

AVAILABILITY OF INDIUM AND GALLIUM SEPTEMBER 2009

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*"Long term, both indium and gallium will be available with intermittent price volatility."
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1. Introduction

Indium is a by-product derived from several common base metals including lead, zinc, copper, tin, silver or other polymetallic ores.

2.1. Indium Ores and Mining

The abundance of indium in the earth's crust is estimated to be 0.05 ppm for the continental and 0.072 ppm for the oceanic crust. This concentration is higher than the concentration of silver. Ulrich Schwartz-Schampera & Peter M. Herzig studied all indium-containing ore deposits worldwide and reported their findings in 2002 in their book titled "Indium Geology, Mineralogy, and Economics". They concluded that *"future increases in indium production are expected to be easily accomplished... indium could enjoy virtually infinite growth in use without supply limitations"*.

Indium production increased from 70 to 500 mt per year over the last 20 years to meet demand. This has been made possible due to improvements in the extraction technology combined with the economics of higher prices. Indium is now recovered as a by-product of a wider range of base metals with concentrations as little as 100 ppm of indium per ton material.

Over the last 5 years, base metal consumption increased and mining companies have made positive financial returns. This profitability, in turn, has prompted many new investments in mining. Mining output increased, increasing supplies of indium-containing feedstock. Still today exploration and mining activities continue and will do so for the future, contributing to increased reserves.

A study undertaken by the Indium Corporation determined that indium reserves (proven and probable, measured and indicated, and inferred) in identified base metal mines in the "western" world amount to 26,000 mt of indium. Those located in the rest of the world, i.e. China and the CIS (former Soviet Union) amount to about 23,000 mt of indium, bringing the total world reserve to close to 50,000 mt of indium

Existing mines of indium-containing ores are dispersed around the globe in terms of geography, political policies, and influences. This broad geographic and political dispersion adds to the stability of the indium supply.

2.2. Indium Extraction

Virgin indium production has increased by a factor of 3 over the last 15 years because base metal smelters improved the extraction process and were able to treat a lower grade of indium in concentrates. In addition, base metal smelters, who can extract the indium from concentrates, are now more actively seeking and purchasing indium-containing concentrates from more sources and at higher volumes. In the past, the revenues these smelters could generate from the indium recoveries were not significant enough for them to change concentrate suppliers or to pay more freight expenses to source these indium-containing concentrates from further distances. Thus, indium-containing concentrates were often treated by smelters who could not extract the indium and these quantities were historically lost as unprocessed. The demand for indium and the improving economics are factors that have steadily driven increasing extraction output.

Recovery yields are another important contributor to increased outputs. Historically, less than 20% of the indium content in concentrates was extracted to yield indium metal. Higher indium prices now make it economically viable for smelters to invest to increase these yields and capacities.

The study undertaken by the Indium Corporation shows that still today only about 30% of the 1,500 mt of indium mined worldwide every year is transformed into refined indium metal for the following reasons:

- a) 30% of indium-containing base metal concentrates still do not reach “indium-capable” smelters and this indium continues to be lost.
- b) 70% of the indium-containing concentrates that do reach indium-capable smelters are only extracted at a final average rate of about 50%

However, the remaining 50% that is not immediately transformed into indium metal and remains associated with other elements and impurities in a residue form is accumulated and is available for further treatment and recovery later as outlined in 2.3 below.

2.3. Indium residues, slags, or tailings

A number of smelters have accumulated large amounts of tailings and slags over the years and continue to do so. These indium-containing materials are more difficult and thus more expensive to treat. However, they can be treated if demand and price warrants. Our study has identified that the total residue reserves worldwide amount to over 15,000 mt of indium and that another 500 mt of indium is generated every year in residue form.

3. Indium extraction and refining capacities

Global refining capacity continues to increase.

Some notable highlights include:

- Korea Zinc installed a brand new extraction and refining processing line at their zinc smelter in Korea.
- Dowa Mining increased their indium refining capacity in Japan.
- New extraction and refining lines are being installed in South America.

- A large number of Chinese companies have installed processing lines to treat material containing less than 0.5% of indium into crude metal.
- Other Chinese companies have installed refining lines to purify crude indium into higher purities.

4. Reclaiming of ITO targets

Flat panel displays (FPD) are the largest application for indium, consuming over 50% of the world virgin output of indium and about 80% of the total availability including reclaimed indium. Planar targets of indium-tin oxide (ITO) are commonly sputtered onto glass panels, but less than 30% of the material from the target is deposited onto the glass. The remaining ~70% is left in “used” ITO targets, grinding sludge, or on the shields of the sputtering chambers.

Factoring in recovery yields, it is estimated that over 70% of the indium from the starting ITO targets is recovered via reclaim processing. The amount of indium coming back from the reclaiming activity is now getting close to 1000 mt indium per year or two times the amount of virgin indium consumed.

Capacity to reclaim these spent ITO targets into refined indium metal also continues to expand in line with the FPD industry growth. The reclaim cycle time has been reduced and is now less than 30 days. These cycle time improvements have the effect of reducing the over-all demand of virgin indium by the large FPD industry.

We therefore conclude that based on mining reserves (100 years at a rate of 500 mt of virgin indium per year), plus residue reserves (30 years at a rate of 500 mt per year), combined with continued improvements in recoveries of virgin and reclaimed materials, and on-going exploration, **the world will not run out of indium**. These reserves quantities do not factor in recovery yields but are significant enough to reassure the CIG industry.

7. Gallium Mining and Extraction Process Overview

Similar to indium, gallium is a minor metal with no primary mining activity. Gallium is extracted from bauxite as part of the bauxite-alumina refining flow that most commonly utilizes the Bayer liquor process.

By all accounts, gallium-containing bauxite is plentiful in the earth’s crust and is widely distributed both geographically and politically. Similar to indium, this contributes to the stability of the supply of gallium feedstocks. More interesting, only a small portion (less than ten percent) of the potentially available gallium in the bauxite is actually extracted. Hence, the existing flow of bauxite processing offers tremendous capacity increases. Historically, the low extraction volume was limited more by the relatively small demand and economics of relatively low prices. For all practical purposes, gallium output is limited only by facilities investment and capacities.

As a conclusion, gallium is plentiful with intermittent volatility. The 2000 – 2001 mega price run-up was primarily due to inventory stocking by the cell-phone supply chain fearful of a shortage. In addition, poor communication up and down the supply chain contributed to the

hoarding of material against a phantom demand. Hence, a massive over-supply (glut) followed the hoarding, driving prices to historic lows. The more recently constrained availability of gallium during 2007 and the resultant price run-up is an example of this intermittent volatility and does not reflect any long-term concern about supply.

GaAs wafers used for ICs in wireless devices consume the majority of gallium today. LED devices represent the second largest consumer of gallium followed by solar, batteries, alloys, and other minor applications. The reclaimed gallium from the GaAs wafer production is a significant part of the gallium reclaim and refining process.

Any near-term supply and demand shortfall will only be due to the time required to bring facilities on-line.

7. Conclusion

Indium- and gallium-containing raw materials exist abundantly worldwide. The metals industry has been investing in process improvements and capacity over the last few years to bring more indium and gallium to the market. Suppliers can and will continue to do so if the demand continues. As described, price volatility and short-term availability may continue intermittently due to numerous factors, including the time-lag required to install additional capacity, government regulation, and the lack of information suppliers receive about future demand. Overall, we anticipate adequate indium and gallium supply and continued price affordability for current, emerging, and new applications.