Gallium

By Brian W. Jaskula

Domestic survey data and tables were prepared by Lisa Mersdorf, statistical assistant.

Gallium metal and gallium arsenide (GaAs) wafer imports continued to account for most of the U.S. gallium consumption. Metal imports were 38% higher than those in 2006, with Germany, Canada, and Ukraine, in descending order, as the leading sources of imported gallium. Doped GaAs wafer imports were 4% lower than those in 2006; Germany and Japan were the principal sources. Almost all the gallium consumed in the United States was in the form of GaAs and gallium nitride (GaN) and was used in integrated circuits (ICs) and optoelectronic devices [laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells]. Gallium consumption increased by 24% from that in 2006. The increase in consumption was less than the increase in imports because a large portion of the U.S. imports was estimated to be low-purity material that was refined in the United States and shipped to other countries.

In 2007, estimated world crude gallium production was 95 metric tons (t), 32% higher than that in 2006. Principal producers were China, Germany, Japan, Kazakhstan, and Ukraine. Plants in Hungary, Russia, and Slovakia also recovered gallium. Refined gallium production was estimated to be about 135 t, which included some new scrap refining. Refined gallium was produced in China, Japan, and the United States.

Legislation and Government Programs

In May, the U.S. Department of Energy (DOE) awarded $13.3 million for eight solid-state lighting (SSL) research and product development projects. These projects continued the DOE’s public-private partnership to advance state-of-the-art SSL used for general lighting applications. Five of these projects involved improvements in LEDs. Of the five, the goals of Carnegie Mellon University, Cree Inc., Inlustra Corp., and Yale University were to increase LED device efficiency. Sandia National Laboratory’s proposal seeks to improve InGaN epitaxial quality (LEDs Magazine, 2007c).

Velox Semiconductor Corp. was awarded $2 million from the U.S. Department of Commerce’s National Institute of Science and Technology to develop a GaN replacement for silicon-based automotive power switching transistors. It is thought that the GaN switching devices will significantly increase the fuel efficiency of hybrid vehicles, as well as increase the efficiency and reduce the size of power supplies used in laptop computers, telecommunications applications, and other consumer and industrial applications (Semiconductor Today, 2007n).

Raytheon RF Components was awarded $8.85 million from the U.S. Department of Defense’s Defense Production Act (DPA) Title III Program to develop a dedicated, long-term domestic foundry source for atomic layer deposition (ALD) hermetic coating of monolithic microwave integrated circuits (MMICs) at the wafer level. The MMICs are used in radar systems, and the atomic layer deposition will allow better quality control (Semiconductor Today, 2007h).

Goodrich Corp. was selected by the Defense Advanced Projects Agency to develop next-generation night vision sensor technology for helmet-mounted and microvehicle applications. The indium gallium arsenide-night vision sensors were expected to significantly reduce the size and weight of vehicle-mounted imaging cameras and head-mounted monoculars by eliminating the cooling systems used in current night vision technologies (Goodrich Corp., 2008).

Production

No domestic production of primary gallium was reported in 2007 (table 1). Recapture Metals Inc. in Blanding, UT, recovered gallium from scrap materials, predominantly those generated during the production of GaAs. Recapture Metals’ facilities have the capability to produce about 40 metric tons per year (t/yr) of high-purity gallium. The company recovered gallium from its customers’ scrap on a fee basis and purchased scrap and low-purity gallium for processing into high-purity material.

In 2007, drilling was completed at Gold Canyon Resources Inc.’s Cordero gallium property in Humboldt County, NV. Based on an updated estimate, indicated resources reportedly increased to 713,930 kilograms (kg) of gallium and inferred resources decreased to 334,590 kg. Gold Canyon plans to collect a bulk sample for metallurgical testing in preparation for a prefeasibility study (Gold Canyon Resources Inc., 2008).

Consumption

Gallium consumption data were collected by the U.S. Geological Survey from a voluntary survey of U.S. operations. In 2007, there were 11 respondents to the consumption of gallium survey, representing 61% of the total canvassed. Data in tables 2 and 3 were adjusted by incorporating estimates to reflect full industry coverage. Many of these estimates were based on the companies’ 2007 10-K reports submitted to the U.S. Securities and Exchange Commission.

