The Future of Indium Supply and ITO

William Jackson
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Indium Corporation: Numbers

- > 77 years of consistent growth
- ~700 employees
- 11 factories worldwide (6 in US)
- High quality earnings
- > 60% of revenue outside of US
Indium Metal and ITO

- Most of the indium in the world today (~60-70%) is used in ITO, on flat-panel liquid-crystal displays.
- Indium is not particularly rare. It ranks 61st in abundance of all chemical elements.
- According to a USGS study, indium is in the earth’s crust and is estimated at 240 parts per billion.
- For comparison purposes, silver is ranked 65th and is not perceived to be in short supply.
- The USGS study of silver is estimated at 75 parts per billion.
- It is NOT a Rare Earth Metal!
Indium – Elementary Facts

- Indium is a by-product of other major mined materials
- Indium comes mainly from residues generated during zinc ore processing, and is then extracted and further purified
- Indium also comes from copper, lead, tungsten, and tin
- Total Proven Reserves = > 50,000 MT, equivalent to 50+ years of consumption
- Supply of zinc and copper concentrates is plentiful
- Extraction and refining have been and can be expanded to meet demand for emerging technologies
Carrier metals

Co-elements with considerable production infrastructure

Co-elements with NO or LIMITED infrastructure. Mostly high-tech metals.

Co-elements that end up in residues or as emissions

Source: The metal wheel
Reuter et al. (2005) and Verhoef et al. (2004)
Where do indium deposits occur?

Canada: 120
Peru: 565
Bolivia: 234
Australia: 88

2010 figures in metric tonnes
Indium Disposition

In the Western world (excluding China and CIS), ~ 1,000 MT Indium are mined yearly

• 25-30% of indium mined yearly becomes refined indium
• 25-30% accumulates in residues
• 40-50% goes to non-indium-capable refineries and is (now) lost

Indium production can be vastly expanded. Capital investments are required.

Source(s): press releases, Indium Corporation, and partners
Indium Market Contributions (Part 1)

Metric tonne (MT) figures are approximate – 2011 figures.

Sources: USGS reports, Indium Geology (Schwarz-Schampera, Herzig), Roskill, Indium Corporation, and partners.
Indium Market Contributions (Part 2)

12.5 million MT

Zn mined

RoW

China

virgin

recycled

950 MT

1,500 MT

Mining → Extraction → Refining → Recycling → World Indium Market

Metric tonne (MT) figures are approximate – 2011 figures
Why is the number of indium refiners so low?

Only 14% of zinc refineries are producing indium—10 out of 73

- Minimum zinc volume required (200 kMT)
- Minimum indium concentration vs. total zinc output (0.010%)
- Zinc refiners’ strategy
- Fear of by-products’ price fluctuations
Reserve Stocks

- 50,000 MT reserves from existing mines
- 15,000 MT above-ground mines
- New mines exploration ongoing

“Future increases in indium production are expected to be easily accomplished…

… indium can enjoy virtually infinite growth in use without supply limitations.”

*Indium Geology, Mineralogy, and Economics,*
Ulrich Schwarz-Schampera & Peter M. Herzig, 2002
Indium Supply and Demand are Well-Matched

Cumulative in Balance

Reclaim Indium Supply
Virgin Indium Supply
Total Indium Use
Indium Supply – Conclusion

Wall Street Journal, 27-Mar-2012:
Canada is the world's biggest miner of zinc and uranium and among the top producers of gold, nickel and a host of other minerals. Mining companies are planning $140 billion of investments in the next decade, according to the Mining Association of Canada.

Indium consumers need to communicate to base metal producers on future needs to enable investments and expansion.
The future of ITO?

...and why it’s tricky to predict the future
Flat Panel Displays

The flat panel display industry...

- Is the largest consumer of indium, accounting for over 60% of all indium uses
- Has a mature reclaim stream that is vital to the health of the indium market
- Will use close to 300 MT virgin indium in 2012

2013 and beyond 5-15% per year growth
Display Forecast (all technologies)

Source: DisplaySearch, Quarterly Advanced Global TV Shipment and Forecast Report, October 11, 2011
Transparent Conductor Forecast
(NanoMarkets, August 2012)
Alternatives to ITO

• Other TCOs such as AZO, etc. are cheaper, but conductivity and/or transparency is always lower

• CNT (carbon nanotubes) are expensive to manufacture in high purity:
  − Separation problem: manufacturing produces both metallic and semiconducting nanotubes
  − Recent advances at the research stage, manufacturing scale-up has not been solved

• Nano wires (copper, silver):
  − Start-ups and VC-funded activities
  − Silver nano wires (Cambrios): traction with Android smart phones

• Graphene: University research stage and successful small scale production and usage
Performance Data ($R_s$ vs. $T$)

