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GALLIUM [ADVANCE RELEASE]

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Gallium

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Gallium metal and gallium arsenide (GaAs) wafer imports continued to account for most of the U.S. gallium consumption. Metal imports were 11% higher than those in 2007, with Germany, Canada, and China, in descending order of imports by gallium content, as the leading sources of imported gallium. Doped GaAs wafer imports were 8% lower than those in 2007; Germany and Japan were the principal sources. Almost all 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 14% from that in 2007. In 2008, gallium consumed in the United States was less than the gallium imported 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 2008, estimated world crude gallium production was 111 metric tons (t), 17% higher than that in 2007. 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 150 t, which included some new scrap refining. Refined gallium was produced in China, Japan, and the United States.

Legislation and Government Programs

In February, the U.S. Department of Energy (DOE) awarded $20.6 million for 13 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. Eight of these projects involved improvements in LEDs. Of the eight, the goals of Cree Inc., Crystal IS Inc., General Electric Co., Georgia Institute of Technology, Lehigh University, Osram Sylvania Development Inc., and Philips Lumileds Lighting LLC were to increase LED device efficiency (Semiconductor Today, 2008b).

TriQuint Semiconductor, Inc. (Hillsboro, OR) was awarded $4.5 million by the Office of Naval Research (ONR) to advance manufacturing methods used to produce high-power, high-frequency GaAs amplifiers required for critical Navy applications including communications, electronic warfare, and phased array radar. The ONR program's objectives were to extend the use of the high voltage GaAs pseudomorphic high electron mobility transistor (pHMET) technology to higher frequencies. It was anticipated that this enhanced high-frequency technology would provide a new capability intermediate between current GaAs technology and emerging GaN technology (TriQuint Semiconductor, Inc., 2008c).

Kopin Corp. (Taunton, MA) was awarded $600,000 by the National Aeronautics and Space Administration to design nanostructured solar cells made of indium gallium phosphide (InGaP) materials to improve open-circuit voltage for photovoltaic cells. Kopin's solar cell design was expected to reach more than 40% efficiency with one p-n junction device, which would be an increase of 20% from current multijunction solar cells (Mass High Tech, 2008).

RF Micro Devices Inc. (RFMD) (Greensboro, NC) was awarded $1.4 million by the U.S. Department of Defense (DoD) for the development of GaN technology and high-power radio frequency (RF) solutions. The DoD award represented an extension to previous RFMD contracts with the DoD and was in support of RFMD's ongoing GaN RF power technology project focusing on high-efficiency amplifiers, military and civilian radar systems, and multiband radios requiring wideband. It is anticipated that RFMD's GaN RF power technology will deliver configurable wideband and high-power amplifiers with improved efficiency and ruggedness compared with currently available high-power RF technologies (RF Micro Devices Inc., 2008b).

In 2008, the DOE's National Renewable Energy Laboratory (NREL) set a world record in solar cell efficiency with a photovoltaic device that converts 40.8% of the light that hits it into electricity. The solar cell uses compositions of InGaP and gallium indium arsenide to split the solar spectrum into three equal parts that are absorbed by each of the cell's three junctions for higher potential efficiencies (Semiconductor Today, 2008g).

Production

No domestic production of primary gallium was reported in 2008 (table 1). Recapture Metals Inc. (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 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 October 2008, Gold Canyon Resources Inc. announced that it suspended the preparation of a prefeasibility study on its Cordero Gallium Project in Humboldt County, NV. The company indicated the suspension was because of turmoil in the global financial markets, the uncertainty of near-term gallium prices, and the sharp rise in prices of the key chemicals needed to recover gallium (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 2008, 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 company 2008 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 67% of domestic consumption, optoelectronic devices accounted for 31%, and 2% was used in research and development and other applications (table 2). GaN principally was used to manufacture LEDs and laser diodes.

