INDIUM

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Indium production in the United States during 2000 was confined to the upgrading of imported metal and the recycling of scrap. Two refiners, one each in New York and Rhode Island, were the major producers of indium metal and indium products in 2000. A number of smaller firms also produced high-purity indium alloys, compounds, solders, indium-tin oxide (ITO) coatings, and related products.

Domestic consumption was estimated by the U.S. Geological Survey to have increased moderately to about 55 metric tons (t) in 2000. Estimated uses were about the same as those in 1999, with stable consumption in all sectors except semiconductors, where there was a moderate increase. By sector, estimated consumption in 2000 was: coatings, 49%; solder and alloys, 33%; electrical components and semiconductors, 14%; and other uses, 4%. The value of primary indium consumed in the United States in 2000 was $10.3 million at an average producer price of $5.84 per troy ounce, calculated from prices published in Platt's Metals Week.

World consumption increased slightly in 2000. World refinery production was estimated at 220 t, a 2.3% increase compared with the 215 t (revised) produced in 1999. The six major producing countries were Belgium, Canada, China, France, Japan, and Russia. The recycling of indium, which became significant for the first time in 1996, was not significant domestically in 2000. However, recycling remains important in Japan (McCullouch, 2000). The increase in world consumption despite greater efficiency in the manufacture of ITO coatings with thin film transistor technology was due to increased demand for display devices and an increase in the production of indium phosphide, a semiconductor. Prices remained low despite strong demand, mostly owing to plentiful low-priced supplies from China (Mining Journal, 2000a).

World reserves, which are based on estimated indium content of zinc reserves, are sufficient to meet anticipated demand beyond the first decade of this century. Canada has greater resources of indium than any other country—about 27% of world reserves totaling 2,600 t. The United States holds about 12% of world reserves.

Legislation and Government Programs

The original National Defense Stockpile (NDS) goal for indium, set in 1989, was 41,990 kilograms (kg). In 1992, when the first purchase of indium was made for the stockpile, the goal was reduced to 7,740 kg. By 1996, as for many other commodities, the Annual Materials Plan for the NDS called for the elimination of indium from the stockpile. No sales were made in 1996, but stockpile disposals of indium amounted to 1,118 kg (35,956 troy ounces) in 1997, and (the last) 443 kg (14,248 troy ounces) in 1998. From that point on, the stockpile was depleted and the United States became completely dependent on imports for primary indium.

Production

U.S. production of primary indium in 2000 consisted of upgrading lower-grade and standard-grade indium (99.97% and 99.99%) into higher purity metal. Indium can be refined to purities up to 99.99999%. All of the indium to be upgraded was imported. Secondary production was mainly from new (unused, preconsumer) scrap and certain types of old (used, postconsumer) scrap. Nevertheless, only a small amount of indium was recycled domestically. Indium was produced in various forms, such as ingot, foil, powder, ribbon, shot, and wire.

Consumption

Domestic consumption in 2000 was estimated at about 55 t, a moderate increase from the 1999 level. Consumption in the various end uses held nearly steady, but semiconductor use increased. Thin-film coatings on glass, which included indium oxide and indium-tin-oxide, constituted almost one-half of total domestic indium use in 2000. The coatings, produced by sputtering the material onto a glass substrate, have been the largest area of research, development, and growth for indium in the past several years.

There are two kinds of indium-containing coatings—electrically conductive coatings and infrared-reflective coatings. Electrically conductive coatings, the more commercially significant group, are used primarily in liquid crystal displays (LCD) for watches, television screens, portable computer screens, and video monitors. They are also used to defog aircraft and locomotive windshields and to keep glass doors on commercial refrigerators and freezers frost-free. In addition, infrared-reflecting indium coatings on window glass limit the transfer of radiant heat through the glass, helping to make the heating and cooling of buildings more energy efficient.

About 33% of the indium consumed was used as an addition to combinations of bismuth, cadmium, lead, and tin to form low-melting-point alloys. These alloys are used in such applications as electrical fuses, fusible links, or as gripping material for the grinding of optical glass. Indium is used as a strengthening agent for lead solders and also as the base material for many low-melting-point solders. Indium-based solders have a number of advantages over ordinary solders: lower melting points, flexibility over a greater temperature range, and negligible leaching of gold components from electronic assemblies. Lead-free solders have been developed starting with indium-based alloys.

