# **INDIUM**

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All domestic production of indium in the United States was confined to the upgrading of imported indium metal and the recycling of scrap. Two refineries, one each in New York and Rhode Island, were the major producers of indium metal and indium products in 2001. In addition, a number of small companies produced high-purity indium alloys, and other indium containing products.

Domestic consumption in 2001 was estimated by the U.S. Geological Survey to have increased to about 65 metric tons (t). Estimated consumption by different sectors remained about the same as in 2000: coatings, 45%; solder and alloys, 30%; electrical components and semiconductors, 15%; and other uses, 10%. The value of domestic consumption in the United States in 2001 was about \$8 million at an average producer price of \$120 per kilogram (\$3.85 per troy ounce), calculated from prices published in Platts Metals Week.

World production in 2001 remained about the same as in 2000. The six major producing countries were Belgium, Canada, China, France, Japan, and Russia. A slight decline in production of primary indium was offset by increased recycling, mainly in Japan. There was a slight increase in world consumption, due to increased demand of laptop computers and flat-screen monitors using indium-tin oxide (ITO) coatings. Increased indium consumption was further promoted by greater production of indium alloys and semiconductors using indium phosphide (InP). The increase in consumption was partially offset by greater efficiency in the production of indium-containing products. Despite increased consumption, prices declined in 2001, mostly owning to oversupply of low-priced indium from China.

World reserves, which are based on estimated indium content of zinc reserves, are sufficient to meet anticipated demand for at least 10 years. Canada has greater reserves of indium than does any other country—about 27% of the world total. The United States holds about 12% of world reserves.

## **Legislation and Government Programs**

An estimated 37 t of indium is at the Superfund site in Kellogg, ID, where Bunker Hill Company once operated a lead and zinc smelter (Platts Metals Week, 2001c). The indium is contained in the flue dust that had accumulated for more than 50 years, until the smelter's closure in 1981. Shortly after the closure, the U.S. Environmental Protection Agency (EPA), declared the former smelter a Superfund site, under a regulation that covers nonoperating sites with environmental problems requiring cleanup (Cami Grandinetti, U.S. Environmental Protection Agency, written commun., October 24, 2002).

## **Production**

U.S. production of indium in 2001 consisted solely of upgrading imported lower-grade and standard-grade indium (99.97% and 99.99%, respectively) into higher purity metal. Low purity imported indium was refined to purities of up to 99.9999%. Two refiners—Indium Corp. of America, Utica, NY, and Arconium Specialty Alloys, Providence, RI—accounted for the major share of U.S.-produced indium metal and products. Indium metal was produced in various forms, such as ingot, foil, powder, ribbon, and wire. Numerous small companies were engaged in production of high-purity indium alloys, compounds, solders, ITO coatings, and other indium products. Because the infrastructure for collection of indium-containing products has not been well established in the United States, and also because of the low price of primary indium, only small amounts of new indium scrap were recycled in 2001.

## Consumption

Most commercial applications of indium metal are for thin-film coatings on glass and liquid-crystal displays (LCDs). This group of indium users, mainly in the form of indium oxide and ITO, constituted nearly one-half of total domestic indium use in 2001. The technology of glass coating has also been the largest area of research, development, and growth for indium in the past several years. Although coatings remained the most widespread use for indium, the production of electrical components and semiconductors has been the most rapidly growing use for indium during the past 5 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 LCDs 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. The infrared-reflective indium coating on window glass limits the transfer of radiant heat through the glass, helping to make the heating and cooling of buildings more energy efficient.

About one-third of the indium consumed was used in combination with bismuth, cadmium, lead, or tin to form low melting-point alloys and solders. These alloys are used in such applications as electrical fuses, fusible links, or as gripping tools for the grinding of optical glass. Indium-based solders have a number of advantages over ordinary solders, such as lower melting points, better flexibility over a greater temperature range, and negligible leaching of gold components from electronic assemblies.

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Indium is used in alkaline batteries to prevent the buildup of hydrogen gas in the sealed battery casing. These batteries are available in many sizes for use in many portable products, such as computers and power tools. Together with semiconductors and other electronic uses, they constitute the fastest growing segment, accounting for about 15% of the indium consumed domestically in 2001.