Gallium Arsenide.—The value of worldwide GaAs device consumption increased to $3.9 billion in 2008, an 11% increase from $3.5 billion in 2007. Demand increased for GaAs-rich third-generation (3G) cellular telephones and smartphones (a cellular telephone with advanced personal computer-like functionality) until the fourth quarter of 2008. These devices use up to four times the amount of GaAs of previous generations of cellular telephones (Compound Semiconductor, 2008b; Semiconductor Today, 2009b).

In March, RFMD completed its purchase of Filtronic Compound Semiconductors Ltd. (a wholly owned subsidiary of Filtronic plc) for $25 million. The acquisition included Filtronic's 6-inch GaAs wafer fabrication in Newton Aycliffe, United Kingdom, and its microwave and millimeter wave RF semiconductor business. The purchase was expected to increase RFMD's GaAs capacity by 30% (RF Micro Devices Inc., 2008a). As a direct result of its Filtronic acquisition, RFMD postponed construction of a planned $103 million 6-inch post-epitaxial processing plant in Greensboro (Semiconductor Today, 2008i).

In April, AXT Inc. (Fremont, CA) announced plans to expand its 6-inch GaAs substrate production capacity by 25% citing an increase in its customer base. At yearend, IQE plc (Cardiff, Wales, United Kingdom) awarded AXT a production order for its 2009 worldwide GaAs substrate requirements. The substrates included both 4-inch and 6-inch GaAs, and the agreement was worth approximately $14.3 million (Compound Semiconductor, 2008a; AXT Inc., 2009).

In May, Freescale Semiconductor Corp. (Austin, TX) announced that it would close its Tempe, AZ, GaAs wafer fabrication facility owing to a decrease in demand from cellular telephone customers as well as from automobile manufacturers for which Freescale makes automotive integrated chips (Semiconductor Today, 2008c).

Also in May, TriQuint Semiconductor acquired WJ Communications Inc., a leading designer and supplier of RF products for wireless infrastructure markets. The acquisition allowed TriQuint to obtain WJ's RF/microwave design expertise, provided TriQuint with a Silicon Valley-based design center, and accelerated TriQuint's evolution to multifunction modules for infrastructure applications. TriQuint thought the acquisition would expand its presence in the communications infrastructure market (TriQuint Semiconductor Inc., 2008a).

To address increased demand for its compound semiconductor products, Skyworks Solutions, Inc. (Woburn, MA) announced the approval of WIN Semiconductors Corp. of Taiwan as a GaAs foundry partner. Semiconductor Today considered WIN Semiconductors to be the leading provider of GaAs radio frequency integrated circuit and monolithic microwave integrated circuit (MMIC) wafer foundry services in the world. WIN Semiconductor has two 6-inch wafer fabrication facilities located in Taiwan. Skyworks also extended its GaAs heterojunction bipolar transistor purchase and supply agreement with epitaxial wafer foundry Kopin Corp. of Taunton, MA (Semiconductor Today, 2008k; Skyworks Solutions Inc., 2008).

Anadigics Inc. (Warren, NJ) announced the first in its new line of specifically engineered GaAs power amplifiers for 3G (third-generation) and 4G (fourth-generation) femtocell markets. Femtocells solve the problem of weak or nonexistent wireless broadband signals in small office and home office environments by connecting users' mobile devices to their carrier's network through a high-speed internet link (Anadigics Inc., 2008).

Gallium Nitride.—The worldwide GaN device market increased to $4.6 billion in 2008, a 21% increase from $3.8 billion in 2007. Previously, the availability of high-quality sapphire and silicon carbide substrates enabled the rapid growth of the GaN device market, mainly in the form of the high-brightness LED. However, increased demand from GaN device applications, namely laser diodes, power electronics, and RF electronics, has provided significant growth opportunities for advanced GaN-based substrates (Yole Development, 2007; Compoundsemi Online, 2009).

Representing the newest generation of amplifier technology, GaN power transistors, commercially released for the first time in 2008, have been shown to operate at higher voltages and with a higher power density than current GaAs devices. GaN power transistors and amplifiers have allowed microwave designers to reduce heat sink requirements and part counts, enabling smaller systems with higher performance and greater efficiency (LaPedus, 2008b).

