kg) from 481 kg in 2019 (table 3). About 98% of the gallium metal consumed was at a purity level of 99.99999% to 99.999999%. Although reported U.S. gallium consumption increased by 6% in 2020 from the previous year, U.S. gallium consumption since 2013 has declined by 58%. The continued decrease in U.S. gallium consumption and gallium wafer imports was attributed to U.S. gallium consumers using GaAs wafer production facilities in Asia to be closer to the Asian-dominated optoelectronics industry.

Global Consumption

Gallium Arsenide.—Wireless applications continued to drive the radio frequency (RF) GaAs device market in 2020. Despite the negative effects the coronavirus disease 2019 (COVID-19) pandemic had upon the global economy, the value of RF GaAs devices consumed worldwide increased by 5.8% to an estimated $9.05 billion in 2020 from $8.55 billion in 2019. Increased deployment of fifth-generation (5G) networks and devices with high RF content was thought to be the most significant factor for the increase in value (Higham, 2020, 2021).

Worldwide shipments of smartphones from device vendors in 2020 decreased by 6.6% to 1.28 billion units from 1.37 billion units shipped in 2019 owing to the negative economic effects of the COVID-19 pandemic (IDC Corp. USA, 2022). As of 2020, China, Asia and the Pacific (other than China), North America, and Western Europe, in descending order, were the principal regions and (or) countries of smartphone consumption; China accounted for 28% of smartphone sales; Asia and the Pacific (other than China), 26%; North America, 10%; and Western Europe, 9% (Gartner Inc., 2020).

Gallium Nitride.—GaN substrates (where GaN is grown epitaxially on sapphire, silicon, silicon carbide, or GaN wafers) were produced and consumed mostly in the Asia and the Pacific region, where China constituted a significant share of the market. Prominent GaN technology companies occupied the Asia and the Pacific region, and significant investments were made in research and development of innovative GaN technologies. North America emerged as the second largest market for GaN substrates owing to increased use of the substrates in the production of white light LEDs and electric vehicles. Europe was the third largest market, owing to the increasing use of GaN substrates in the automotive industry and the rapid industrialization of the region (Semiconductor Today, 2019).

Increased demand for RF GaN devices provided significant growth for advanced GaN-based products. In 2020, the value of RF GaN devices consumed worldwide was $891 million, a 20% increase from $740 million in 2019. RF GaN 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 2019, military applications accounted for 46% of sales; telecommunications infrastructure, 43%; satellite communications, 6%; wired broadband applications, 2%; commercial radar and avionics applications, 1%; RF energy applications, 1%; and other uses, 1% (Yole Développement, 2020, 2021a).

GaN power devices operate at higher voltages, power densities, and switching frequencies and offer greater power efficiency than existing GaAs and silicon devices. In 2020, the value of GaN power devices consumed worldwide more than doubled to $46 million from $20.7 million in 2019 owing to the rapid penetration of GaN devices into smartphone fast-charger applications. Yole Développement reported that fast charging was likely to be the leading application for the GaN power device market. In 2020, consumer electronics applications accounted for 62% of sales; telecommunication and data communication applications, 20%; industrial applications, 7%; defense and aerospace applications, 3%; automotive and mobility applications, 1%; energy applications, 1%; and other applications, 6% (Yole Développement, 2021b).

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.

Worldwide LED consumption decreased in 2020 owing to the economic effects of the COVID-19 pandemic. Large declines in consumption for commercial lighting applications and automotive lighting applications were two key factors. According to TrendForce Corp., packaged LED market sales revenue was valued at $15.1 billion in 2020, a decrease of 9% from $16.6 billion in 2019. Packaged LED market sales revenue previously decreased by 10% in 2019 from that in 2018 owing to a combination of the trade dispute between the United States and China, increased production capacity, and stagnant demand (Chu, 2019, 2020). LED prices in 2020 decreased by 6% from those in 2019 (Carbone, 2021). Significant LED capacity expansion began in 2011, mostly brought about by the creation of Government-subsidized LED companies in China. The LED market was in surplus since 2012, and prices for packaged LEDs have decreased continuously since then (Wright, 2016, 2018).