More than 95% of the gallium consumed in the United States was in the form of GaAs or GaN. GaAs was used to manufacture optoelectronic devices (laser diodes, LEDs, photodetectors, and solar cells) and ICs. ICs accounted for 65% of domestic consumption, optoelectronic devices accounted for 29%, and 6% was used in research and development and other applications (table 2). GaN principally was used to manufacture LEDs and laser diodes.

Gallium Arsenide.—In September, RF Micro Devices Inc. (RFMD) announced plans to expand its compound semiconductor manufacturing capacity with the construction
of a $103 million 6-inch post-epitaxial processing plant at the company’s Greensboro, NC, facility. This would be the company’s sixth expansion in its 16-year history. The plant will be RFMD’s second 6-inch post-epitaxial wafer processing operation, and it was expected to produce additional GaAs power amplifier chips for cellular telephones (Compound Semiconductor.net, 2007b). In November, RFMD completed its $900-million acquisition of radio-frequency (RF) component supplier Sirensa Microdevices Inc. The acquisition would allow RFMD to apply its cellular-focused RF expertise across Sirensa’s markets, which include aerospace, broadband, defense, wireless, and worldwide interoperability for microwave access (WiMax) (Semiconductor Today, 2007g).

In December, RFMD agreed to purchase Filtronic Compound Semiconductors Ltd. for $25 million. The acquisition included Filtronic’s 6-inch GaAs wafer fabrication facility in Newton Aycliffe, United Kingdom, and its microwave and millimeterwave RF semiconductor business. It was expected that the purchase will increase RFMD’s GaAs capacity by 30% (Semiconductor Today, 2008b).

In October, Skyworks Solutions Inc. began conversion of its internal GaAs heterojunction bipolar transistor fabrication facility in Newbury Park, CA, from 4-inch wafers to 6-inch wafers. The conversion was a result of demand for Skyworks’ products from tier-one handset original equipment manufacturers and other customers. Increased GaAs content per handset for new, third-generation (3G) cellular telephones also added to demand. Skyworks also expanded its partnerships with several leading Taiwanese foundries to meet the need for extra capacity (Compoundsemi Online, 2007b). Skyworks agreed to purchase Freescale Semiconductor Inc.’s GaAs power amplifier (PA) business. The agreement included Freescale’s GaAs PA designs, intellectual property, inventory, and product lines, but it did not include Freescale’s GaAs wafer fabrication facility, located in Tempe, AZ (Compound Semiconductor.net, 2007e).

AXT Inc. (Fremont, CA) increased GaAs wafer production capacity in China by 40% during the third quarter of 2007. The company cited increased interest from bipolar field effect transistor power amplifier (BiFet PA) and solar cells manufacturers and expectations of continued strong demand as the reasons for the capacity increases (Compound Semiconductor.net, 2007b). In December, AXT was awarded a production order from IQE plc for its 2008 worldwide GaAs substrate requirements. The substrates were primarily 6-inch GaAs, and the agreement was worth approximately $15.1 million, with an option for IQE to purchase an additional $3.5 million of substrates (AXT Inc., 2007).

In September, Anadigics Inc. (Warren, NJ) acquired Fairchild Semiconductor Inc.’s RF design team. The acquisition provided Anadigics with an additional 23 RF designers and engineers to further develop the company’s 3G cellular, WiFi (a wireless networking technology), and WiMax semiconductor devices (Compound Semiconductor.net, 2007a).

Also in September, TriQuint Semiconductor Inc. (Hillsboro, OR) announced the acquisition of RF transistor supplier Peak Devices Inc. (Boulder, CO). Peak Devices had developed a silicon-based technology that allows a single power amplifier device to operate over multiple octaves, including the range in which most wireless networks operate. TriQuint claimed that the technology can be incorporated into its GaAs and GaN designs. TriQuint’s goal had been to diversify beyond mobile handsets, and think its acquisition of Peak Devices will probably strengthen its position among multiple RF power markets including base-station products, broadband solutions, and military communications (Semiconductor Today, 2007f).