Indium is used in alkaline batteries to prevent the buildup of hydrogen gas in the sealed battery casing. These batteries are available in popular small consumer sizes, and together with semiconductors and other electronic uses, accounted for about

14% of the indium consumed domestically.

Prices

The domestic producer price as reported by Platt's Metals Week for 99.97%- to 99.99%-pure indium decreased from \$6.22 per troy ounce at the beginning of 2000 to \$4.58 per troy ounce at the end of the year; prices for higher grades of metal were not published. The price decline was a reflection of the world supply and demand situation. The average producer price was \$6.22 per troy ounce at the beginning of the year. It held steady until early May, when it was lowered to \$5.83 per troy ounce. The price fell again in October, first reaching \$5.20 and then \$4.58 per troy ounce (Platt's Metals Week, 2000b). The average indium price for the year was \$5.84 per troy ounce.

The price for indium increased markedly in 1995 and then decreased just as markedly in 1996. Only modest fluctuations occurred in 1997. The price was nearly constant in 1998 and began a slow decline in 1999 which continued in 2000. The falling prices in 2000 were caused by good supply rather than poor demand. Chinese producers continued to sell at lower and lower prices, especially during the second half of the year. Higher purity indium is required for ITO, and Western indium producers were able to obtain a premium for their metal, creating a two-tier market (Platt's Metals Week, 2000c), but plentiful low-priced Chinese offers pulled down world prices (Platt's Metals Week, 2000e). One negative on the demand side was that demand was lower than expected from new Taiwanese consumers, manufacturing LCDs (Metal Bulletin, 2000a).

Trade

Imports decreased 10% by weight and 33% in value. For the first time China replaced Canada as the top supplier. These two provided 68% of the total. Next, in order of importance, were France, Russia, Peru, and Japan. Data on U.S. exports of indium were unavailable, but total exports were estimated at about 15 t.

World Review

Asia.—The world indium market in 2000 was dominated by a more than adequate supply from China. Japan remained the world's largest consumer of indium, with three-fourths of it going for ITO coatings. Low-priced indium was so readily available from China that prices remained low despite strong demand, especially in Japan (Mining Journal, 2000b, c).

Canada.—An interruption of indium production occurred at the Kidd Creek, Ontario, plant of Falconbridge Ltd. at the beginning of the year. A runout at a copper furnace combined with regular maintenance stopped production for 6 weeks, beginning in December 1999. Indium production was only reduced slightly (Mining Journal, 2000b).

China.—Chinese indium producers began to control sales in an attempt to prevent indium prices from falling further. Since indium is a byproduct of zinc, which must be produced continuously, the actual cost of indium production is low. Therefore, producers allow their stocks to increase rather than choose to curtail production, even if this creates a greater oversupply (Platt's Metals Week, 2000a).

Japan.—Indium demand reached a record 335 t in 2000 in Japan, with slightly more than one-half of the material coming from recycled scrap. ITO production increased 26% by weight over 1999 (Roskill's Letter from Japan, 2001b). Indium phosphide production increased 57% in value over 1999 (Roskill's Letter from Japan, 2001a).

Showa Denko K.K., already the world's leading producer of indium phosphide wafers using the metal-organic chemical deposition process, invested \$29 million to triple its capacity at its Chichibu plant, northwest of Tokyo. Production of both indium phosphide epitaxial wafers and indium phosphide mirror wafers was expected to triple by mid-2001 (Furukawa, 2000a).

Owing to the booming electronics sector in Japan, Sumitomo Electric Industries Ltd. announced plans to expand its output of indium (and gallium and zinc) at its Itami plant, northwest of Tokyo. The materials produced are for compound semiconductors used in products like mobile phones (Platt's Metals Week, 2000d). Sumitomo also announced plans to establish new production facilities for indium phosphide and other semiconductors in the United States. The operation will produce gallium arsenide as well as indium phosphide (Furukawa, 2000b).