The Asia and the Pacific region historically has been the leading consumer of LED material, followed distantly 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, 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).

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. There were five major TMG producers worldwide in 2020—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.—Neodymium-iron-boron (NdFeB) magnets, which accounted for the overwhelming majority of total rare-earth magnet production, were estimated to contain approximately 0.2% gallium. China produced about 85% of all rare-earth magnets. In 2019, gallium consumed by rare-earth magnets was estimated to be between 10 and 50 t (Roskill Information Services Ltd., 2020, p. 82; Asian Metal, 2021b).

Prices

According to Asian Metal Ltd. (2020, 2021a), the low-grade gallium price in China increased by 96% in 2020, from $140 per kilogram in January to $275 per kilogram in December. The increase in China's low-grade gallium price resulted for 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 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 rebounded in the second half of 2020, and gallium prices increased significantly beginning in the last quarter of 2020. The rise in price also was driven in part by China's increased gallium consumption in the production of NdFeB magnets (Anhui Fitech Materials Co., Ltd, 2021; Messecar, 2021).

From U.S. Census Bureau data, the average unit value for imported low-grade gallium in 2020 was estimated to be $163 per kilogram, an increase of 7% from that in 2019 (table 1). The estimated average unit value for imported high-grade (≥99.999%-pure) gallium increased by 4% to $596 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 2020, gallium metal imports were 22% lower than those in 2019 (table 4), most likely owing to the continuation of higher import tariffs on gallium from China. In 2018, gallium imports from China increased by 300% from those in 2017 and were most likely stockpiled owing to the discussion of potential tariffs on imports from China. Gallium metal imports from China (including Hong Kong) decreased by 96% from those in 2019. Germany (59%), Taiwan (22%), and Japan (11%) were the leading sources of imported gallium metal in 2020. 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 34% from those in 2019. Germany was the leading source, accounting for 31% of imports. Taiwan (29%), Italy (12%), and Japan (9%) 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 2020 may be higher than the actual total weight of imported wafers.

World Review

Reported gallium production for China and Japan and imports of gallium into Germany, Japan, and the United States, three leading gallium-consuming countries, were used as the basis for estimating world gallium production. China decreased its production of low-grade primary gallium in 2020 by approximately 6% (Asian Metal Ltd., 2021a) and was estimated by the USGS to account for 97% of worldwide low-grade primary gallium production. Global low-grade primary gallium production was estimated by the USGS to be 327 t in 2020, a decrease of 7% from that in 2019 (table 6). Principal world producers, in descending order of production, were China, Russia, Japan, and the Republic of Korea. Ukraine was thought to have stopped production of low-grade primary gallium in 2019. Production of high-grade primary refined gallium (sourced from current and stockpiled low-grade primary gallium) in 2020 was estimated by the USGS to be 239 t, 27% less than low-grade primary production. Canada, China, Japan, the United States, and possibly Slovakia refined high-grade gallium from low-grade primary material. The United Kingdom stopped production of high-grade refined gallium in 2018 (5N Plus Inc., 2019, p. 7).

The USGS estimated worldwide gallium consumption to be 575 t in 2020, an increase of 21% from the revised worldwide gallium consumption estimate of 475 t in 2019. Based on historical low-grade and high-grade gallium consumption patterns, approximately 45% to 50% of high-grade gallium consumed was from recycled material (Spicer, 2013). Therefore, assuming a 47% recycle rate, about 363 t of low-grade primary gallium, of which 239 t was refined into high-grade primary gallium, and 212 t of high-grade recycled gallium were estimated by the USGS to have been consumed in 2020. The remaining 124 t of low-grade primary gallium was estimated

to have been consumed directly by China in the production of neodymium magnets and other industrial applications; some may also have been stockpiled. Gallium was recycled from new scrap in Canada, China, Germany, Japan, Slovakia, and the United States. The United Kingdom stopped recycling gallium in 2018 (5N Plus Inc., 2019, p. 7).