**Gallium Nitride.**—Companies continued to try to improve the substrate material on which GaN is grown to improve the quality of the GaN material. In March, Hitachi Cable Ltd. (Tokyo, Japan) announced it had successfully developed an easily reproducible 3-inch diameter GaN substrate. The diameter enlargement was made possible by a newly developed technology for separating the base substrate. The technology, called void-assisted-separation, created a low-strength “sacrifice layer” by generating a microscopic void between a layer of GaN film and the base substrate to allow for easier separation. The sacrifice layer enables the GaN film to separate from the base substrate owing to thermal stress generated at the time of temperature drop after Hydride Vapor Phase Epitaxy growth. The process allows for easily reproducible substrates (Tadashi, 2007).

Sandia National Laboratories demonstrated the growth of GaN on the A-GaN substrates of Aonex Technologies Inc. (a subsidiary of Arrowhead Research Corp). Aonex claimed the A-GaN substrates provide a way to reduce the cost of GaN-based devices while improving performance. The company described its A-GaN wafers as effective veneers of bulk GaN wafers, with the thin GaN layer providing the high-quality surface for device fabrication, while the aluminum nitride support material is chosen for its low cost, fracture resistance, process compatibility, and ease of removal following device growth (Semiconductor Today, 2007l).

In response to growing demand for its low-defect-density nonpolar native GaN substrates, Kyma Technologies Inc. announced that it had partnered with Caracal Inc. and the Pennsylvania State University’s Electro-Optics Center to increase effective manufacturing capability and capacity. Demand for nonpolar native GaN had grown rapidly because of its promise to enable better performance electronic and optoelectronic devices (Compoundsemi Online, 2007a).

RFMD completed the technical qualification of its first generation 48 volt (V) GaN process technology and began preproduction volume shipments of the technology to customers. RFMD claimed the electrical properties of its GaN technology delivered higher efficiency, wider operating bandwidth, and greater ruggedness than currently available technologies. The applications targeted by RFMD included high-linearity cable television line amplifiers, military radar applications, power modules for high-lumen light generation applications, and wide bandwidth wireless infrastructure power amplifiers (RF Micro Devices Inc., 2007).

To address the requirements driving the emerging standards of 3G cellular telephones and WiMax, Nitronex Corp. introduced its first 48V GaN-on-Silicon RF power transistors for high-power broadband operation. The 48V power transistors take advantage of thermal enhancements in wafer processing and transistor design and allow devices to operate with reduced...
memory effects and wider RF output bandwidth (Nitronex Corp., 2007a, b). Nitronex also completed its new 7,900 square-meter research and development facility, which increases Nitronex’s manufacturing capacity and provides additional space for expanding research and development efforts (Nitronex Corp., 2007c).

Sony Corp. increased its production capacity of GaN-based blue semiconductor lasers to 1.7 million per month. Owing to an increase in blue-violet laser diode demand, Sony installed wafer processing equipment capable of producing 5 million blue-violet laser diodes and was to expand its assembly capacity when demand increases. Sony claimed that demand for Blu-ray disc players, high-definition DVD recorders, and high-end games consoles would ensure that GaN lasers are a major component of market growth (Compound Semiconductor.net, 2007j).

In October, Toshiba Corp. developed a GaN power field-effect transistor (FET) for the Ku-band [12 gigahertz (GHz) to 18 GHz] frequency range that achieved output power of 65.4 watts (W) at 14.5 GHz, the highest level of performance yet reported at this frequency band. Mass production of the FET was expected to begin by April 2008. The FET will be used mainly in base stations for satellite microwave communications, which carry high capacity signals, including high definition broadcasts. At high microwave frequencies, GaN devices offer advantages over GaAs devices in heat dissipation and high power performance characteristics (Toshiba Corp., 2007). Toshiba also developed the first high-power semiconductor weather radar based on its GaN FET technology. The FETs allow Toshiba to manufacture systems without the electron tubes that had previously been used in weather radar transmitter modules. The GaN-based weather radar was made possible because the GaN FETs offer twice the power output of similar-sized silicon devices. The GaN transistors also allow the weather radar to make more efficient use of the radio spectrum by narrowing the frequency range scanned (Compound Semiconductor.net, 2007f).

Light-Emitting Diodes. — Many LED manufacturers introduced new LEDs based on GaAs and GaN technology that offer improvements from current LEDs. In many cases, the new LEDs are brighter, last longer, and can be used in new applications. These new products have applications that include automotive lighting, cellular telephones, entertainment and decorative lighting, and signage.

