

INDIUM

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Indium is a soft and very versatile metal with several important applications, the most prominent of which is its use as a transparent conductor in flat panel displays. This is a long-standing application, but, with the advent of mass market flat panel TVs, this minor metal has been thrust into prominence in a dramatic way.

Occurrence and extraction

Indium and silver have approximately the same relative abundance, being around 0.1ppm of the Earth's crust. However Indium, unlike silver, does not occur in sufficient concentrations to be mined in its own right. Instead, it is obtained as a by-product of major metal extraction, principally associated with commercial ores of zinc, lead, copper and tin. The majority of commercial indium extraction is centred around zinc and tin production. Ascertaining the exact volume of economically recoverable reserves is extremely difficult and refining often takes place far from the mine sources, sometimes in different countries and on different continents.

The residues of major metal extraction are often bought by third parties in order for them to extract the indium content, particularly in China where many smaller indium refining operations have developed based on purchased concentrates.

The US Geological Survey has estimated that there are around 2,500 t of indium in recoverable reserves, with a total of about 6,000 t in the 'Reserve Base'. The most significant mine sources of indium-bearing major metals are in China and Canada although there are other sources in Japan and Russia.

Indium is separated from flue and sinter dusts, slags, residues and drosses. It is also usually concentrated in lead bullion dross during the treatment of electrolytic zinc plant residues. The dross is treated for the recovery of matte copper and lead bullion, and the resultant slag contains a few per cent indium, plus high levels of copper, lead and tin. A flotation process concentrates the copper to generate tailings, which are sintered and reduced electrothermally to produce a crude bullion. Electrolytic treatment of the bullion generates an anode slime containing up to 30% indium. Commercial-grade indium is produced by leaching, cementation and electro-refining. Solvent extraction is used to recover indium from leach residues.

Production

The main countries supplying indium are China, Canada, the US, Belgium and Japan, although Korea Zinc announced the start of indium production in late 2004, with an estimated output of 40-50 t/y.

There are a number of major producers in China, but also numerous smaller producers, relying on purchasing the concentrates from the larger base-metal

refiners. However, there have been problems with power and pollution. The Chinese Government forced 30 small smelters to close in Hunan province in early 2004 due to water pollution concerns. Several others were closed for a period of three weeks during March 2005 in order to clean up their operation, and these were later allowed to open again. In addition to this, occasional power cuts have disrupted manufacture from time to time.

In addition to primary production there is also a substantial capacity for recycling the metal as approximately 70% of the indium contained in the main product, indium tin oxide, can be recovered and refined for re-use. Recovery operations take place, particularly in Japan and China, but also in Korea, the US, the UK and Canada.

Estimated world primary indium production (tonnes)

Country	tonnes
China	240
Japan	60
Korea	30
Canada	40
US	40
Europe	40
CIS	4
Peru	3
Total	417

Applications

The most dominant application (78%) for indium is in the production of indium tin oxide (ITO), which is used as a coating on all types of flat-panel displays. It is deposited as a thin layer, generally by 'sputtering' from a target, and acts as a transparent electrode enabling LCDs, PDPs and OLEDs to be activated. It is this demand from the more widespread uses of flat-panel displays that has caused the soaring demand for indium metal in the past 18 months. There are applications in mobile telephones, navigation devices and other displays, but the large increase is due to the consumer switch from CRT televisions to flat-panel TVs.

Several large companies have invested billions of dollars in the market, particularly those located in Japan, Korea, Taiwan and China. Many household names are involved including LG Philips, Samsung, Sharp and Matsushita. LG Philips is the leading producer of PDP screens and Sharp is to increase its annual production of >40" LCD TVs tenfold to 1 million units by late 2006. Its output of 32" LCD panels is to increase to 4.8 million units later in 2005.

There are many other important uses for indium, including its inclusion as an element of many lead-free solders, which are mandatory in many countries now. Also, due to its malleable nature and maintenance of mechanical strength down to very low temperatures, indium is used to seal electronic

assemblies, scientific instruments and in cryogenics, as exemplified by its use in body scanner technology.

Other applications include batteries, SOX lamps, bearings, low melting-point alloys and/or as an element in cathodic protection systems.

Supply and demand and pricing

Due to the large increase in demand for indium by the flat-panel display industry, supply has been stretched at times and hence the price has risen dramatically, from an average of US\$358/kg in January 2004 to around US\$1,105/kg in August 2005. In 2003, the price averaged US\$95/kg in 2003.

Primary supplies have increased, particularly in China and now Korea, but the increase in recycling capacity has also served to keep the market supplied with this much needed metal.

However, demand is expected to continue to rise, with annual TV sales increases of 30%-40% anticipated. Corning and Nippon Electric are installing extra glass capacity, and flat-panel display factories are still being built. This will place additional pressure on the supply chain with further price increases to the US\$1,200-US\$1,500/kg range possible during 2006.

Japanese imports (kg)

	1997	1998	1999	2000	2001	2002	2003	2004	2005 (six months)
Belgium	3,984	2,906	3,014	3,408	3,286	1,894	2,799	2,415	-
Canada	3,391	-	4,004	22,730	20,110	13,830	29,578	34,800	18,089
China	23,360	23,737	42,045	50,296	85,957	75,224	156,062	298,987	157,530
CIS	11,057	7,515	1,361	919	1,295	184	12,862	19,740	2,191
France	46,800	41,763	36,650	49,259	41,605	16,188	5,103	1,795	-
US	8,903	7,008	2,404	2,581	10,913	29,987	47,798	26,947	18,338
Other	3,301	2,465	1,731	3,568	7,834	3,167	10,316	36,013	18,073
Total	100,796	85,394	91,209	132,752	171,000	140,474	264,518	420,697	214,221

Outlook

The general demand for indium chemicals, alloys and high-purity items are generally fairly steady, but the big driver for the market will be the continued increasing demand for flat-panel TVs. This will ensure strong demand for years to come. There has been research to replace the metal in some applications because of its high price, but so far indium's usage in display panels is undiminished as it is still the best transparent electrode available, and even at the current elevated price levels the impact on the price of TVs and other displays is very small.

The key to the continued supply and, hence, also more stable price levels, will be the ready availability of indium-containing concentrates. So far sufficient has been available for the increased demand, but some are forecasting future shortages and so the supply/demand balance at any one point could become critical.