USGS
science for a changing world

USGS Mineral Resources Program

49
In
[Kr]$5s^2 4d^{10} 5p^1$
114.8

Indium—Bringing Liquid-Crystal Displays Into Focus

As part of a broad mission to conduct research and provide information on nonfuel mineral resources, the U.S. Geological Survey (USGS) supports science to understand

- *How and where indium resources form and concentrate in the Earth's crust*
- *How indium resources interact with the environment to affect human and ecosystem health*
- *Trends in the supply and demand for indium in domestic and international markets*
- *Where future indium resources might be found*

Why is this information important? Read on to learn about indium and the important role it plays in the national economy, in national security, and in the lives of Americans every day.

Indium is rare in the Earth's crust. The continental crust contains an average of about 50 parts per billion of indium, whereas the oceanic crust contains about 72 parts per billion, which is similar to meteoritic abundances and comparable to the crustal abundance of silver. Indium minerals are rare in nature and only 12 indium minerals are known. In its elemental form, indium is a soft, lustrous, silver-white metal with a low melting point relative to other metals. It is ductile and malleable, even at temperatures approaching absolute zero, making it ideal for cryogenic applications.

Indium was discovered in the mid-1800s by two German chemists who were investigating zinc ores from Freiberg, Saxony. They named it after the distinctive indigo-blue color observed in its emission spectrum. For years indium remained only a scientific curiosity and early applications of indium were few, but included manufacturing of light-emitting diodes (LEDs) and coatings for bearings used in aircraft engines. Indium-bearing nuclear control rods became more widely used in the 1970s, and today the major application of indium is in manufacturing liquid-crystal displays (LCDs).

Compared to more abundant industrial metals such as lead and zinc, information about the behavior and toxicity of indium in the environment is limited. However, many indium compounds have been proven to be toxic to animals.

How Do We Use Indium?

Flat screen liquid-crystal displays.

The leading use of indium is for the production of indium-tin-oxide (ITO), which is used in virtually every flat-panel display and touchscreen, and has few chemical substitutes. ITO is typically deposited as a thin-film coating on the display surface where it transforms incoming electrical data into an optical form. Most ITO production is concentrated in Japan, with significant quantities also produced in China, Republic of Korea, and Taiwan.

Solders and alloys are the second most important use of indium globally. Indium-containing wire-, ribbon-, and foil-solders have lower crack propagation potential and improved resistance to thermal fatigue when compared to tin-lead solders. Indium-alloys, such as copper-indium-gallium-diselenide (CIGS), are becoming an increasingly preferred thin film product because of their relatively low material and manufacturing costs. CIGS photovoltaic cells are in the initial stages of commercialization, but they are expected to eventually compete with other forms of energy production. Some indium alloys can be used as bonding agents between nonmetallic materials, which makes them useful for applications such as dental alloys. Indium alloys have been used as a substitute for mercury and are still used in nuclear control rods.

Another important use of indium is for semiconductor materials used in LEDs and laser diodes. Indium-based LEDs are used predominantly to optically transmit data and, to a lesser extent, in LED flat-panel displays commonly used in outdoor store signs, billboards, and signs on public transport vehicles. Indium-based laser diodes are used in fiber-optic communications.

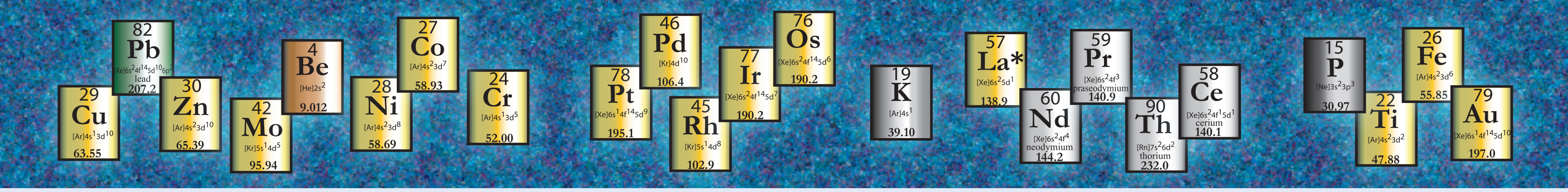
Where Does Indium Come From?

Indium occurs in base metal-bearing hydrothermal ore deposits of all ages that form within active oceanic- or continental-plate margins and orogenic belts that have had abundant magmatic activity. These deposits range from active volcano edifices on the seafloor to billion-year-old volcanic layers preserved in metamorphic greenstone belts. Indium is not concentrated enough to be a major commodity in deposits, but it is recovered primarily as a byproduct during the refinement of zinc ores, most commonly the zinc ore mineral sphalerite. Typical indium-rich ores contain zinc concentrations between 10 and 22% and copper concentrations at or more than 2%. Because indium is typically in very low concentrations in these ores, it can only be extracted as a byproduct with the appropriate technical and processing conditions. Concentrations of 20 to 25% indium are typically recovered from the anode slime residues within zinc refineries, followed by concentration and further refinement to a purity of greater than 99.99%.