BluGlass Ltd. (Sydney, Australia) announced that it had developed the world’s first blue light emission from the uniform deposition of GaN on a 6-inch-diameter coated glass wafer, which it thinks will yield much cheaper blue, green, and white LEDs for general lighting applications (Semiconductor Today, 2007b). BluGlass awarded Irish epitaxy equipment vendor EMF Semiconductor Systems Ltd. a contract to supply components forming the basis of the first commercial-scale prototype GaN-on-glass reactor. The manufacturing process is based on BluGlass’ processing technique called remote plasma chemical vapor deposition, which uses nitrogen gas rather than ammonia as the source of nitrogen in the compound semiconductor films (Compound Semiconductor.net, 2007d). BluGlass was also awarded $5 million from the Australian Government to assist in the commercialization of its technology. Independent analysis indicated that the technology could achieve GaN cost savings of more than 48% at the wafer level and 10% at the LED device level compared with production systems in current use (LEDs Magazine, 2007a).

To strengthen its leadership position in the SSL market, Koninklijke Philips Electronics N.V. acquired several prominent SSL manufacturers. The manufacturers included Belgium-based Partners in Lighting International, Canada-based TIR Systems Ltd., and the United States-based firms Color Kinetics Inc. and Genlyte Group Inc. Philips claimed the acquisitions of PLI and Color Kinetics would strengthen its LED portfolio, technology base, and intellectual property position, while the acquisitions of TIR Systems and Genlyte would provide Philips with a strong line of fully integrated SSL modules used to deliver integrated lighting products to fixture manufacturers (Koninklijke Philips Electronics N.V., 2007).

Further consolidation in the LED lighting industry took place when Cooper Industries Ltd. acquired two companies with commercial LED expertise. United Kingdom-based Clarity Lighting and United States-based Io Lighting LLC, which specialize in white light and red/green/blue LED color-changing technical lighting applications and advanced indoor/outdoor architectural lighting respectively, would enhance Cooper Industries’ position in the LED market by strengthening the company’s global offerings in LED solutions (LEDs Magazine, 2007b).

Because of growing demand for ultrabright LED applications in automotive parts and outdoor displays, Showa Denko K.K. (SDK) announced that it would increase the production capacity of its aluminum gallium indium phosphide (AlGaInP) blue LED chips from 100 million units per month to 200 million units per month by yearend 2008. The expansion is in addition to an earlier expansion from 30 million units per month to 100 million units per month completed in October 2007 (LEDs Magazine, 2007d).

Solar Cells. — Sustained high energy prices sparked renewed interest in solar energy. Most of the solar cells that are being manufactured for terrestrial applications are multijunction cells, with a substrate of germanium and layers of indium gallium arsenide and other gallium compounds.

To meet increasing demand for terrestrial solar power systems, EMCORE Corp. added two additional production MOCVD systems to its chip fabrication facility in Albuquerque, NM. The additional systems increased EMCORE’s solar cell manufacturing capacity to 75 megawatts (MW) per year (Compound Semiconductor.net, 2007c, k).

In May, EMCORE announced it had achieved a record conversion efficiency of 30.9% for a new class of multijunction solar cells optimized for space applications. The new cell architecture reduced the number of lattice defects seen in previous designs and allowed sunlight to be absorbed more effectively. The company claimed the new solar cells would enable a new class of lightweight, high-efficiency solar arrays to power the next generation of spacecraft and satellites (Semiconductor Today, 2007d).

In July, WIN Semiconductors Corp. (Taiwan, China) announced that it was diversifying into multijunction solar cell production and had ordered a production MOCVD tool from
German equipment vendor Aixtron AG. The MOCVD tool is
typically designed to handle either twelve 4-inch or seven 6-inch
wafer configurations (Compound Semiconductor.net, 2007i).

SolFocus Inc. (Mountain View, CA) received venture
funding of $52 million to provide expansion of concentrator
photovoltaic systems (CPV) at its manufacturing site in India.
SolFocus announced that the CPV expansion would support
the company’s first commercial deployment—the Castilla La
Mancha project in Spain, an installation earmarked for 3 MW
photovoltaic energy generation using CPV systems (Compound
Semiconductor.net, 2007i).

