Availability and Sourcing of Cerium, Gallium, Indium and Iridium, Key Critical Materials for the Display Market

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Abstract

Sourcing and recycling of Cerium, Gallium, Indium and Iridium, critical materials for the display market, are key to its long-term success. Prices, availability, competing technologies, rapid increase in demand, inefficient consumption and geopolitics are all common reasons to affect the supply chain of critical materials. Each critical material will be presented with historical and current information to understand the threat of its availability for the display market.

Keywords

Critical materials, Cerium, Gallium, Indium, Iridium, ITO.

INTRODUCTION

Any supply chain is subject to disruptions. Over the years, their level of complexity increased because most markets, especially the ones related to semiconductors, require specific materials and components. Moving upstream in the supply chain (closer to raw materials), many markets are competing for the same materials. When the demand rises, availability becomes an issue, and political measures can be put into place to help fix scarcity. Markets realize that some key materials are essential to their technology, and governments then realize that without it, there will be consequences for their citizens. While the notion of critical materials has been around for many years, countries and markets have been listing for the past few years what is or could be missing in their supply chain, making them vulnerable.

It is easy to understand that geological resources are not spread evenly throughout the world but relationships between countries can have a domino effect on the whole supply chain. Tariffs, export controls, quotas are now common in today's world and everyone paying attention can see issues coming. Another very important factor affecting the supply chains is decarbonization through clean energy sources. These sources of energy require their own critical materials, and this market is most likely the biggest in the world. These upcoming technologies are not yet efficient, supply chains are being built and recycling becomes imperative to support the growth.

The display market has many of them, but this paper will focus on Cerium, Gallium, Indium and Iridium. Cerium is part of the rare-earth elements (REE), which are difficult and inefficient to extract from ores. Around 70% of the world's production of REE is coming from China and they have seen issues over the years. Recycling is part of the supply chain. Gallium is easier to extract but is usually a by-product of aluminum refining. The primary production of aluminum is more than 10,000 larger than gallium, while its market price is more than 100 times lower. The incentive to value gallium in the aluminum refining supply chain is therefore very low. China produces around 90% of the primary Gallium in the world, making recycling essential to worldwide supply chains. Of the four listed critical materials above, Indium is the one that has the biggest consumption. Primary production and recycled Indium are both high contributors to global output. Primary production mostly comes from Zinc refinery, but the Indium rich ores are mostly located in China, who is producing above 60% of the world's indium. Finally, Iridium is part of the Platinum group metals (PGM). Iridium is one of the least abundant elements on Earth and most of the PGM production comes from South Africa (around 90%). PGM are usually extracted together and must be separated during the process.

In this paper, each of these critical materials will be introduced to understand their application in the display market, how they are extracted and their challenges. Based on these factors, a conclusion will be drawn on the level of threat to the display market supply chain. This paper aims to gather relevant information to have a high-level understanding of the supply chain of these critical materials. It will raise awareness in the community and allow it to better understand what is at stake and have an influence on key decisions. There are no easy solutions to complex problems, but understanding them better helps moving forward.

CERIUM

Cerium can be a key component as a phosphor to emit light [1], but it is also used as an oxide to polish glass, making it essential for displays requiring glass components. Primary sources of Cerium are from Monazite and Bastnäsite [2]. African and American sources tend to have less Ce content than and the ones from Asia. In 2009, China restrained access to rare earths by imposing tariffs and quotas on exports. The US, EU, Japan and other countries challenged China's measures in 2012 to the World Trade Organization (WTO), and the quotas were removed in 2015 [3]. For that reason, both the Chinese and US supply chains are now strong, and the price dropped. New quotas were put in place in 2023 and 2024 [4], but given the current low prices in the market, these are not threatening the supply chain. 2023 saw a boost in production while demand was low which helped lower the price [5]. These circumstances can lead to manufacturers stopping their operations and discourage others from joining.