TriQuint Semiconductor released the first of its GaN power transistors developed for a wide range of high-frequency applications including defense communications systems, mobile base stations, and space communications systems. TriQuint also opened one of the compound semiconductor industry's first GaN foundry services (TriQuint Semiconductor, Inc., 2008b).

Cree Inc. (Durham, NC) announced the first commercially available GaN RF MMIC amplifiers. The MMICs integrate GaN RF transistor technology with other circuit elements to form fully integrated amplifier circuits, allowing for a significant reduction in size and increase in performance compared with hybrid amplifiers. Cree also opened one of the compound semiconductor industry's first GaN foundry services (Cree Inc., 2008a, c).

In early 2008, IQE received its largest order to date for GaN wafers from TriQuint Semiconductor. The wafers were to be manufactured at IQE's New Jersey operation, and were to be used in TriQuint's commercial and military communications power amplifier products, as well as its ongoing research and development efforts (Semiconductor Today, 2008f).

Light-Emitting Diodes.—The worldwide high-brightness LED market increased to $5.1 billion in 2008, an 11% increase from $4.6 billion in 2007, even though the LED market deteriorated in the fourth quarter. Research and consulting firm Strategies Unlimited (a subsidiary of PennWell Corp.) listed the main global segments for LEDs in 2008 as follows: mobile appliances, 43%; signs and displays, 17%; automotive, 15%; lighting, 9%; signals, 1%; and other uses, 15%. White LED fixtures were increasingly used in commercial and residential lighting applications and accounted for 50% of the total LED lighting fixture market in 2008 (Steele, 2009; Strategies Unlimited, 2009).

Many LED manufacturers introduced new LEDs based on GaAs and GaN technology that offer improvements from current LEDs. In July, BluGlass Ltd. (Sydney, Australia) opened its new headquarters and LED demonstration plant in Sydney. The demonstration plant featured BluGlass's first commercial-scale semiconductor reactor fitted with Remote Plasma Chemical Vapor Deposition (RPCVD) technology which was used to grow GaN-based LED materials. BluGlass' RPCVD process was specifically developed for low temperature growth of nitride-based thin films on buffered glass substrates in addition to sapphire or silicon. BluGlass planned to use the plant to demonstrate large cost benefits in the manufacture of LED devices (LEDs Magazine, 2008a).

In March, Cree announced that it had acquired LED Lighting Fixtures, Inc. (LLF) in a cash and stock transaction valued at $77 million, plus up to an additional $26.4 million during a 3-year period. LLF pioneered the development of LED lighting retrofit products, and was reported by Semiconductor Today as the first company to develop an energy-efficient LED downlight for general illumination. This downlight, based on its patented color-mixing technology combined with Cree's XLamp LEDs, was used in commercial and residential applications. The acquisition of LLF expanded Cree's market by providing the company with direct access to the lighting market, as well as enabling Cree to drive retrofit solutions to convert existing lighting infrastructure to more energy-efficient lighting (Cree Inc., 2008b; Semiconductor Today, 2008a).

In April, Osram Opto Semiconductors (Munich, Germany) opened the last section of its new LED chip factory in Regensburg, Germany. Osram also formed an LED lighting joint venture with Traxon Technologies Ltd. of Hong Kong to focus on integrated LED projects for markets such as architectural, hospitality, and shop lighting (LEDs Magazine, 2008b; Semiconductor Today, 2008h).

Vitec Group plc (Kingston-upon-Thames, United Kingdom) acquired the business and assets of Litepanels, Inc. and Litepanels, LLC, a Hollywood, CA, manufacturer of LED-based lights for television, broadcast, video, and film industries, for $14.5 million plus potentially $50 million in profit-related payments. Lighting and broadcast professionals use LED lighting in studio and film set applications because of its low power consumption and low heat generation compared with traditional light sources (LEDs Magazine, 2008c).

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 thin-film multijunction cells, with a substrate of germanium and layers of gallium indium arsenide and other gallium compounds. A lightweight, flexible, durable, and low-cost thin-film photovoltaic technology, copper indium gallium selenide (CIGS), has begun to enter the solar cell market. CIGS modules can be directly integrated into building materials, consumer electronics for portable power, space applications, or configured as stand-alone modules for large-scale terrestrial deployment.