## **Prices**

The domestic producer price, as reported by Platts Metals Week for 99.97% to 99.99% pure indium, decreased from \$143 per kilogram (\$4.58 per troy ounce) at the beginning of 2001 to \$120 per kilogram (\$3.85 per troy ounce) at the end of the year. The decline of indium prices began in 1999 and continued through 2000 and 2001. Although indium is a byproduct of zinc production, zinc mining and processing cutbacks during 2001 did not effect the availability of indium because zinc smelters that recover indium remained mostly unaffected by reductions in zinc output. Despite the use of indium for popular LCD flat-screens and products employing flat-screen technology, excessive Chinese production in recent years has led to an oversupply of indium (Mining Journal, 2001b). Lower quality Chinese indium continued to be freely available for about \$80 per kilogram. At that price, even recycling indium from scrap was no longer cost effective (Mining Journal, 2001a). Another reason for the large supply/demand imbalance was that markets for electronic applications remained stagnant during 2001. The abundance of indium compelled Indium Corp. of America to reduce the list price for its higher grade indium to \$100 per kilogram, effective September 21. This action represented a \$25 decrease from the previous price (Platts Metals Week, 2001d).

## Trade

Imports of indium in 2001 increased by 14% by weight, to 79,400 kilograms (kg), but decreased by 20% in value, due to lower prices. With 49,500 kg, representing 62% of total imports, China was the biggest source of imported indium in 2001; it was followed, in declining order of importance as a source, by Canada, Japan, and Russia. Data on U.S. exports of indium were not available but were estimated to be about 10 t.

## **World Review**

China.—Chinese indium output for 2002 is expected to decline by about 44 t to 104 t, as supply of raw material from the Guangxi Province became scarce at the end of 2001. The reason for the declining supply of indium was the closure of numerous small mines in the Province by the Chinese Government in response to mine accidents in mid-2001. Reduced Chinese output of indium, however, will have only an insignificant effect on the world market due to overproduction during the past few years (Antaike, 2002).

As some of the small Chinese indium producers cut production due to low prices and lack of raw material supplies, the country's largest producers increased output. For example, Liuzhou Intai Technology Co. produced 35 t of indium ingot

(99.995% pure) in 2001, up from 20 t in 2000. Despite these increases by large companies, overall Chinese production in 2001 fell by 30%, and it is forecast to decline even further. Even some large Chinese producers found it difficult to operate profitably as price declines persisted. Some producers increased exports of value-added products, such as indium oxide and ITO, and they embarked on research in the production of high purity material for compound semiconductors.

With its advanced technology, Intai is able to produce high-quality, low-cost indium. In April 2001, the company installed a new production line to produce 99.9999%-pure indium to satisfy demand from overseas consumers, mainly in Europe, Japan, and the United States, and to improve earnings from these exports. The new high-purity line has a capacity of about 6 metric tons per year (t/yr) (Platts Metals Week, 2001a).

Despite oversupply and a saturated international market, Zhuzhou smelter in Hunan Province has maintained its 30 t/yr indium output throughout 2001. The company exports 90% of its indium production to Japan and the rest to domestic markets. Zhuzhou expects that its indium production will decrease slightly in 2003 owing to tighter raw material supplies. However, the company also aims to introduce new indium products within a few years; Zhuzhou officials hoped that these value added products would help to increase profit margins (Platts Metals Week, 2001b).

*France.*—Metaleurop SA's plans to end primary zinc production at its Noyelles-Godault smelter and rely solely on secondary supplies that could affect indium production. The cessation of primary production, which could be completed by the end of 2003, would eliminate the company's need of concentrate, which contains indium that has been generated as a byproduct (CRU International Ltd., 2002).

*Japan.*—Following a strong rise in demand for indium in semiconductors and LCD panels during 2000, Japanese consumption of indium was forecast to increase in 2001. As a result, imports of indium rose in 2001 to meet the anticipated demand. The increase did not materialize, and the consumption of primary indium dropped by 20% to 105 t in 2001.

Indium prices in Japan had been falling since late 2000 and bottomed out in June 2001 before stabilizing. By mid-August, Japanese traders hoped that indium prices might rebound on the heals of recovery by information technology industries (Platts Metals Week, 2001f). This demand did not take place either. The sluggish demand that ensued reflected a slowdown in production of electronic devices, which are major users of indium-tin oxide (Platts Metals Week, 2001e).

Despite weak demand in 2001, Japanese demand for indium is forecast to rise by 13% in 2002 (Roskill's Letter from Japan, 2002a). Further growth is expected to be fueled by increased demand for LCD panels, the largest market for indium. This optimistic forecast is based on increased production capacity for LCD panels, growth in demand for personal computers, new markets for LCDs, lower LCD prices, and the development of larger LCDs (Roskill's Letter from Japan, 2002b).

