GALLIUM

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Gallium demand in the United States was satisfied by imports, primarily high-purity material from France and low-purity material from Russia. More than 95% of gallium consumed in the United States was in the form of gallium arsenide (GaAs). Analog integrated circuits (IC's) were the largest application for gallium, with optoelectronic devices [mostly laser diodes and light-emitting diodes (LED's)] as the second largest end use. Many of the U.S. GaAs manufacturers expanded their production capacities for wafers; increasing demand for GaAs devices in wireless communications was cited as the principal reason. In some cases, companies are increasing the size of the GaAs wafers that they produce (e.g. from 3- to 4-inch diameter or from 4- to 6-inch diameter) resulting in lower production costs. Commercialization of gallium nitride (GaN) laser diodes and LED's is scheduled for 1999. The new GaN devices are expected to be used in high-density data storage (compact disk players and digital videodisk players), high-quality laser printing, communications, and lighting.

World production of virgin gallium was estimated to be 60 metric tons (t); demand for this material was centered in Japan, the United States, and Western Europe. Significant quantities of new scrap were recycled and supplemented supplies, particularly in Japan.

Production

No domestic production of primary gallium was reported in 1998 (table 1). Eagle-Picher Industries Inc. recovered and refined gallium from domestic and imported sources at its plant in Quapaw, OK. Recapture Metals Inc., Blanding, UT, recovered gallium from scrap materials, predominantly that generated during the production of GaAs. Recapture Metals' facilities have the capability to process about 15 t of high-purity gallium per year. 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.

Granaria Holdings B.V., a privately held firm in the Netherlands, acquired Eagle-Picher in February. Although not all terms of the transaction were disclosed, its value was estimated to be more than $700 million. Eagle-Picher management and the Netherlands bank ABN AMRO Investments each will have an equity interest in the company. The change in ownership was not expected to affect Eagle-Picher's gallium and germanium operations in Quapaw, which will remain part of Eagle-Picher's Technologies Division (Eagle-Picher Industries Inc., February 24, 1998, Granaria Holdings, a Dutch-based firm, acquires Cincinnati-based Eagle-Picher for over $700 million, accessed March 30, 1999, at URL http://www.tech.epcorp.com/n022498.html).

Consumption

More than 95% of the gallium consumed in the United States was in the form of GaAs. GaAs was manufactured into optoelectronic devices (LED's, laser diodes, photodetectors, and solar cells) and IC's. Analog IC's were the largest end-use application for gallium, with 52% of total consumption. Optoelectronic devices accounted for 45% of domestic consumption, and the remaining 3% was used in digital IC's, research and development, and other applications (tables 2-3).

Gallium data are collected by the U.S. Geological Survey (USGS) from two voluntary surveys of U.S. operations. In 1998 there were nine responses to the "Consumption of Gallium" survey, representing 50% of the total canvassed. Because of the poor response rate, data in tables 2 and 3 were adjusted to reflect full industry coverage.

Commercial development of blue laser diodes and LED's manufactured from GaN progressed more rapidly than originally anticipated. Nichia Chemical Industries Inc. of Japan plans to begin commercial shipment of blue GaN laser diodes, which would cost less than $8 each, by the beginning of 1999. Prototype lasers developed by Nichia have been operated for more than 4,000 hours at elevated temperatures, which is equivalent to about 10,000 hours at room temperature (Whipple, 1998).

Although the growth of GaN thin films has been demonstrated since 1969, a suitable substrate material was not developed until 1986. Early GaN thin films were grown on silicon carbide (which was expensive) or sapphire substrates (which were not an exact lattice match). The sapphire substrates caused so many defects in the GaN thin film that the device would not lase. In 1986, Japanese researchers solved the defect problem by growing a sacrificial thin film of aluminum nitride on top of the sapphire substrate before laying the GaN film onto the surface. In addition, the researchers discovered how to dope GaN, making it electronically active. Blue lasers have potential applications in high-density data storage (compact disk players and digital videodisk players), high-quality laser printing, communications, and lighting (Whipple, 1998).

EMCORE Corp. announced the development of commercial-quality indium gallium nitride blue LED material. The material was produced on the largest GaN metal-organic chemical vapor deposition equipment that produces commercial LED's in the world. With the projected demand for the blue

LED’s, EMCORE is increasing its wafer production capacity at its Somerset, NJ, manufacturing facilities. Potential applications for the LED’s include full-color outdoor displays, traffic signals, automotive lighting, and commercial message signs (EMCORE Corp., March 25, 1998, EMCORE unveils bright blue LED technology, accessed on May 4, 1998, at URL http://www.emcore.com/press/blueLED.html).