Global Solar Energy Inc. (Tucson, AZ) announced that its 750-kilowatt CIGS solar array was in full operation at its manufacturing facility in Tucson. It was the largest solar array using CIGS technology in the world, and was the first commercial-scale use of Global Solar's CIGS technology. The solar array helped power the company's manufacturing facility, and was expected to generate more than 1.1 million kilowatthours of electricity annually (Metal-Pages Ltd., 2008b).

Ascent Solar Technologies Inc. (Thornton, CO) announced it had achieved greater than 9.5% efficiency for its CIGS monolithically integrated modules using a plastic substrate. NREL independently verified the results and considered the 9.5% efficiency rating to be a substantial advance toward realizing high-performance, inexpensive thin-film solar photovoltaics (Metal-Pages Ltd., 2008a).

In October, Solyndra Inc. (Fremont, CA) announced its new cylindrical CIGS photovoltaic system for the rooftops of commercial buildings. Solyndra's photovoltaic system was designed to generate considerably more solar electricity from conventional low-slope commercial rooftops while having lower installation costs than standard photovoltaic flat-panel technologies. The cylindrical shape allows sunlight to be captured across a 360° photovoltaic surface capable of converting direct, diffuse, and reflected sunlight into electricity. Conventional flat-surfaced solar panels typically offer poor collection of diffuse light and fail to collect reflected light from installation surfaces (Compoundsemi Online, 2008).

In November, Solyndra signed a multiyear sales contract worth up to $320 million with Carlisle Energy Services, a manufacturer of energy-efficient single-ply membrane roofing systems. Carlisle planned to install Solyndra's cylindrical modules in conjunction with its Energy Star-certified cool roof systems for commercial buildings. Solyndra also opened its European headquarters in Holzkirchen, Germany, in response to demand for its CIGS photovoltaic systems in Europe (Semiconductor Today, 2008l; 2009a).

In September, SolFocus Inc. (Mountain View, CA) announced the completion of its full-scale concentrator photovoltaic (CPV) installation at the Institute of Concentration Photovoltaic Systems (ISFOC) 3-megawatt municipal power production facility in Castilla La Mancha, Spain. The ISFOC project was created both as a municipal powerplant and a proving ground for CPV technology (SolFocus Inc., 2008).

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 decreased in 2008. At the beginning of the year, the low-grade gallium price was reported to be about $550 per kilogram. By August, the price had decreased to about $475 per kilogram. By December, the price had recovered to about $490 per kilogram.

From U.S. Census Bureau import data, the annual average value for low-grade (99.99%-pure) gallium was estimated to be $361 per kilogram, 15% higher than the estimated average value for 2007. For high-grade (>99.99%-pure) gallium, the annual average estimated value increased to $579 per kilogram, about 9% higher than that in 2007. 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 2008, U.S. gallium imports were 11% higher than those in 2007 (table 5). Germany (33%), Canada (25%), and China (16%) were the leading sources of imported gallium. One reason for the increase in gallium imports was that after Recapture Metals (Blanding, UT) and Mining & Chemical Products Ltd. (Northants, United Kingdom) 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 2008, 955 kilograms (kg) of undoped GaAs wafers and 165,000 kg of doped GaAs wafers were imported. Imports of undoped GaAs wafers were 71% less than those in 2007, while imports of doped GaAs wafers were 8% lower than those in 2007. The large decrease in imported undoped GaAs wafers was most likely owing to reduced demand for LEDs and compound semiconductor alloys in 3G cellular telephones and automobiles during the latter half of 2008. Additionally, the imported undoped GaAs wafer quantity for 2007 was estimated 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, quantities may be higher than the actual total weight of imported wafers.

World RevieImports 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 111 t in 2008. 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 150 t; this included some new scrap refining. China, Japan, and the United States refined gallium. Gallium was recycled from new scrap in Canada, Germany, Japan, the United Kingdom, and the United States.