There are also secondary sources for Cerium such as Red Mud (a byproduct of Aluminum refining) or glass polishing wastes. Out of 54,400 t of CeO2, 40,000 t are for the glass industry, with 16,000 being for polishing slurry [6]. Recycling is well established in this market and the low price should not impact its streams. There seems to be no risk to the display market's supply chain.

GALLIUM

Gallium is very important for any Gallium nitride (GaN) based semiconductors, as well as indium gallium zinc oxide (IGZO) compounds for thin film transistors (TFT). Aluminum Gallium Indium Phosphide (AlGaInP) is also relevant to the display market. Gallium has been at the center of the current trade war between China and the US. Since August 2023, Gallium and Germanium require an export permit to leave China [7]. While export permits are common for many products, it became clear that the US were directly targeted because almost no Gallium or Germanium products made their way from China to the US since. In December 2024, it was made official that Gallium and

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Germanium were banned from leaving China to the US [8]. Since China is by far the main primary producer of Gallium, it created stress in many supply chains. It is important to note that not all gallium containing products require a permit to be exported.

Table 1. List of controlled commodities by the export restrictions in China, and their associated HS-code [9].

Commodity Name	China 10-digit HS Code
Gallium Metal	8112.9290.10 8112.9290.90 8112.9990.00
Gallium Nitride	2850.0019.01 3818.0090.01 3825.6900.01
Gallium Oxide	2825.9090.01 3818.0090.02 3825.6900.02
Gallium Phosphide	2853.9040.30 3818.0090.03 3825.6900.03
Gallium Arsenide	2853.9090.26 3818.0090.04 3825.6900.04
Indium Gallium Arsenide	2853.9090.28 3818.0090.05 3825.6900.05
Gallium Selenide	2842.9090.24 3818.0090.06 3825.6900.06
Gallium Antimonide	2853.9090.29 3818.0090.07 3825.6900.07

Elements in Table 1 completely shut down key components of the compound semiconductors (CS) market for anyone wanting to compound its own bulk crystals or grow by molecular beam epitaxy (MBE) since Gallium metal is on the list. Gallium Arsenide (GaAs), Gallium Nitride (GaN) and Gallium Antimonide (GaSb) substrates are also key semiconductors in today's technology, which removes key Chinese suppliers from the chain. On the other hand, metal-organic (MO) sources such as Trimethyl Gallium (TMG) or Triethyl Gallium (TEG) can still be supplied to the metal-organic chemical vapor deposition (MOCVD) market. As shown in Table 2, the markets associated with compound semiconductors (ICs, GaAs, GaP and GaN) are the ones needing the most Gallium. For the display market, IGZO targets remain unaffected by these export restrictions. In other words, the display market may not fully feel these restrictions now in terms of availability, but prices are rising, especially outside China.

Since China produces around 89% of the world's Gallium [10], it remains a concern. Gallium is extracted from Bauxite, which is the main source of Aluminum. Aluminum producers are mostly using the Bayor process, which leaves the Bayor liquor with a high content of Gallium [11]. Now, the production of Aluminum is much higher than Gallium, and the competition is high. Aluminum is considered a commodity on the market, and with a metal price around $3/kg, processes must be cost effective. Considerations for Gallium extraction in the process are therefore omitted by choice. Only a few Aluminum refineries have an adjacent gallium refinery next to it to make it efficient. Adding such capabilities require capex, environmental and safety investigations. Geopolitics are pushing companies and politicians to invest, as it was recently announced in Canada [12]. There is also a strong contribution from secondary sources of gallium through recycling. Secondary production could account for 20 – 25% of the total production.

Table 2. Gallium consumption per market from 2000 to 2021 [13].