China.—China produced a reported 317 t of low-grade primary gallium in 2020 (table 6) (Asian Metal Ltd., 2021a). China's HC Semitek Corp. estimated that China consumed approximately 180 t of gallium for its LED industry in 2020, approximately 40% of worldwide consumption. China's share of worldwide consumption was forecast to increase to between 210 and 250 t by 2022 owing to the rapid growth of the country's LED industry (Asian Metal Ltd., 2022). 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 (Shanxi Province); Shanxi Zhaofeng Gallium Industry Co. (Shanxi Province); Vital Materials (Guangzhou, Guangdong Province); Xiaoyi Xingan Gallium Co., Ltd. (Guangxi Province); and Zhuhai 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 Organization for Metals and Energy Security (JOGMEC) estimated that Japan's gallium supply in 2020 totaled 167 t, about 4% lower than that in 2019; 55% of the gallium supply was sourced from imports, 43% from recovered scrap, and 2% from low-grade primary gallium produced in Japan as a byproduct of zinc refining. Of Japan's 91.5 t of imported gallium, 75% came from China. Japan consumed an estimated 140 t of gallium in 2020, approximately 24% of worldwide consumption (Kazuhiro Kojima, Director General, Rare Metals Stockpile Department, JOGMEC, written commun., November 5, 2020).

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 Développement, 2017).

Outlook

Gallium consumption is expected to increase as the use of GaN technology in defense applications and wireless infrastructure increases, as well as the implementation of new 5G networks globally. 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, as driven by devices with three-dimensional (3D) sensing function.

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 16% from 2018 to 2022. General lighting is expected to remain the largest segment of the LED market, accounting for 77% by 2021, and the Asia and the Pacific region is expected to account for 52% of the market by 2022. The Asia and the Pacific region is expected to remain the leading consumer of LED material owing to rapid development in many Asian countries, Asian government incentives to encourage use of energy-efficient lighting, and the presence of the majority of the LED industry in the region (Semiconductor Today, 2017; Technavio Research, 2018).

References Cited

5N Plus Inc., 2019, Annual information form for the fiscal year ended December 31, 2018: Montreal, Quebec, Canada, 5N Plus Inc., February 26, 27 p. (Accessed May 6, 2019, at https://www.5nplus.com/files/15/Final%20AIF-Dec%202018_2019-02-26-19-36.pdf.)

Anhui Fitech Materials Co., Ltd., 2021, Gallium—Price floor set to rise in 2021: Roskill Information Services Ltd., December 6. (Accessed January 22, 2022, at https://www.fitechem.com/news/gallium-price-floor-set-to-rise-in-2021/.)

Asian Metal Ltd., 2020, Monthly gallium market report January 2020: Beijing, China, Asian Metal Ltd., February 12. (Accessed May 4, 2020, via http://www.asianmetal.com.)

Asian Metal Ltd., 2021a, Monthly gallium market report December 2020: Beijing, China, Asian Metal Ltd., January 11. (Accessed April 10, 2021, via http://www.asianmetal.com.)

Asian Metal Ltd., 2021b, Optimistic with the prices trend of gallium metal in 2021: Beijing, China, Asian Metal Ltd. (Accessed January 5, 2022, at https://wap.asianmetal.com/interview/2021/interview_fengchenEn.shtml.)

Asian Metal Ltd., 2022, Gallium consumption from the semiconductor industry continues growing: Beijing, China, Asian Metal Ltd. (Accessed May 6, 2022, at https://wap.asianmetal.com/interview/2022/interview_chaoyangEn.shtml.)

Carbone, James, 2021, LEDinside—The buyer's market for high-brightness LEDs will continue in 2021: Crowborough, East Sussex, United Kingdom, Electronics Sourcing, February 15. (Accessed July 9, 2022, at https://electronics-sourcing.com/2021/02/15/the-buyers-market-for-high-brightness-leds-will-continue-in-2021/.)