Prices

Since 2002, producer prices for gallium have not been quoted
in trade journals. Data in table 4 represent the average customs
value of gallium imported into the United States. Reports
in Mining Journal indicated that low-grade gallium prices
increased considerably in 2007. At the beginning of the year,
the low-grade gallium price was reported to be about $330 per
kilogram. By August, the price had increased to about $600 per
kilogram. By December, the price had fallen to about $550 per
kilogram.

From U.S. Census Bureau import data, the annual average
value for low-grade gallium was estimated to be $314 per
kilogram, 10% higher than the estimated average value for
2006. For high-grade gallium, the annual average estimated
value increased to $530 per kilogram, about 20% higher than
that in 2006. Import data reported by the U.S. Census Bureau
do not specify purity, so the values listed in table 4 are estimated
based on the average value of the material imported and the
country of origin.

Foreign Trade

In 2007, U.S. gallium imports were 38% higher than those
in 2006 (table 5). Germany (30%), Canada (27%), and Ukraine
(17%) were the leading sources of imported gallium. One reason
for the increase in gallium imports was that after Recapture
Metals and Mining & Chemical Products Ltd. (MCP) purchased
a gallium recovery facility in Germany, some of the gallium
produced in Germany was refined in the United States rather
than in France, where it had previously been refined.

In addition to gallium metal, GaAs wafers were imported into
the United States (table 6). In 2007, 178,000 kilograms (kg) of
doped GaAs wafers was imported. Approximately 3,300 kg of
undoped GaAs wafers was also imported; however, this quantity
was an estimate owing to apparently inaccurate U.S. Census
Bureau import data from China and Taiwan. The data listed in
table 6 may include some packaging material and, as a result,
may be higher than the actual total weight of imported wafers.

World Review

Imports of gallium into Japan and the United States, the
two leading consuming countries, were used as the basis for
estimating world gallium production. Estimated crude gallium
production was 95 t in 2007. Principal world producers were
China, Germany, Japan, Kazakhstan, and Ukraine. Gallium
also was recovered in Hungary, Russia, and Slovakia. Refined
gallium production was estimated to be about 135 t; this
included some new scrap refining. China, Japan, and the United
States refined gallium. Gallium was recycled from new scrap in
Germany, Japan, the United Kingdom, and the United States.

China.—To support anticipated growth beyond its primary
wafer fabrication located in Warren, NJ, Anadigics began
construction of a new 6-inch GaAs integrated circuit wafer
fabrication plant in Jiangsu Province of China in July. The
company planned to supply the fast-growing wireless and
wireline broadband markets in China and the larger Asia-
Pacific Region. Total investment during the plant’s lifetime was
expected to be $50 million, and construction was expected to be
completed by mid-2008 (Anadigics Inc., 2007).

Cree Inc. acquired Hong Kong-based COTCO Luminant
Device Ltd., a leading supplier of high brightness LEDs. The
company announced plans to significantly increase white LED
manufacturing capacity at its plant in Guangdong, China,
tripling Cree’s existing capacity for packaging lighting-class
LEDs (Semiconductor Today, 2007c).

In October, Century Epitech Company, Ltd. completed
construction of the first stage of an extensive compound
semiconductor epitaxial wafer and chip production facility in
Shenzhen. The initial priority for the facility will be production
of epitaxial wafers for GaAs-based RF components, lasers,
and LEDs. Century Epitech claimed that the total investment
planned for the Shenzhen base will be $4.3 billion, and will,
in time, become the largest single compound semiconductor
facility in the world (Hatcher, 2007).

Japan.—Mitsubishi Chemical Corp. announced plans to
expand production capacity of its 2-inch GaN wafers 10-
fold at the company’s Tsukuba plant. A capital investment
of $46 million was to be spent on specially built equipment for
Mitsubishi’s GaN production processes, and the new equipment
was expected to produce 1,000 2-inch wafers per month when at
full capacity (Compound Semiconductor.net, 2007g).

Malaysia.—In May, Osram GmbH announced that its
subsidiary (Osram Opto Semiconductors) would significantly
expand LED production capacity at its assembly plant in Penang
by building its second LED chip fabrication plant. The new
plant was expected to open by spring 2009. Osram announced
it would also expand the capacity of the existing LED assembly
line in Penang by 50% (Semiconductor Today, 2007f).