Taiwan.—Mitsui Mining & Smelting Co. Ltd. of Japan plans to build an ITO sputtering target plant in Taiwan. Taiwan is becoming one of the world's largest producers of the targets. The plant, a wholly owned subsidiary of Mitsui, is to be named the Taiwan Target Company and will be located near Taichung (Metal Bulletin, 2000b).

Current Research and Technology

In 2000, the growth rate for the thin film transistor LCD, which requires only one-third as much indium per unit as the supertwisted nematic (STN) LCD, was four times higher than that for the STN LCD. Since more than one-half of the world's indium consumption is for ITO coatings, the conversion to a more efficient technology has the same effect as would an increase in indium reserves.

Demand for indium phosphide wafers increased in 2000 for use in dense wavelength division multiplexing (DWDM) systems. These DWDM systems greatly increase the amount of information that can be transmitted on the Internet through optical glass fibers (Furukawa, 2000a).

At the Sandia National Laboratory of the U.S. Department of Energy, scientists researched uses and properties of indium gallium arsenic nitride semiconductor alloys. The addition of nitrogen to this system reduces gallium arsenide's bandgap energy requirement by one-third. The new material has potential for use in fiber optic lasers and communication satellites. As a part of a solar cell to provide power for space systems, this material could provide twice the efficiency of a standard silicon solar cell—up to 40%. A solar collecting package using this material would be smaller and lighter, providing increased payloads and cheaper launches. The utilization of this system for lasers makes it possible to adjust the gallium arsenide bandgap and provide a laser needed for short-distance fiber optics systems with greater manufacturing efficiency (Allan, 2000).

A new solar cell, based on a copper/indium/selenium compound has been developed in Germany. Cis-Solartechnik, GmbH, partly owned by Norddeutsche Affinerie AG, will continue development work on the new product, which is made mostly by deposition through galvanic processes onto a flexible copper strip. The new cell, with greater than 10% efficiency, is light in weight and extremely tough (American Metal Market, 2000).

Outlook

Consumption of indium is expected to increase throughout the next decade, especially for LCDs, high-definition television, semiconductor materials, batteries, and low-temperature solders for military and electronic applications. The main driving force for this increase will continue to be Japanese production of LCDs using ITO and the production of telecommunications-use lasers and photo-diodes and other optic telecommunication systems using indium phosphide (Furukawa, 2000b).

Roskill predicted a world demand of 250 t by 2005 (Roskill Information Services, 1999). Japanese plus U.S. consumption of primary indium reached 225 t in 2000, mostly for ITO. Demand for indium needed for replacement nuclear control rods should remain steady, and that for fusible alloys and solders is likely to increase. If the price of indium rises sufficiently, recycling of the metal could increase in the United States and would tend to limit upward movements in price as long as a supply of appropriate scrap existed. Stocks of scrap increase when little recycling is occurring—as in recent years. World reserves, together with increases in production capacity (achieved through new plants and increased yields in primary recovery and improvements in manufacturing and recycling technology) are expected to be sufficient to meet the demand for indium beyond 2010.

However, other possible economic scenarios could diminish optimistic forecasts. For example, any slowdown of sales and profit growth in the telecommunications industry, which has been forecast by some industry observers, could significantly decrease indium demand (Berenson, 2001; Romero, 2001).

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF INDIUM, BY CLASS AND COUNTRY 1/

Class and country	1999 Quantity (kilograms)	1999 Value (thousands)	2000 Quantity (kilograms)	2000 Value (thousands)
Unwrought and waste and scrap:				
Belgium	1,850	$323	158	$33
Canada	31,800	6,390	19,800	2,600
China	28,700	4,690	26,900	3,310
France	5,780	1,230	10,800	1,680
Germany	80	12	163	19
Hong Kong	396	54	40	3
Japan	634	226	2,230	487
Kazakhstan	--	--	229	21
Peru	2,100	382	2,570	333
Russia	5,100	984	5,120	787
Singapore	30	3	--	--
Switzerland	500	93	1,000	140
United Kingdom	410	137	507	208
Total	77,400	14,500	69,400	9,620

-- Zero.

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

Source: U.S. Census Bureau.