TriQuint Semiconductor Inc., a manufacturer of GaAs IC’s, purchased the Monolithic Microwave Integrated Circuit (MMIC) operations of Raytheon Co. in Dallas, TX, for stock and cash transactions valued at $39 million. The acquisition will allow TriQuint to expand into markets for commercial satellites, local multipoint distribution systems, and point-to-point digital radio. This will complement TriQuint’s markets in wireless, telecommunications, and computer systems (GaAsNet, January 9, 1998, TriQuint Semiconductor Inc. announces acquisitions of Raytheon/TI Systems’ gallium arsenide MMIC operations, accessed January 16, 1998, at URL http://www.gaasnet.com/news/tqnt_0198.html).

In the first quarter of 1998, Raytheon Microelectronics doubled its production capacity for GaAs MMIC’s at its Andover, MA, production facility because of increasing market demand in the wireless communication market. Capacity was increased to 1 million from 500,000 GaAs substrates per week. Raytheon anticipates continued growth for power amplifiers for digital cellular phones and in satellite communications and local multipoint distribution systems (GaAsNet, February 10, 1998, Raytheon doubles MMIC production capacity, accessed March 10, 1998, at URL http://www.gaasnet.com/news/raytheon_0298.html).

RF Micro Devices Inc. opened its new GaAs heterojunction bipolar transistor (HBT) facility in Greensboro, NC, in June, 6 months earlier than anticipated. The opening of the new plant finished the transfer of TRW Inc.’s proprietary technology to RF Micro Devices. RF Micro Devices’ plant, however, produces 4-inch wafers instead of the 3-inch wafers produced by TRW. The two firms agreed to provide each other’s customers with a second supplier of GaAs HBT’s; essentially each will serve as a redundant supplier, which will assure their customers a consistent supply of material. In addition, TRW has a long-term agreement to supply RF Micro Devices with fully processed 3-inch HBT wafers and 4-inch molecular beam epitaxy (MBE) wafers to supplement its existing capacity (GaAsNet, June 3, 1998, RF Micro Devices opens GaAs HBT facility for production, accessed July 13, 1998, at URL http://www.gaasnet.com/news/RFMicro_0698.html). American Xtal Technology, Inc. has a 3-year contract to supply TRW with GaAs wafers produced by American Xtal’s vertical gradient freeze technology; some of the material will be supplied to RF Micro Devices through TRW.

As part of its strategy to lower manufacturing costs and to streamline operation, ANADIGICS Inc. accelerated the qualification period for its new 6-inch GaAs wafer fabrication facility in Warren, NJ. As soon as wafers from the 6-inch facility are fully qualified, the company will close its 4-inch wafer facility at the same location. The new plant originally was scheduled to produce 4-inch wafers and was expected to begin operating in the second half of 1999; instead, it will be a 6-inch-wafer facility with initial production scheduled for the third quarter of 1999 (GaAsNet, December 8, 1998, ANADIGICS new CEO comments on product and technology strategy, accessed December 17, 1998, at URL http://www.gaasnet.com/news/ANAD_1298.html).

EMCORE opened its new facility, EMCOREwest, in October in Albuquerque, NM, with production scheduled for the first quarter of 1999. The new 50,000-square-foot facility will enable EMCORE to expand along all the company’s compound semiconductor industry product lines, including epitaxial wafer foundry services, device fabrication, and commercializing emerging technologies. The company also plans to increase the facility’s size to 70,000 square feet by 2002 by means of a three-phase construction project. EMCORE also tripled the production capacity at its MicroOptical Device subsidiary, which manufactures vertical-cavity surface-emitting lasers used in such applications as Internet access, local area networks, digital videodisk, and fiberoptic switching (EMCORE Corp., October 8, 1998, EMCORE opens new Albuquerque facility to expand its compound semiconductor production capacity, accessed February 23, 1999, at http://www.emcore.com/press/ewest.html).

EMCORE entered into a 4-year purchase agreement with Loral Space & Communications Ltd. to supply high-efficiency GaAs solar cells for Loral’s satellite requirements. Once EMCORE completes Loral’s qualification and test procedures, deliveries are expected to begin in the second quarter of 1999. Initial value of the contract is estimated to be more than $5 million (GaAsNet, December 21, 1998, EMCORE and Loral sign multiyear strategic agreement, accessed February 22, 1999, at URL http://gaasnet.com/news/emcore_211298.html).