More than half of the byproduct indium in the world is produced in southern China from base metal-bearing ore deposits including seafloor volcanogenic massive sulfide (VMS) deposits and sedimentary exhalative massive sulfide (SEDEX) deposits. Much of the remaining production comes from zinc concentrates from sedimentary basin Mississippi Valley-type (MVT) deposits. Many other deposit types worldwide also contain significant indium, including epithermal, polymetallic base metal-vein, granite-related tin-base metal, skarn, and porphyry copper deposits.

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2015–3012
July 2015



Worldwide Supply of and Demand for Indium

Estimating reserves of indium is difficult because it is a byproduct commodity that comes from a wide variety of zinc-rich ore deposit types. More than 95% of global indium production comes from the electrolytic zinc refinement process. Zinc reserves in the United States are estimated to be about 5% of the global total (250,000,000 tonnes). Concentrations of indium in sphalerite are not commonly reported, and consequently data are insufficient to determine reserves more accurately.

Globally, primary production of indium metals in 2011 was estimated to be about 662 tonnes, of which more than half was produced in China. Other leading producers were the Republic of Korea, Japan, Canada, and Belgium. These five countries accounted for almost 95% of primary indium production. Not all zinc refineries have the facilities to process their own residues to recover indium. In many cases, the metal-rich residues are sold to secondary producers that have the appropriate facilities. As a result, many of the large primary indium-producing countries do not have significant indium-bearing ore deposits. The number of indium producers and specialized refineries has increased greatly since 2000, especially in industrialized countries like Japan, the United States, Republic of Korea, Germany, and China. Whereas China dominates the 2014 international market for many raw materials such as indium, a number of refineries outside of China have abandoned low-grade indium production and are currently focusing on the production of higher-purity indium.

Sphalerite is the zinc ore mineral from which indium is commonly recovered. This specimen is approximately 10 centimeters across. Photograph courtesy of Rob Lavinsky, iRocks.com—released under CC-BY-SA-3.0 license.

In 2011, the United States did not produce indium metal as a byproduct at any smelters or refineries. Instead, domestic production of indium consisted of upgrading imported indium metal and powder. Imports reached 150 tonnes in 2011, an increase of 43% from 2009. The annual refinery capacity of indium in the United States is about 40 tonnes. Two U.S. companies account for the majority of U.S. production of indium metal and products.

Did you know... ***Indium has potential to help reduce the carbon footprint from energy production because of its use in copper-indium-gallium-diselenide (CIGS) photovoltaic cells***

How Do We Ensure Adequate Supplies of Indium for the Future?

The recovery of indium from secondary sources like residues and end-of-life scrap currently exceeds the production from primary sources by about 250%. The recovery of secondary indium metal and the recycling of indium compounds are already important in some producing countries such as Japan, Republic of Korea, the United Kingdom, Canada, the Philippines, Taiwan, and Germany. However, to meet increased demand for indium in the future, we need (1) better metallurgical recovery technology from ore concentrates, (2) more careful implementation of recycling of electronic products and production waste, and (3) increased ore deposit exploration.

Exploration for indium-bearing deposits has increased following the growing markets for liquid-crystal displays and photovoltaics and the closure of the world's largest producer of indium in 2006, the Toyoha polymetallic base metal-vein deposit, Japan. Current projects worldwide are focusing on magmatic base metal-rich deposits, hydrothermal base metal-vein deposits, and most importantly, on massive base metal-sulfide deposits. The most favorable deposits with high indium concentrations have been reported from the Mount Pleasant porphyry tin-tungsten deposit in New Brunswick, Canada, and from several deposits in Argentina, Australia, Brazil, Bolivia, Finland, Portugal, and the United States. The Crypto Zinc-Copper-Indium Project, Juab County, Utah, is a new domestic indium resource with significant indium reserves. Copper and zinc skarn deposits in the district average about 31 parts per million indium and the inferred indium resources of this area are about 475 tonnes.

Adex Mining Inc.'s Mount Pleasant mine site, located in New Brunswick, Canada, is seen reflected in the tailings pond (foreground) with Mount Pleasant in the distance. The North Zone deposit, situated in the northwestern part of the Mount Pleasant property, contains one of the globe's richest and largest known indium resources. Photograph courtesy of Adex Mining Company.

Did you know... ***Recycling of indium from electronic products and from manufacturing waste is a significant contributor to production***

For More Information

- On production and consumption of indium: http://minerals.usgs.gov/minerals/pubs/commodity/indium/
- On recent uses of indium in the United States: http://pubs.er.usgs.gov/publication/cir1377/
- On historical statistics for indium in the United States: http://minerals.usgs.gov/minerals/pubs/historical-statistics/

The USGS Mineral Resources Program is the principal Federal provider of research and information on indium and other nonfuel mineral resources.

For more information, please contact:

Mineral Resources Program Coordinator
U.S. Geological Survey
913 National Center
Reston, VA 20192
Telephone: 703–648–6100
Fax: 703–648–6057
Email: minerals@usgs.gov
Home page: http://minerals.usgs.gov

49
In
[Kr]5s²4d¹⁰5p¹
114.8

Text prepared by C.N. Mercer.

ISSN 2327–6932 (online)
http://dx.doi.org/10.3133/fs20153012