Chu, Roger, 2019, China manufacturers raise capacity, causing general stagnation in revenue growth for top 10 LED packaging suppliers, says TrendForce: Taipei, Taiwan, TrendForce Corp. press release, April 23. (Accessed December 2, 2019, at https://press.trendforce.com/press/20190423-3234.html.)

Chu, Roger, 2020, Trendforce—Global LED demand set to rebound from rock bottom in 2021, with forecasted US$15.7 billion in yearly revenue, says TrendForce: Taipei, Taiwan, TrendForce Corp. press release, December 23. (Accessed December 28, 2020, at https://www.trendforce.com/presscenter/news/20201223-10614.html.)

Gartner Inc., 2020, Gartner says worldwide smartphone sales will grow 3% in 2020: Egham, United Kingdom, Gartner Inc. press release, January 28. (Accessed November 15, 2020, at https://www.gartner.com/en/newsroom/press-releases/2020-01-28-gartner-says-worldwide-smartphone-sales-will-grow-3--.)
Higham, Eric, 2020, 2019 RF GaAs revenue snapshot: Boston, MA, Strategy Analytics Inc., March 19. (Accessed October 5, 2020, at https://www.strategyanalytics.com/access-services/components/advanced-semiconductors/reports/report-detail/2019-rf-gaas-revenue-snapshot.)
Higham, Eric, 2021, RF GaAs device forecast and outlook—2020–2025 (data tables): Boston, MA, Strategy Analytics Inc., July 19. (Accessed September 17, 2021, at https://www.strategyanalytics.com/access-services/components/advanced-semiconductors/market-data/report-detail/rf-gaas-device-forecast-and-outlook-2020---2025-(data-tables).)
Huy, Dieter, and Liedtke, Maren, 2016, Supply and demand of lithium and gallium: Hannover, Germany, Bundesanstalt für Geowissenschaften und Rohstoffe, May 1, 50 p. (Accessed October 12, 2016, at https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/Downloads/studie_Li_Ga.pdf?__blob=publicationFile&v=4.)
IDC Corp. USA, 2022, Smartphone shipments declined in the fourth quarter but 2021 was still a growth year with a 5.7% increase in shipments, according to IDC: Framingham, MA, IDC Corp. USA press release, January 27. (Accessed February 5, 2022, at https://www.idc.com/getdoc.jsp?containerId=prUS48830822.)
Indium Corp., [undated], Gallium: Clinton, NY, Indium Corp. (Accessed November 19, 2021, at https://www.indium.com/products/metals/gallium/.)
Juncong, Feng, 2017, China's minor metals market and the supply and demand of gallium, selenium, and tellurium: Beijing, China, China Nonferrous Metals Industry Association, Gallium, Selenium, and Tellurium Branch presentation, April 26, 24 p.
Lee, K., Nubbe, V., Rego, B., Hansen, M., and Pattison, M., 2021, 2020 LED manufacturing supply chain: U.S. Department of Energy, March, 28 p. (Accessed June 9, 2021, at https://www.energy.gov/sites/default/files/2021-05/ssl-2020-led-mfg-supply-chain-mar21.pdf.)
Messecar, Caroline, 2021, Viewpoint—US gallium consumers left with few options: Argus Media group, Argus Metals International, December 30. (Accessed January 10, 2022, at https://www.argusmedia.com/en/news/2287879-viewpoint-us-gallium-consumers-left-with-few-options.)
Neo Performance Materials Inc., 2021, Annual information form for the year ended December 31, 2020: Toronto, Ontario, Canada, Neo Performance Materials Inc., March 22, 69 p. (Accessed June 15, 2021, at https://www.neomaterials.com/wp-content/uploads/2021/03/NPM_Annual_Information_Form_2021.03.22.pdf.)
QY Research, 2021, Global trimethylgallium (TMG) sales market report 2021: Beijing, China, QY Research press release. (Accessed January 6, 2022, at https://www.qyresearch.com/index/detail/2766699/global-trimethylgallium-tmg-sales-market-report-2021.)