The U.S. Department of Defense completed its 4-year program to strengthen the U.S. base for GaAs production. The project was begun under the Title III Program of the Defense Production Act, which promotes creation and strengthening of U.S. industrial capabilities to support national security needs. The U.S. firms participating in the project were American Xtal Technology, Litton Airtron, and M/A Com Inc. At the beginning of the project, U.S. firms accounted for less than 25% of the total sales of semi-insulating GaAs wafers worldwide; in 1998 U.S. producers had a 60% share of the world market, and the three participants increased their sales of GaAs wafers more than five times compared with those of 1994. In addition, the value of these sales has more than tripled even though the average wafer price decreased by about one-third. Production capacity at the three contractors’ facilities increased by more than 300%, and production yields doubled. Defense applications of the GaAs wafers include advanced electronics in radars, smart weapons, electronic warfare, and communications (GaAsNet, April 21, 1998, United States DOD Title III SI GaAs program ends, accessed April 23, 1998, at URL http://www.gaasnet.com/news/titleIII_0498.html).

The growing use of cellular telephone technology has proven to be a boon for GaAs. TRW increased production of its GaAs-based multichip electronic modules as a result of a $15 million order from Nokia Telecommunications Oy for millimeter-wave transceivers. These transceivers will be used in Nokia's new FlexiHopper radio product in its cellular and personal communications services (PCS) wireless networks. Each transceiver contains a number of GaAs MMIC's in one compact housing; this takes the place of multiple, larger hybrid components, thereby reducing size and cost. TRW will manufacture the components at its TRW, MilliWave Inc. subsidiary's Diamond Springs, CA, facility (GaAsNet, June 12, 1998, TRW receives $15 million order from Nokia, accessed July 13, 1998, at URL http://www.gaanet.com/news/2_0698.html). Other firms, including ANADIGICS, Celeritek Inc., Motorola Inc., RF Micro Devices, Siemens Microelectronics Inc., and TriQuint, have introduced new GaAs components for the cellular market.

Prices

In 1998, producer-quoted prices for gallium did not change from those at yearend 1997, which were revised to $595 per kilogram for 99.99999%-pure gallium and $550 per kilogram for 99.9999%-pure gallium (table 4). In September 1998, selling prices in Japan were reported to be from $420 to $440 per kilogram for 99.99%-pure gallium. Russian 99.999%- to 99.9999%-pure gallium was reported to be selling at $480 per kilogram. For most of the year, 99.9999%-pure material from France was selling at $525 per kilogram (Roskill's Letter from Japan, 1998a); by December, the price reportedly had increased to $543 per kilogram (Roskill's Letter from Japan, 1998b).

Foreign Trade

U.S. gallium imports increased significantly in 1998; much of the increase was manifested in a resumption of imports of gallium from Kazakhstan (table 5). France (33%), Russia (23%), and Kazakhstan (23%) were the principal sources of imported gallium. In addition to gallium metal, GaAs wafers were imported into the United States. In 1998, 19,600 kilograms (kg) of undoped GaAs wafers was imported, mostly from Japan (82%). Japan (36%) and the Republic of Korea (13%) were the main import sources for doped GaAs wafers, totaling 136,000 kg during the year. Quantities of GaAs wafers reported by the Bureau of the Census may include the weight of the packaging material and thus may be overstated.

World Review

Estimated crude gallium production was 60 t in 1998. Principal world producers were Australia, Kazakhstan, and Russia. China, Hungary, Japan, and Slovakia also recovered gallium. Refined gallium production was estimated to be about 55 t. France was the largest producer of refined gallium using crude gallium produced at Rhône-Poulenc S.A.'s 50-ton-per-year plant in Australia and from gallium produced in Germany. Japan and the United States also refined gallium. Gallium was recycled from new scrap in Germany, Japan, the United Kingdom, and the United States.

World demand for gallium was forecast to be 152 t in 1998 by Dowa Mining Co.; this figure includes significant quantities of recycled gallium scrap. Dowa Mining estimated that recycled gallium supplied 50% to 60% of world consumption. Regional demand was estimated to be as follows: Japan, 99 t; the United States, 38 t; Europe, 9 t; and other countries, 6 t (Roskill's Letter from Japan, 1998a).