Market	Share
Integrated Circuits (ICs)	36%
Gallium Arsenide (GaAs)/ Gallium Phosphide (GaP) LEDs	22%
NdFeB Magnets	21%
Others	11%
Gallium Nitride (GaN)	8%
Copper Indium Gallium Selenide (CIGS)	2%

Gallium is critical for IGZO, but the demand for the market remains small and it is always easier to secure smaller quantities of material, especially when prices are high since securing large volume requires a lot of cash flow.

INDIUM

Indium might be the most critical material in this paper in the form of indium tin oxide (ITO).

Table 3. Indium consumption per market in 2021 [14].

Market	Share
ITO	90%
Solders and alloys	4%
Electrical components	3%
Intermetallic	2%
Others	1%

As shown in Table 3, ITO dominates the indium market, which has a direct impact on the supply chain for secondary sources. Indium is mainly refined from Sphalerite (zinc sulfide) as a byproduct of zinc refining. Most of the primary world's production comes from China, but secondary (recycled) sources of indium are also high [15]. When ITO planar targets are used, their utilization rate is low (around 30%) [16], which requires a third party to recycle them. Rotary targets have a much higher utilization rate (above 75%), but they also can be recycled. The deposition process does not have a 100% hit rate, but shields can collect off target ITO for reclaims. It is usually convenient for ITO producers and recyclers to be nearby large consumers of ITO: where sputtering deposition of ITO occurs. Japan and South Korea produce state-of-the-art ITO targets, but China is catching up on quality and size. Also, China can use its own products, as well as imported targets for their growing capacity in ITO sputtering. It enables China to reclaim a lot of Indium and recycle it [17].

Pricewise, indium metal in the Chinese market and outside of

China are following the same trends, at a very similar price. In 2024, Indium price went up ($250/kg to $400/kg), but as time goes by, this should be seen as a punctual event (a spike). It is due to the futures price on the Zhonglianjin Exchange [18].

IRIDIUM

Iridium is an important material for this market as a phosphorescent complex for organic light emitting diode (OLED) [19]. The main issue with Iridium is most likely its price. It sat around $34/g in January 2018 to reach a peak of $186/g in January 2024. The price dropped slightly since, but remains high, around $160/g. Just like any precious metal, the main issue is scarcity. While China was the main supplier of gallium and indium, Iridium mostly comes from the Bushveld Igneous Complex (BIC) in South Africa where more than 70% of the platinum resources are. The processes to extract PGMs are complex, and in succession. From concentrates, Palladium and Platinum contents are filtered out. Ruthenium, Rhodium and Iridium contents are further processed in different streams, and they can get extracted. The complexity of the processes increases the cost, but it also makes it challenging for the environment [20].

Iridium is mainly used for the electrodes in the chlor-alkali process. It allows Chlorine and Hydrogen production from sodium chloride in water (brine) by electrolysis. Iridium plays a major role in clean hydrogen production as a catalyst in the proton exchange membrane (PEM) electrolysis [21]. There are a lot of challenges related to the required Iridium per Gigawatt (GW), but since technology is novel, improvements are expected and will release some stress on the market [22]. Recycling of catalysts and electrodes is common and relatively straightforward. The display market may see a rise in price for Iridium, but the community should trust that the PEM electrolysis market will develop and improve, reducing their own demand.

CONCLUSIONS

Each critical material has its own issues and may affect the display market's supply chain differently. Cerium's supply chain has been challenged over the years, but it is now stable both for primary and secondary sources. Its low price and quotas will most likely impact its value. For Gallium, the current trade war between the US and China raised the price and created supply chain challenges. Compound semiconductors have been affected by these events, but they are nonetheless moving along, generating solutions. The display market has much lower consumption and should see a limited impact. Indium, or ITO, is highly critical to the display market. The current price spike is temporary and influenced by futures. China centralized ITO manufacturing and recycling, which could impact the supply chain if the trade war expands. Finally, Iridium is already scarce and will see its demand increase over the year to support decarbonization of the energy industry. Technological improvements are required in the PEM electrolysis market to limit high demand of Iridium which would impact the whole supply chain.

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