China.—In August, Anadigics Inc. (Warren, NJ) reported that it would delay further construction of its new 6-inch GaAs IC wafer fabrication plant in Jiangsu Province owing to a weakening in demand from its cellular telephone customers. 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 (LaPedus, 2008a).

In November, the Aluminum Corp. of China Ltd. (CHALCO) announced that it had reduced its output of primary aluminum by more than 50% since the middle of October because of the deteriorating global economy and declining price of aluminum. As the largest producer of byproduct gallium in China, CHALCO's cut in aluminum production was expected to affect the worldwide supply of gallium (Metal-Pages Ltd., 2008c).

Russia.—In December, ONEXIM Group Ltd., the Ural Optical and Mechanical Plant, and the Russian Corp. of Nanotechnologies formed a joint venture to manufacture GaN-based LED chips, lamps, and lighting systems. Fabrication of the epitaxial heterostructures were to be based in St. Petersburg, while LED chip, lamp, and lighting product assembly were to be based in Yekaterinburg (Semiconductor Today, 2008j).

Singapore.—IQE formally opened its new advanced semiconductor wafer facility in Singapore, following the relocation of its Asia manufacturing facility. The new facility would not only continue to produce wafers for wireless applications such as cellular telephones and Wireless Fidelity (WiFi) devices, but would also provide capacity for new products such as materials for advanced electronics and high-efficiency solar cells. The facility was expected to allow for significant future expansion of manufacturing capacity in the Asia-Pacific region (IQE plc, 2008).

Outlook

The research and consulting firm Strategy Analytics Inc. predicted that sales in the GaAs device market would decline by 5% in 2009 owing to the global recession affecting growth across nearly all major end-use markets. The company also forecast that sales in the corresponding GaAs substrate market would decline by 10% in 2009. Demand from the cellular telephone market was expected to still be the primary growth engine for the GaAs industry, accounting for 70% of GaAs use until 2012. GaAs use in the WiFi market was expected to increase at a compound annual average growth rate (CAAGR) of 20% from 2009 through 2012, becoming the second ranked market for GaAs in 2012 (Semiconductor Today, 2008e).

Strategy Analytics also predicted that the market for GaN devices would grow at a CAAGR of 98% from 2009 to 2012, and concluded that military and defense applications would dominate demand for GaN devices, accounting for 55% of the total GaN market in 2012. The wireless infrastructure market was thought to represent the primary commercial opportunity for GaN (Business Wire, 2008).

Strategy Analytics announced that the global terrestrial photovoltaic market was worth $20.2 billion in 2008 and was expected to grow at a CAAGR of 23% to $35.2 billion by 2012 as a result of increasing worldwide demand for renewable energy. It is thought that crystalline silicon-based solar technology, while still dominant in the terrestrial photovoltaic market in 2008, would slowly give way to less expensive competing technologies based on thin-film and compound semiconductors. GaAs-based CPV technology also offers advantages of high cell conversion and lower material usage, which Strategy Analytics thought would result in a CAAGR of 133% through 2012, accounting for 10% of the total terrestrial photovoltaic market (Semiconductor Today, 2008d).

According to a report by Strategies Unlimited, the high-brightness LED market would decrease from $5.1 billion in 2008 to $4.9 billion in 2009, a 3.7% decline, as a result of the worldwide economic recession's impact on LED end-product demand. However, not all LED markets would be affected equally. Mature LED market segments including automotive lighting, cellular telephones, and outdoor video screens would decrease, while emerging LED market segments, such as backlights for liquid crystal displays (LCD) in televisions and notebook computers, would continue to increase (Semiconductor Today, 2009c).

In 2009, scientists at the Massachusetts Institute of Technology (MIT) successfully integrated GaN with silicon to create a hybrid microchip that was expected to be smaller, faster, and more efficient than current silicon-based microprocessors. The MIT scientists anticipated that the new integration process would enable circuit and system designers to choose the best semiconductor material for each device in the microchip (Massachusetts Institute of Technology, 2009).