France.—Rhône-Poulenc merged its chemicals and fibers and polymers operations, which included its gallium business, into a new subsidiary, effective January 1, 1998. The new firm is named Rhodia Inc., and although it is a subsidiary, it will operate as a separate entity. An initial public offering of stock in Rhodia was held in June, which was expected to raise $1.15 billion to be used toward reducing debt (Rhodia Inc., June 24, 1998, Rhodia shares to be sold by Rhône-Poulenc at a prices of 140 French francs per share, accessed March 31, 1999, at URL http://www.rp.rpna.com/htm/news/6_24.html). Some press reports have indicated that Rhodia planned to sell its gallium operations, but no buyer has been announced (Roskill's Letter from Japan, 1998b).

Japan.—In 1998, Japanese gallium supply was estimated to be 128 t. Of that, domestic production of virgin gallium supplied 6 t, imports supplied 53 t, and recycled gallium scrap supplied 69 t. Of the total imported gallium, 28% came from Kazakhstan; 21%, from France; 11%, from Russia; and 10% each, from China and Germany (Roskill's Letter from Japan, 1998a).

Dowa Mining announced that it would double its capacity to produce high-purity gallium to 100 t by April 1999. The firm was building a new plant in Akita City at a cost of $12.3 million. This increase in capacity includes capacity to reprocess gallium and GaAs scrap. In addition, Dowa Mining is building a plant to manufacture 6-inch GaAs wafers at the same site; this plant is scheduled to be operational in spring 2000. Wafers from the new plant will supplement Dowa Mining's supplies of GaAs to the LED market (Furukawa, 1998).

Sumitomo Electric Industries Ltd. announced that it would increase production capacity for epitaxial wafers by building three plants in Hyogo Prefecture. The new plants will increase monthly production capacity to 4,500 wafers for cellular applications, about 1.5 times the company's current level, and 500 wafers for optical communications applications, about 5 times current capacity. The new plants were scheduled to be operational by April 1999 (GaAsNet, June 15, 1998, Sumitomo Electric to increase epitaxial wafer output, accessed July 13, 1998, at URL http://www.gaasnet.com/news/Sumi_0698.html).

In response to increasing demand for wireless communications devices, Hitachi Cable Ltd. doubled its capacity for GaAs metal-organic-vapor-phase-epitaxy wafers to 7,000 4-inch wafers per month at its plant in Hitachi-shi, Ibaraki Prefecture. The company also increased production capacity for 4-inch semi-insulating wafers to feed the new epitaxial production line (GaAsNet, April 16, 1998, Hitachi Cable expands production capacity of GaAs MOVPE wafers, accessed April 23, 1998, at URL http://www.gaasnet.com/news/hitachicable_0498.html).

United Kingdom.—Wafer Technology Ltd. added 400 square meters of production space for the company's vertical gradient freeze growth of GaAs. According to the company, the increased space will allow it to add furnaces to supply the increasing demand for GaAs substrates for laser diodes and LED's (GaAsNet, February 27, 1998, Wafer Technology adds manufacturing space, accessed March 10, 1998 at URL http://www.gaasnet.com/news/wafertech_0298.html).

Current Research and Technology

EMCORE signed an agreement with the Bell Laboratories Division of Lucent Technologies Inc. to develop new technologies to grow materials for devices used in advanced optical networks. Research will be focused on developing new epitaxial growth machines, diagnostic tools, and control software and increasing product yields and subsequently lowering device production costs. The team already has developed a portable mini–clean-room environment that docks with the growth apparatus. This environment can house up to twenty-one 2-inch wafers and can reduce clean-room costs by allowing devices to be moved directly from the growth chamber to the clean room without being exposed to ambient air (GaAsNet, July 16, 1998, Lucent's Bell Labs and EMCORE to jointly develop materials growth technology for telecommunications devices, accessed April 5, 1999, at URL http://www.gaasnet.com/news/emcore_0798. html).

Scientists at Renssalaer Polytechnic Institute have developed a method for growing bulk aluminum nitride crystals, which if commercially feasible, could provide a better substrate on which to grow GaN. The technique, called sublimation-recondensation, involves evaporating polycrystalline aluminum nitride and recondensing the vapor into a single-crystal structure in a specially designed tungsten crucible at 2,300° C. So far, the resulting aluminum nitride boule measures 1.2 centimeters long and 1 centimeter wide; researchers hope to improve the crystal diameter to 5 centimeters within 2 years (Hardin, 1998a).