Roskill Information Services Ltd., 2020, Gallium—Outlook to 2030 (10th ed.): London, United Kingdom, Roskill Information Services Ltd., August, 114 p.
Semiconductor Today, 2017, LED market growing at 18% CAGR, boosted by demand for energy-efficient lighting: Semiconductor Today, September 8. (Accessed September 13, 2017, at http://www.semiconductor-today.com/news_items/2017/sep/technavio_080917.shtml.)
Semiconductor Today, 2019, GaN substrate market to grow at 10% CAGR to 2027: Semiconductor Today, November 8. (Accessed February 16, 2020, at http://www.semiconductor-today.com/news_items/2019/nov/transparency-081119.shtml.)
Shen, Daisy, 2015, Chinese 6N gallium market flat, business slow: Metal-Pages, July 8. (Accessed September 17, 2015, via http://www.metal-pages.com/.)
Spicer, Andi, 2013, ESM13—Most specialty and minor metals lost in the copper recycling process—PPM: Metal-Pages, September 11. (Accessed September 11, 2013, via http://www.metal-pages.com/.)
Technavio Research, 2018, Global LED market 2018–2022 to post a CAGR of 16%: Elmhurst, IL, Technavio Research press release, June 25. (Accessed December 5, 2018, at https://www.businesswire.com/news/home/20180625006042/en/Global-LED-Market-2018-2022-Post-CAGR-16.)
Wright, Maury, 2016, Strategies Unlimited reports packaged LED revenue has been stymied by oversupply: LEDs Magazine, March 3. (Accessed June 21, 2016, at http://www.ledsmagazine.com/articles/2016/03/strategies-unlimited-reports-packaged-led-revenue-has-been-stymied-by-oversupply.html.)
Wright, Maury, 2018, Strategies in Light investor forum previews LED and SSL market data: LEDs Magazine, February 13. (Accessed February 14, 2018, at http://www.ledsmagazine.com/articles/2018/02/strategies-in-light-investor-forum-previews-led-and-ssl-market-data.html.)
Yole Développement, 2017, Bulk GaN—From technology to market: Lyon, France, Yole Développement press release, February 21. (Accessed March 23, 2017, at http://www.yole.fr/BulkGaN_Applications_Players.aspx#.Wpch8IPwZhE.)
Yole Développement, 2020, Driven by military applications and 5G telecom infrastructure, GaN RF continues growing: Lyon, France, Yole Développement press release, May 13. (Accessed December 20, 2020, at http://www.yole.fr/iso_upload/News/2020/PR_RF_GAN_MarketGrowth_YOLE_SYSTEM_PLUS_CONSULTING_May2020.pdf.)
Yole Développement, 2021a, GaN for RF electronics—GaN-on-SiC vs GaN-on-Si?: Lyon, France, Yole Développement press release, June 3. (Accessed August 10, 2021, at http://www.yole.fr/iso_upload/News/2021/PR_RF_GAN_MarketUpdate_YOLE_June2021.pdf.)
Yole Développement, 2021b, GaN power 2021—Epitaxy, devices, applications and technology trends: Lyon, France, Yole Développement market & technology report, May. (Accessed August 10, 2021, at https://s3.i-micronews.com/uploads/2021/05/YINTR21190_GaN_Power_May2021_Flyer.pdf.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Gallium. Ch. in Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, 2017.
Gallium. Ch. in Mineral Commodity Summaries, annual.
Gallium (Ga). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.
Historical Statistics for Mineral and Material Commodities in the United States, Data Series 140.

Other

Gallium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Gallium and Gallium Arsenide—Supply, Technology, and Uses. U.S. Bureau of Mines Information Circular 9208, 1988.
Gallium—Global Industry Markets & Outlook (8th ed.). Roskill Information Services, Ltd., 2011.
Minor Metals in the CIS. Roskill Information Services Ltd., 1997.