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

(Kilograms unless otherwise specified)

		2004	2005	2006	2007	2008
Production		--	--	--	--	--
Imports for consumption		19,400	15,800	26,900	37,100	41,100
Consumption		21,500	18,700	20,300	25,100	28,700
Price[2]	dollars per kilogram	550	538	443	530	579

-- Zero.

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

[2]Estimate 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)

End use	2007	2008
Optoelectronic devices:		
Laser diodes and light-emitting diodes	2,450	3,800
Photodetectors and solar cells	4,790	5,040
Integrated circuits:		
Analog	14,700	16,900
Digital	1,760	2,310
Research and development	1,360	497
Other	75	110
Total	25,100	28,700

[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)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2007:				
99.99% to 99.999%	634	2,900	--	3,530
99.9999%	1,230	8,450	7,260	2,420
99.99999% to 99.999999%	30	457	436	51
Total	1,890	11,800	7,700	6,010
2008:				
99.99% to 99.999%	3,530	155	976	2,710
99.9999%	2,420	6,060	7,550	929
99.99999% to 99.999999%	51	622	500	173
Total	6,010	6,830	9,030	3,820

-- Zero.

[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)

Gallium metal	2007	2008
Purity ≥ 99.9999%; average value of U.S. imports	530	579
Purity ≤ 99.99%; average value of U.S. imports	314	361

TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF GALLIUM (UNWROUGHT, WASTE, AND SCRAP), BY COUNTRY[1]

Country	2007 Quantity (kilograms)	2007 Value[2]	2008 Quantity (kilograms)	2008 Value[2]
Armenia	--	--	888	$396,000
Canada	10,000	$5,420,000	10,200	6,130,000
China	5,270	2,290,000	6,600	2,930,000
France	44	42,800	98	107,000
Germany	11,000	4,090,000	13,500	5,080,000
Hungary	1,280	410,000	1,410	639,000
Japan	1,300	624,000	616	548,000
Russia	341	128,000	20	10,600
Singapore	247	104,000	516	204,000
Slovakia	108	38,200	--	--
Ukraine	6,380	1,790,000	1,170	445,000
United Kingdom	509	216,000	5,930	1,950,000
Other	577	370,000	125	18,800
Total	37,100	15,500,000	41,100	18,500,000

-- Zero.

[1]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
U.S. IMPORTS FOR CONSUMPTION OF
GALLIUM ARSENIDE WAFERS, BY COUNTRY[1]

	2007		2008	
Material and country	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Undoped:				
Austria	13	$4,250	94	$37,600
China[3]	850 [e]	360,000 [e]	--	--
France	--	--	250	48,800
Japan	15	6,070	112	12,600
Singapore	102	20,200	150	25,000
Taiwan[3]	1,700 [e]	283,000 [e]	324	101,000
Ukraine	586	152,000	--	--
Other	2 [r]	8,710 [r]	25	15,500
Total	3,300 [e]	834,000 [e]	955	241,000
Doped:				
China	15,100	15,600,000	20,800	19,500,000
Finland	14,300	8,530,000	12,600	6,030,000
France	10,900	7,860,000	2,810	6,480,000
Germany	30,300	44,900,000	34,100	33,500,000
Italy	2,820	171,000	2,330	352,000
Japan	57,600	55,800,000	60,900	54,000,000
Korea, Republic of	15,400	11,100,000	13,600	2,400,000
Malaysia	1,840	425,000	3,720	853,000
Russia	4,050	1,240,000	288	572,000
Singapore	3,890	5,610,000	2,180	5,180,000
Taiwan	12,400	15,800,000	7,860	22,000,000
United Kingdom	3,240	3,620,000	1,290	1,190,000
Other	6,390 [r]	4,250,000 [r]	2,290	3,120,000
Total	178,000	175,000,000	165,000	155,000,000

[e]Estimated [r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

[3]The 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, 2008[1]

(Metric tons)

Country	Capacity
China	59
Germany	35
Hungary	8
Japan	20
Kazakhstan	25
Russia	19
Slovakia	8
Ukraine	10
Total	184

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