Scientists at Germany's Fraunhofer-Institut, in collaboration with researchers at Nichia, Japan, demonstrated a white-light-emitting LED by using luminescent conversion. The scientists combined a GaN blue LED with an organic dye that emits long wavelengths of light. The new LED's, called lucoleds, can produce a wider range of colors than is possible with conventional LED's. Germany's Siemens AG planned to begin manufacturing the devices by 1999 (R&D Magazine, 1998).

At Cornell University, scientists reported significant progress in developing high-power, high-frequency GaN transistors for wireless communications. The research is sponsored by the Office of Naval Research and the Defense Advanced Research Projects Agency. Normally the GaN transistors are fabricated by doping the GaN with atoms of another material, but the Cornell researchers are growing a thin film of gallium aluminum nitride on the GaN base. The bond between the two layers places a strain on the upper layer that allows electrons to flow freely into the GaN layer. The free-flowing electrons produce a material that has low resistance and that can support high voltages. One of the most important new uses for the GaN transistors is in a new generation of communications satellites that support wireless communications. Currently, cellular telephones communicate through ground-based transmitting towers. Developing systems will use hundreds of low-Earth-orbiting satellites to relay the signals, and with the new GaN devices, fewer higher orbiting satellites will be needed to cover the globe, resulting in cost savings (Cornell University, August 20, 1998, A new generation of high-frequency, high-power transistors is being developed at Cornell, accessed May 17, 1999, at URL http://www.news.cornell.edu/releases/Aug98/gallium_nitride.bs.html).

Bell Laboratories reportedly developed the first highly stable GaAs-based metal-oxide semiconductor field effect transistor (MOSFET). Unlike silicon, which is used in most IC applications, gallium does not have what is referred to as a "native oxide" to act as an insulator to protect the channel in the chip from the electrode; silicon has SiO_2. Without an insulator, the chip would short circuit. The researchers at Bell used a mixture of gallium oxide and gadolinium oxide deposited by MBE to improve the stability and electrical characteristics of the gate oxide. If the MOSFET's prove commercially producible, then they have potential applications in cellular telephones and wireless base stations. Because of the lower power consumption of GaAs MOSFET's, battery lives for cellular phones could be increased, and wireless base stations would become more powerful and efficient (Bell Laboratories, December 7, 1998, Improved class of GaAs transistors may lead to wireless applications, accessed May 17, 1999, at URL http://www.bell-labs.com/news/1998/december/8/2.html).

Researchers at the USGS and the U.S. Forest Service used a GaAs laser diode to measure the depth and character of controlled mudslides in Oregon's Willamette National Forest. Mudslides were being studied because they cause millions of dollars in damage and kill hundreds of people each year. Unlike avalanches, where the moving material behaves like a solid, and floods, where the moving material behaves like a liquid, mudslide flow dynamics have solid and liquid characteristics. Researchers originally tried ultrasound and visible spectrum lasers to model the mudslide flow, but these devices did not provide the effective measurements needed. The GaAs infrared laser is affixed at an angle above the slide. Light from the laser reflects off the flow and into a photodetector. The photodetector, in combination with pressure and flow sensors in the bed provide optical triangulation, which enables precise measurements of the flow depth (Photonics Spectra, 1998).

Development of new GaAs-based laser diodes that emit light in the midinfrared range (3-12 micrometers) have increased their potential for use as environmental monitoring devices.

Many air pollutants absorb light in the midinfrared range, and the new laser diodes can be used to detect the presence of certain chemicals. One advantage of the lasers is that they avoid some of the strong absorption bands of water and carbon dioxide (common compounds in stack emissions); thus, they have increased sensitivity for the compounds that they can detect. Some of the atoms and molecules that the laser diodes can detect are chloride, fluoride, ammonia, ethane, and methane (Hardin, 1998b). In addition, lasers that operate in the midinfrared range also could be used for protection against heat-seeking missiles, for laser radar, and for laser surgery.

A photovoltaic device that can generate hydrogen from sunlight and water was developed by scientists at the National Renewable Energy Laboratory. The new single device combines functions that are generally separate on other systems that convert sunlight and water into electricity. A tandem cell is immersed into a electrolyte. The visible light in the sunlight is absorbed by the top layer of the tandem cell made of gallium indium phosphide and converted to hydrogen. The bottom layer, made of GaAs, absorbs near-infrared light that passes through the top cell and produces oxygen. Although the device can convert about 12.4% of the available light into hydrogen, compared with 4% to 6% for conventional devices, it is still three to four times more expensive than producing hydrogen through steam reforming of natural gas (Hand, 1998).