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

(Kilograms unless otherwise specified)

	2016	2017	2018	2019	2020
Production, primary crude	--	--	--	--	--
Imports for consumption:					
Metal	10,500	20,200	32,000	5,740	4,460
Gallium arsenide wafers, gross weight[2]	1,290,000	803,000	444,000	272,000	178,000
Consumption, reported	18,100	17,900	15,000	14,900	15,700
Price,[e, 3] dollars per kilogram:					
Purity ≥99.999%	690	477	508	573 [r]	596
Purity ≤99.99%	125	124	185	153 [r]	163

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through July 7, 2021. Data are rounded to no more than three significant digits.
[2]Data include imports of undoped and doped wafers in 2016, but only doped wafers since 2017.
[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)

End use	2019	2020
Optoelectronic devices:		
Laser diodes and light-emitting diodes	3,380	2,840
Photodetectors and solar cells	369	443
Integrated circuits:		
Analog	9,340	11,100
Digital	1,430	1,020
Research and development	376	354
Total	14,900	15,700

[1]Table includes data available through July 7, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes gallium metal and gallium content of compounds produced domestically.

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

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2019:				
99.99% to 99.999%	1,870	--	--	1,870
99.9999%	595	12	12	595
99.99999% to 99.999999%	455	400	469	386
Total	2,920	412	481	2,850
2020:				
99.99% to 99.999%	1,870	--	--	1,870
99.9999%	595	15	15	595
99.99999% to 99.999999%	386	668	602	452
Total	2,850	683	617	2,920

-- Zero.
[1]Table includes data available through July 7, 2021. 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]

Country or locality	2019 Quantity (kilograms)	2019 Value[2]	2020 Quantity (kilograms)	2020 Value[2]
Belgium	47	$20,100	--	--
Canada	--	--	84	$7,350
China	494	70,200	66	46,000
Czechia	3	3,010	--	--
France	109	75,100	163	92,400
Germany	1,750	289,000	2,630	428,000
Hong Kong	1,000	140,000	--	--
Japan	400	220,000	512	312,000
Korea, Republic of	11	2,350	--	--
Russia	1,000	148,000	--	--
Taiwan	500	74,800	1,000	147,000
United Kingdom	428	294,000	--	--
Total	5,740	1,340,000	4,460	1,030,000

-- Zero.
[1]Table includes data available through June 29, 2021. 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	2019 Quantity (kilograms)	2019 Value[2]	2020 Quantity (kilograms)	2020 Value[2]
Doped:				
Austria	39	$41,300	1,480	$249,000
Barbados	--	--	8	3550
Belgium	1,730	48,000	987	430,000
Canada	20	126,000	12	6,000
China	6,770	7,080,000 r	6,550	5,210,000
Denmark	402	195,000	33	198,000
Finland	5,600	8,950,000	2,930	4,810,000
France	52,800	64,000,000	7,750	18,100,000
Germany	125,000	20,100,000	55,000	18,500,000
Indonesia	21,000	32,700	--	--
Israel	28	64,500	3	3,000
Italy	485	198,000	21,000	6,680,000
Japan	12,400	22,200,000	16,600	21,600,000
Korea, Republic of	2,410	1,440,000	11,700	7,960,000
Malaysia	108	91,200	512	65,100
Netherlands	5	12,400	1,010	101,000
Poland	175	121,000	117	293,000
Singapore	441	277,000	160	164,000
Taiwan	41,100	44,600,000	50,900	71,100,000
United Kingdom	635	2,080,000	1,060	2,000,000
Other	202	186,000	403	71,600
Total	272,000	172,000,000	178,000	157,000,000

[r]Revised. -- Zero.
[1]Table includes data available through June 29, 2021. 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	2016	2017	2018	2019	2020
China	171,000	319,000	404,000	338,000	317,000
Germany, crude	16,000	--	--	--	--
Japan	3,000	3,000	3,000	3,000	3,000
Korea, Republic of[e]	3,000	3,000	3,000	2,000	2,000
Russia[e]	9,000	7,000	6,000	8,000	5,000
Ukraine[e]	9,000	4,000	4,000	--	--
Total	211,000	336,000	420,000	351,000	327,000

[e]Estimated. -- Zero.
[1]Table includes data available through June 30, 2021. 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.