Taiwan.—In March, the Taiwan Optoelectronic
Semiconductor Industry Association was formed by the
Government-sponsored Industrial Technology Research
Institute and 14 Taiwanese LED manufacturers with the goal
of strengthening Taiwan’s LED industry. The association
would attempt to bolster cooperation and exchanges among
companies and researchers involved in the optoelectronics
and semiconductor industries. In addition, Taiwan’s Ministry
of Economic Affairs and the Department of Industrial Technology
have established an alliance for research and development on
LED lighting standards and quality, involving seven Taiwanese
LED lighting-related member companies. The alliance’s goal
was to integrate technologies within the LED and lighting
industries and develop the first complete LED lighting
measurement standard in Taiwan (Semiconductor Today,
2007j, k).
**United Kingdom.**—The Department of Trade and Industry awarded a 3-year, £5.96 million contract to a consortium to develop high-quality GaN-based LEDs on 6-inch silicon substrates. The project’s goal was to enable large-scale production of low-cost LED lamps for solid-state white lighting. The consortium planned to reduce costs and improve consistency by applying mature large-scale semiconductor processing methods to grow GaN-based light-emitting structures on large-diameter silicon substrates (Semiconductor Today, 2007).

**Outlook**

The research and consulting firm Strategy Analytics Inc. predicted in 2008 that the GaAs market for digital cable networks would reach $109 million by 2012—compared with the $72 million recorded in 2007—as operators strive to deliver high-definition television signals to homes. The company forecast that continued rollout and upgrade of networks would result in infrastructure applications such as line amplifiers and hybrid amplifiers to account for 57% of the GaAs device market from digital cable in 2007, growing to 67% by 2012 (Compound Semiconductor.net, 2008).

In a separate report, Strategy Analytics predicted that the market for 4-inch semi-insulating (SI) GaAs bulk substrates would decline by more than 20% by 2009, with demand shifting to 6-inch material. Bulk 6-inch substrates would account for 76% of total market revenues in 2012, up from 63% in 2007. The company indicated that the market for GaAs devices was driven primarily by cellular handset and other wireless markets, and forecast that the overall SI GaAs substrate market would increase by an annual growth rate of 5%, with merchant demand accounting for 95% by 2012 (Compoundsemi Online, 2008).

Strategy Analytics predicted that market revenues for GaN-based laser diodes would increase by an annual growth rate of 103% through 2011. It projected that the consumer-based optical data storage market would dominate all other applications, driven by use in game consoles, home theater, and personal computers, with home theater eventually gaining dominance as Blu-Ray achieves mass market acceptance (Semiconductor Today, 2007).

According to a report by Strategies Unlimited (a unit of PennWell Corp.), the largest market for packaged high-brightness LEDs in 2007 was mobile appliances, with 44% market share. The company forecast that the high-brightness LED market would increase by 12% in 2008. With growth accelerating as applications outside the mobile telephone market become more prominent, an annual growth rate of 20% in the next 5 years was predicted, to a total market of $11.4 billion in 2012. The largest application in 2012 was expected to be signs and displays, including backlighting for large computer monitor and television LCD screens (Semiconductor Today, 2008a).

Strategy Analytics predicted that the automotive LED market was expected to increase to $1 billion by 2014. New performance capabilities are expanding their use beyond simple switch illumination applications into automotive LED backlighting and exterior lighting, including fully LED-based front headlights (Semiconductor Today, 2007a).

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**TABLE 1**

**SALIENT U.S. GALLIUM STATISTICS**

(Kilograms unless otherwise specified)

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports for consumption</td>
<td>14,300</td>
<td>19,400</td>
<td>15,800</td>
<td>26,900</td>
<td>37,100</td>
</tr>
<tr>
<td>Consumption</td>
<td>20,100</td>
<td>21,500</td>
<td>18,700</td>
<td>20,300</td>
<td>25,100</td>
</tr>
<tr>
<td>Price$</td>
<td>dollars per kilogram</td>
<td>411</td>
<td>550</td>
<td>538</td>
<td>443</td>
</tr>
</tbody>
</table>

$Zero.