Considerations for Transparent Conductor Materials

• As $R_s$ and $T$ performances become similar, other key metrics come into play
  - Reliability: average replacement cycle time:
    • Flat panel displays: 10 years
    • Cell phone: 1.7 years

• Sole supplier/proprietary material vs. group of (competing) suppliers

• Integration and compatibility with other materials
ITO on Roll-to-Roll Processes (Equipment Is Available)

- EFUN (touch-panel manufacturer, Taiwan)
- Applied Materials: SmartWeb tool
- Announced in July 2011
Other ITO and TCO Materials/Processes on Flexible Substrates

- Evonik Aerosil material (Printed ITO) – shown at Printed Electronics 2011 in Santa Clara

- Solar companies that use roll-to-roll processing/flexible substrates:
  - Ovonic, Nuvosun, Global Solar, Miasole, others
  - Thin-film, flexible PV cells which need TCOs; need to address brittleness in other layers (CIGS, CdTe, etc.) as well
Cost Impact of ITO Per LCD Panel

• Indium/ITO cost impact on screen area: $4.80/m²
• Includes sputter process cost and yield, at $800/kg indium price
• A 42” screen uses
  (0.52m x 0.9m x $4.8/m²) = $2.24 in ITO direct material
• TV retail price > $430

30-Mar-2012
$550/kg
LCD Manufacturing – Bill of Materials Trends

• LCD manufacturers are extremely reluctant to switch away from ITO
• Switch would need to disrupt established manufacturing lines
• Bill-of-materials price trends (see data on next slide) as the average FPD size increases:
  – ↘ Electronic components move down experience curve
  – ↔ Glass substrates price erosion↘, display sizes ↗
  – ↗ ITO: more material is consumed as panel area goes up
  – Net effect: ITO % of BOM goes up
### ITO Sputter Targets – Highest Growth in BOM for LCDs

<table>
<thead>
<tr>
<th>Material</th>
<th>2008</th>
<th>2009</th>
<th>Y/Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB &amp; Other Module Components</td>
<td>$8.5</td>
<td>$6.6</td>
<td>-22%</td>
</tr>
<tr>
<td>Inverter</td>
<td>$1.4</td>
<td>$1.5</td>
<td>7%</td>
</tr>
<tr>
<td>Backlight</td>
<td>$14.8</td>
<td>$12.6</td>
<td>-15%</td>
</tr>
<tr>
<td>Driver IC</td>
<td>$4.5</td>
<td>$4.3</td>
<td>-4%</td>
</tr>
<tr>
<td>Other Cell Components</td>
<td>$0.8</td>
<td>$0.5</td>
<td>-38%</td>
</tr>
<tr>
<td>Liquid Crystal</td>
<td>$1.4</td>
<td>$1.5</td>
<td>7%</td>
</tr>
<tr>
<td>Polarizer</td>
<td>$5.8</td>
<td>$5.7</td>
<td>-2%</td>
</tr>
<tr>
<td>Color Filter</td>
<td>$7.9</td>
<td>$8.1</td>
<td>3%</td>
</tr>
<tr>
<td>Chemical &amp; Indirect Materials</td>
<td>$2.3</td>
<td>$2.1</td>
<td>-9%</td>
</tr>
<tr>
<td>Sputtering Target</td>
<td>$0.8</td>
<td>$0.9</td>
<td>13%</td>
</tr>
<tr>
<td>Glass</td>
<td>$4.8</td>
<td>$4.8</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>$53.0</td>
<td>$48.6</td>
<td>-8%</td>
</tr>
</tbody>
</table>

Source: displaysearch.com

Note: Table data represents revenues of components across entire LCD industry.
Summary: Display Applications

- ITO sputtering = incumbent technology
- Significant developments:
  - ITO sputter deposition will move from planar to rotary targets
  - ITO deposition will become fully compatible with printing and roll-to-roll processing
  - ITO alternatives:
    - Nano silver is a credible player
    - Alternative solutions need to create a great value proposition in their specific application market. Maintaining that ITO and indium are suffering shortages is NOT a credible marketing strategy
- Transparent Conductive Oxides (TCOs) will play an important role in AMOLEDs, as the TFT materials replacing a-Si: indium-gallium-zinc-oxide (IGZO or GIZO)
Disclaimer

- Historically, the minor metal markets have experienced periods of price volatility (similar to most other metals and commodities).
- This presentation contains historical information based on public sources and internal analysis. Future projections are forward-looking estimates and are not statements of fact. We ask the audience to rely on their own interpretations and draw their own conclusions.
- Indium Corporation assumes no obligations, nor any liabilities, based on written or verbal, expressed, or implied information.
Thank you!

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