TABLE 7
ESTIMATED WORLD ANNUAL LOW-GRADE PRIMARY GALLIUM PRODUCTION CAPACITY, DECEMBER 31, 2020[1, 2]

(Kilograms)

Country or locality	Capacity
China	650,000
Germany	40,000
Hungary	8,000
Japan	10,000
Kazakhstan	25,000
Korea, Republic of	16,000
Russia	10,000
Ukraine	15,000
Total	774,000

[1]Table includes data available through July 7, 2021. 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.

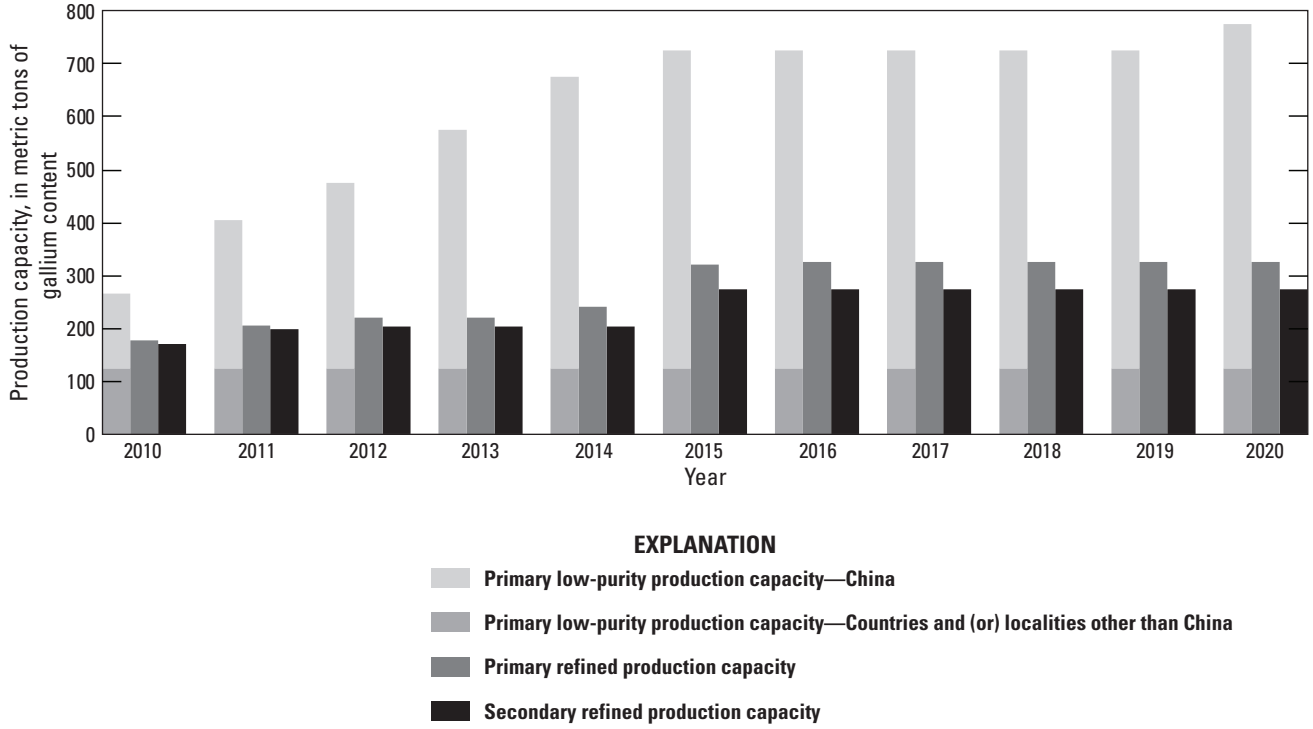

Figure 1. Estimated worldwide gallium production capacity from 2010 through 2020.