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

2Estimate based on average value of U.S. imports of high-purity gallium.
### TABLE 2
U.S. CONSUMPTION OF GALLIUM, BY END USE\(^1,2\)

(Kilograms)

<table>
<thead>
<tr>
<th>End use</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optoelectronic devices:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser diodes and light-emitting diodes</td>
<td>3,670</td>
<td>2,450</td>
</tr>
<tr>
<td>Photodetectors and solar cells</td>
<td>303</td>
<td>4,790</td>
</tr>
<tr>
<td><strong>Integrated circuits:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog</td>
<td>12,000</td>
<td>14,700</td>
</tr>
<tr>
<td>Digital</td>
<td>1,400</td>
<td>1,760</td>
</tr>
<tr>
<td>Research and development</td>
<td>2,840</td>
<td>1,360</td>
</tr>
<tr>
<td>Other</td>
<td>77</td>
<td>75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20,300</td>
<td>25,100</td>
</tr>
</tbody>
</table>

\(^1\)Data are rounded to no more than three significant digits; may not add to totals shown.

\(^2\)Includes gallium metal and gallium compounds.

### TABLE 3
STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM, BY GRADE\(^1,2\)

(Kilograms)

<table>
<thead>
<tr>
<th>Purity</th>
<th>2006: Beginning stocks</th>
<th>Receipts</th>
<th>Consumption</th>
<th>Ending stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.99% to 99.999%</td>
<td>503</td>
<td>131</td>
<td>--</td>
<td>634</td>
</tr>
<tr>
<td>99.999%</td>
<td>1,160</td>
<td>2,970</td>
<td>2,900</td>
<td>1,230</td>
</tr>
<tr>
<td>99.9999% to 99.999999%</td>
<td>136</td>
<td>496</td>
<td>602</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,800</td>
<td>3,590</td>
<td>3,500</td>
<td>1,890</td>
</tr>
</tbody>
</table>

| 2007:                          |                        |          |             |              |
| 99.99% to 99.999%             | 634                    | 2,900    | --          | 3,530        |
| 99.999%                       | 1,230                  | 8,450    | 7,260       | 2,420        |
| 99.99999% to 99.9999999%      | 30                     | 457      | 436         | 51           |
| **Total**                     | 1,890                  | 11,800   | 7,700       | 6,010        |

\(^1\)Consumers only.

\(^2\)Data are rounded to no more than three significant digits; may not add to totals shown.

### TABLE 4
ESTIMATED AVERAGE GALLIUM PRICES

(Dollars per kilogram)

<table>
<thead>
<tr>
<th>Gallium metal</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purity ≥ 99.99999%; average value of U.S. imports</td>
<td>443</td>
<td>530</td>
</tr>
<tr>
<td>Purity ≤ 99.99%; average value of U.S. imports</td>
<td>285</td>
<td>314</td>
</tr>
<tr>
<td>Country</td>
<td>Quantity (kilograms)</td>
<td>Value $</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Canada</td>
<td>2,410</td>
<td>$593,000</td>
</tr>
<tr>
<td>China</td>
<td>5,780</td>
<td>1,820,000</td>
</tr>
<tr>
<td>France</td>
<td>1,120</td>
<td>593,000</td>
</tr>
<tr>
<td>Germany</td>
<td>4,600</td>
<td>1,380,000</td>
</tr>
<tr>
<td>Hungary</td>
<td>2,200</td>
<td>676,000</td>
</tr>
<tr>
<td>Japan</td>
<td>1,960</td>
<td>584,000</td>
</tr>
<tr>
<td>Russia</td>
<td>718</td>
<td>187,000</td>
</tr>
<tr>
<td>Singapore</td>
<td>354</td>
<td>26,300</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1,710</td>
<td>671,000</td>
</tr>
<tr>
<td>Ukraine</td>
<td>5,380</td>
<td>1,450,000</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>387</td>
<td>133,000</td>
</tr>
<tr>
<td>Other</td>
<td>298 r</td>
<td>89,400 r</td>
</tr>
<tr>
<td>Total</td>
<td>26,900</td>
<td>8,210,000</td>
</tr>
</tbody>
</table>

1Revised.
2Data are rounded to no more than three significant digits; may not add to totals shown.
3Customs value.