*Korea, Republic of.*—The indium market in the Republic of Korea was in the same predicament as in Japan. By the end of 2001, demand for indium on the country's market was not increasing at the anticipated rate, leaving traders with excessive

stocks of indium. When its price reached \$70 per kilogram in November, traders in the Republic of Korea began looking offshore to sell unwanted stocks of indium. The drive to export excess material, mainly to Brazil and India, fell short of target levels, as demand in those countries was not much stronger than in the Republic of Korea itself (Platts Metals Week, 2001g).

*Taiwan.*—In anticipation of future rapid growth in demand for ITO, the Mitsui Mining & Smelting Co. Ltd. of Japan built a new ITO-manufacturing plant in Taiwan during 2001. The indium oxide and tin oxide powder for ITO initially will be procured from Japan, but the Taiwan operation eventually will produce its own intermediary material. The new plant includes a production line in which product purity has been increased from 99% to 99.5% indium. One-half of ITO production will be exported to Japan and Southeast Asia. Secondary ITO material, collected in Taiwan, is to be shipped to Japan for processing (Roskill's Letter from Japan, 2001).

## **Current Research and Technology**

Velocium (a subsidiary of TRW Inc.) has developed the world's fastest direct frequency synthesizer—a chip that produces the radio frequencies used to carry telecommunication signals—using InP. The chip operates at 7 billion cycles per second, which is more than three times faster than any previous direct digital frequency synthesizer. It was developed under contract to the U.S. Department of the Navy's Office of Naval Research. InP is an advanced compound semiconductor that offers a number of performance improvements over currently available semiconductors. These performance improvements result in excellent power efficiency and provide the signal quality improvements needed for wideband applications. In a cellular telephone system, the InP chip increases capacity by 10 times that of analog systems, improves signal quality, enhances privacy, and increases the duration of talk time (TRW Inc., 2001§<sup>1</sup>).

## Outlook

Consumption of indium is expected to increase in the next several years, especially for LCDs, high-definition televisions, semiconductor materials, batteries, and low-temperature solders for electronic applications. The current slowdown in the telecommunication industry, however, could significantly limit demand growth rates (Berenson, 2001). Roskill predicted a world demand of 250 t by 2005 (Roskill Information Services Ltd., 1999). The main driving force behind this increase will continue to be the Japanese production of LCDs using ITO and the production of lasers, photo-diodes, and other optic telecommunication systems using InP (Furukawa, 2000).

Indium prices should start inching upward as zinc mine closings begin to effect the primary indium market. As the main source of primary indium, zinc ore production has a direct effect on indium supply. The prolonged stagnation in the zinc market has forced many small and less efficient underground mines to close. The resulting concentration of zinc ore

production may stabilize the indium market. Mining companies with a higher profit margin and low unit cost can more easily control output of coproducts, such as indium, than can small companies that need to make a profit on every component of mined ore. If the price of indium rises sufficiently, recycling of the metal could increase in the United States and could limit upward price movement as long as a large enough supply of appropriate scrap is available. An estimated 60% of ITO scrap could be reused.

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<sup>&</sup>lt;sup>1</sup> A reference that includes a section twist (§) is found in the Internet Reference Cited section.

 ${\it TABLE~1}\\ {\it U.S.~IMPORTS~FOR~CONSUMPTION~OF~INDIUM,~BY~CLASS~AND~COUNTRY~1/2}}$ 

	2000		2001	
	Quantity	Value	Quantity	Value
Class and country	(kilograms)	(thousands)	(kilograms)	(thousands)
Unwrought and waste and scrap:				
Belgium	158	\$33		
Canada	19,800	2,600	7,710	\$762
China	26,900	3,310	49,500	3,740
France	10,800	1,680	4,980	575
Germany	163	19	69	20
Hong Kong	40	3		
Italy			4	2
Japan	2,230	487	5,360	1,330
Kazakhstan	229	21		
Peru	2,570	333	3,660	322
Russia	5,120	787	5,000	511
Singapore			278	90
Switzerland	1,000	140	2,650	259
United Kingdom	507	208	158	63
Total	69,400	9,620	79,400	7,670

<sup>--</sup> Zero.

Source: U.S. Census Bureau.

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