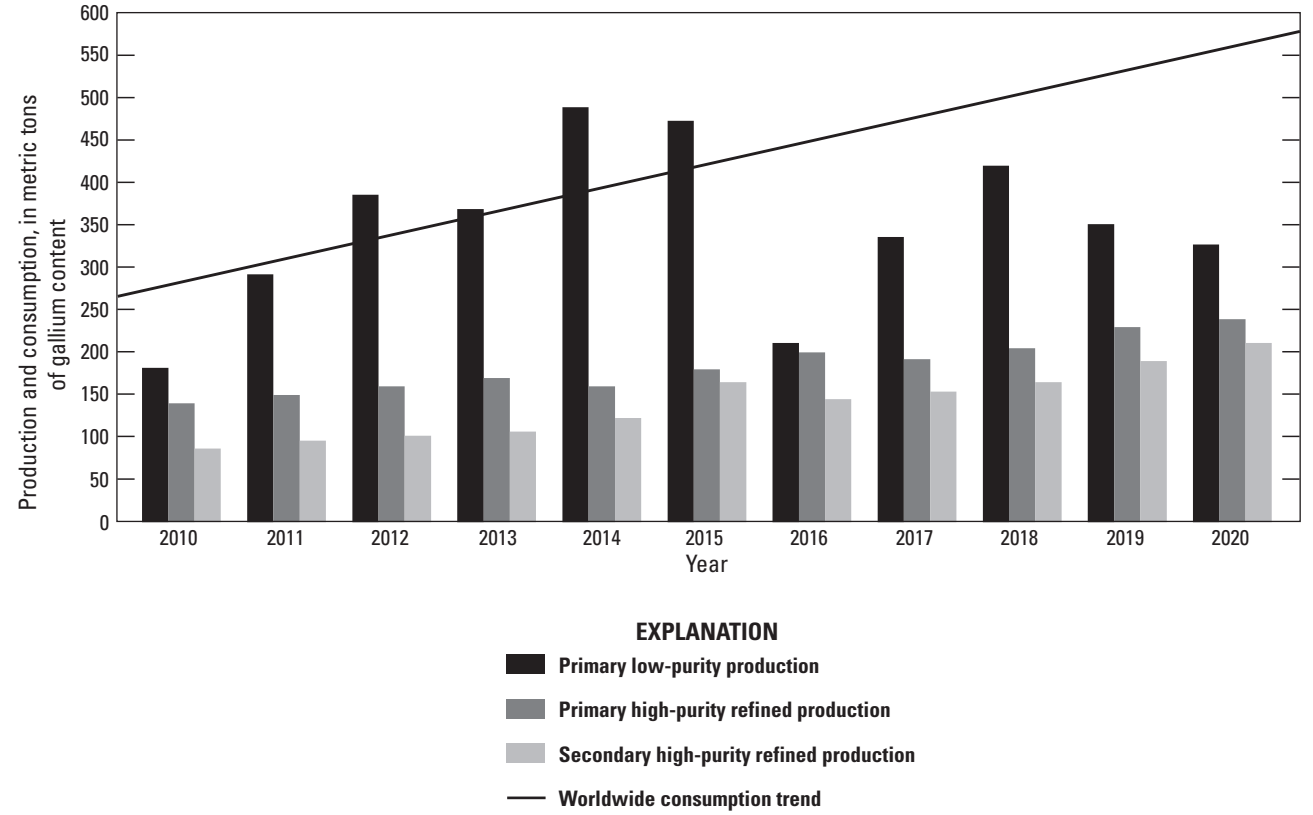

Figure 2. Estimated worldwide gallium production and consumption from 2010 through 2020.