Outlook

Wireless communications systems and the commercialization of GaN devices represent the applications with the most growth potential for gallium. Allied Business Intelligence, Inc. forecasts that the overall market for power semiconductors, IC's, and modules will grow at an average annual rate of 19%, reaching $2.8 billion by yearend 2003. The driving factor in the market will be PCS and cellular systems; GaAs power amplifiers for these uses are expected to grow at an average annual rate of 26% during the same timeframe. Many GaAs transistors have been replaced by GaAs MMIC's in the cellular base stations; the GaAs transistor segment is expected to have an average annual growth of only 5% during the next 5 years (Wireless Design, October 28, 1998, New technology driving power semiconductor market growth, accessed May 18, 1999, at URL http://news.wirelessdesignonline.com/market-trends/19981028-1101.html). Many GaAs manufacturers have increased production capacities to prepare for the projected demand increase. These firms continue to introduce new devices with enhanced properties to increase the penetration of GaAs devices into the wireless communications market. If one or more systems of Earth-orbiting satellites are deployed to serve as relay stations for cellular communications signals, then this could be a new application for gallium-based devices.

Applications that have the potential for using GaN laser diodes and LED's will need time to adjust equipment that contains these GaN diodes, even if commercial quantities of GaN are sold into the marketplace within the next year. For example, equipment that is designed to use red laser diodes, such as compact disk and digital videodisk players, will need to have some adjustments before models containing the blue diodes can be marketed; this is not a "plug and play" technology. Although average annual growth rates as high as 38% have been predicted for these GaN diodes (Whipple, 1998), this growth is not expected to begin as soon as the diodes are introduced to the market.

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TABLE 1
SALIENT U.S. GALLIUM STATISTICS 1/

(Kilograms, unless otherwise specified)

	1994	1995	1996	1997	1998
Production	--	--	--	--	--
Imports for consumption	16,900	18,100	30,000	19,100	26,300
Consumption	15,500	16,900	21,900	23,600	26,900
Price per kilogram	$395	$425	$425	$595 r/	$595

r/ Revised.
1/ Data are rounded to three significant digits.

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

(Kilograms)

End use	1997	1998
Optoelectronic devices:		
Laser diodes and light-emitting diodes	8,350	10,300
Photodetectors and solar cells	2,080	1,710
Integrated circuits:		
Analog	11,500	14,000
Digital	631	844
Research and development	38	46
Other	961	57
Total	23,600	26,900

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes gallium metal and gallium compounds.

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

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
1997:				
99.99% to 99.999%	434	1,400	999	834
99.9999%	422	10,200	10,400	181
99.99999% to 99.999999%	1,020	12,100	12,100	1,000
Total	1,880	23,700	23,600	2,020
1998:				
99.99% to 99.999%	834	159	103	890
99.9999%	181	11,900	12,000	108
99.99999% to 99.999999%	1,000	14,800	14,800	1,000
Total	2,020	26,900	26,900	2,000

1/ Consumers only.
2/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 4
YEAREND GALLIUM PRICES

(Dollars per kilogram)

	1997	1998
	595 r/	595
Gallium metal, 99.9999%-pure, 100-kilogram lots	425	550
Gallium metal, 99.9999%-pure, imported	380-425	380-425
Gallium oxide, 99.99%-pure, imported	275-350	275-350

r/ Revised.

Source: American Metal Market.

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

Country	1997 Quantity (kilograms)	1997 Value	1998 Quantity (kilograms)	1998 Value
China	910	$338,000	600	$248,000
France	11,400	4,710,000	8,560	4,050,000
Germany	243	129,000	751	149,000
Hungary	997	224,000	894	233,000
Japan	166	48,000	1,140	510,000
Kazakhstan	--	--	6,020	2,580,000
Netherlands	201	62,100	--	--
Russia	4,540	1,520,000	6,100	2,230,000
United Kingdom	--	--	1,070	441,000
Other	549 r/	129,000 r/	1,150	225,000
Total	19,100	7,160,000	26,300	10,700,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 6
ESTIMATED WORLD ANNUAL PRIMARY GALLIUM
PRODUCTION CAPACITY, DECEMBER 31, 1998 1/

(Metric tons)

Continent and country	Capacity
North America: United States 2/	3
Europe:	
France	20
Germany	20
Hungary	4
Kazakhstan	20
Slovakia	3
Russia	15
Ukraine	3
Total	85
Asia:	
China	8
Japan	7
Total	15
Oceania: Australia 2/	50
World total	153

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

2/ Standby capacity as of December 31, 1998.