Source: U.S. Census Bureau.
TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF
GALLIUM ARSENIDE WAFERS, BY COUNTRY

<table>
<thead>
<tr>
<th>Material and country</th>
<th>2006 Quantity (kilograms)</th>
<th>2006 Value</th>
<th>2007 Quantity (kilograms)</th>
<th>2007 Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undoped:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1,140</td>
<td>$354,000</td>
<td>850</td>
<td>$360,000</td>
</tr>
<tr>
<td>Hungary</td>
<td>200</td>
<td>60,000</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Singapore</td>
<td>--</td>
<td>--</td>
<td>102</td>
<td>20,200</td>
</tr>
<tr>
<td>Taiwan</td>
<td>2,160</td>
<td>260,000</td>
<td>1,700</td>
<td>283,000</td>
</tr>
<tr>
<td>Ukraine</td>
<td>--</td>
<td>--</td>
<td>586</td>
<td>152,000</td>
</tr>
<tr>
<td>Other</td>
<td>50</td>
<td>36,400</td>
<td>30</td>
<td>19,000</td>
</tr>
<tr>
<td>Total</td>
<td>3,550</td>
<td>711,000</td>
<td>3,300</td>
<td>834,000</td>
</tr>
<tr>
<td>Doped:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>19,500</td>
<td>20,000,000</td>
<td>15,100</td>
<td>15,600,000</td>
</tr>
<tr>
<td>Finland</td>
<td>11,000</td>
<td>6,470,000</td>
<td>14,300</td>
<td>8,530,000</td>
</tr>
<tr>
<td>France</td>
<td>12,600</td>
<td>28,400,000</td>
<td>10,900</td>
<td>7,860,000</td>
</tr>
<tr>
<td>Germany</td>
<td>36,500</td>
<td>40,200,000</td>
<td>30,300</td>
<td>44,900,000</td>
</tr>
<tr>
<td>Japan</td>
<td>53,500</td>
<td>61,300,000</td>
<td>57,600</td>
<td>55,800,000</td>
</tr>
<tr>
<td>Korea, Republic of</td>
<td>26,400</td>
<td>24,100,000</td>
<td>15,400</td>
<td>11,100,000</td>
</tr>
<tr>
<td>Russia</td>
<td>318</td>
<td>743,000</td>
<td>4,050</td>
<td>1,240,000</td>
</tr>
<tr>
<td>Singapore</td>
<td>5,400</td>
<td>6,810,000</td>
<td>3,890</td>
<td>5,610,000</td>
</tr>
<tr>
<td>Taiwan</td>
<td>8,730</td>
<td>10,900,000</td>
<td>12,400</td>
<td>15,800,000</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1,050</td>
<td>799,000</td>
<td>3,240</td>
<td>3,620,000</td>
</tr>
<tr>
<td>Other</td>
<td>10,100</td>
<td>1,570,000</td>
<td>11,000</td>
<td>4,850,000</td>
</tr>
<tr>
<td>Total</td>
<td>185,000</td>
<td>201,000,000</td>
<td>178,000</td>
<td>175,000,000</td>
</tr>
</tbody>
</table>

1Estimated 2Revised. -- Zero.
1Data are rounded to no more than three significant digits; may not add to totals shown.
2Customs value.
3The U.S. Census Bureau’s undoped gallium arsenide wafers quantity and value data for China and Taiwan in 2007 appear to be inaccurate. The data have consequently been estimated by the USGS for 2007 based on previous years’ imports for consumption patterns and 2007 pricing data.

Source: U.S. Census Bureau.

TABLE 7
ESTIMATED WORLD ANNUAL PRIMARY GALLIUM
PRODUCTION CAPACITY, DECEMBER 31, 2007

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>59</td>
</tr>
<tr>
<td>Germany</td>
<td>35</td>
</tr>
<tr>
<td>Hungary</td>
<td>8</td>
</tr>
<tr>
<td>Japan</td>
<td>20</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>25</td>
</tr>
<tr>
<td>Russia</td>
<td>19</td>
</tr>
<tr>
<td>Slovakia</td>
<td>8</td>
</tr>
<tr>
<td>Ukraine</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>184</td>
</tr>
</tbody>
</table>

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