Capacity Issues in the Material Supply Chain

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Abstract

Since early in 2000, GaAs device manufacturers and epitaxial foundries have encountered difficulty procuring substrates needed to meet production requirements. Wafer suppliers acting to remedy the shortage have invested in new capacity but now find that the worldwide supply of gallium does not meet demand. With gallium in short supply, prices have risen sharply. GaAs substrate prices have also increased. This paper examines the nature of material shortage and the prospects for the coming year.

Introduction

The GaAs device industry depends on an adequate supply of single crystal wafers, and the wafer manufacturers need high purity gallium and arsenic to grow crystal. The supply of arsenic is large relative to the consumption used for GaAs devices, with much of the world's arsenic production used in the treatment of lumber for preservation. High purity arsenic, however, is produced only by Furukawa in Japan and Metaleurop PPM of Germany. By contrast, approximately 95% of the world's supply of gallium is used for the production of compound semiconductors.

With the rapid growth in compound semiconductors, tight capacity of materials and the associated price increases have become a source of concern for device manufacturers. A rapidly growing market for cellular handsets created strong demand for components, and that demand has propagated through the material supply chain. Expansion of the supply of these materials requires investments in plant and equipment by industries that have not seen consistent returns on past investments.

Leadtimes for capital investment in crystal growth

The majority of GaAs crystal in production today is manufactured by either a variation of the Cz method, liquid encapsulated Cz (LEC) or by one of the vertical growth techniques, vertical boat (VB) and vertical gradient freeze (VGF). Leadtimes for most of the capital equipment used in crystal growth and wafering is typically on the order of 4-6 months. However, most of the LEC crystal growth processes use high pressure chambers, for which extensive safety testing is required. These high pressure chambers require longer leadtimes (close to one year). The longer leadtime for high pressure LEC has important implications for capital equipment planning. It takes considerably longer to correct an undersupply situation and increases risk for new investment. This longer leadtime for high pressure LEC equipment has greater impact on the production of ion implanted devices, which use a higher proportion of LEC grown crystal.

Market Trends and the Wafer Shortage of 2000

The wafer shortage of 2000 began with the transition to six-inch GaAs. In the 2nd half of 1999, six-inch substrate prices fell near $400/pc. As the market moved into 2000, some wafer vendors continued to experience lower than expected six-inch yields. The combination of low prices and yield problems made short term prospects for profitable business poor, and led to slower investment in new six-inch production equipment.

Capacity investment for 4 inch GaAs in 1999 and 2000 followed expected trends in the device market. Many major device manufacturers were converting to 6 inch or making plans for conversion. Handset power amplifiers were using higher proportions of HBT and PHEMT devices. Investment in new 4 inch wafer capacity focused on the low dislocation density materials (VB, VGF) often preferred for epitaxy. Flexible LEC capacity shifted from four inch to six production. While capacity for four inch VB/VGF materials continued to grow, it is believed that the worldwide capacity for four inch LEC declined in 2000.

New Investment in Wafer Manufacturing Capacity

Most of the major substrate manufacturers responded to the wafer shortage with massive new capital equipment and several new production facilities.

- Sumitomo Electric announced new production facilites in Yokohama, Kobe, and Hillsboro, Oregon. The company will increase from 27,000 4-inch equivalent wafers per month in late 2000 to 58,000 wafers per month by the end of 2001. Current plans for 2002 are to increase capacity further to 73,000 4-inch equivalent wafers per month.

- Freiberger's 2001 capacity will increase 70% over 2000 capacity. In 2002, 6-inch capacity will be 260,000 wafers per year. This will include 36,000 6-inch VGF wafers. 4-inch wafer capacity in 2002 will be 150,000, including 35,000 VGF wafers. The company will invest $65 million in plant and equipment in 2000-2002.

- Hitachi Cable announced a 130% expansion in 2001 to a total production of 45,000 4-inch equivalent wafers per month.

- AXT has announced an expansion of their facility in China to be completed by October 2001.

- Airtron was able to convert much of its 4-inch LEC capacity to 6-inch production. The company declined to comment on capacity expansion.

Capacity for four and six inch wafers is expected to be more than adequate to meet market needs in 2001 and beyond. In 1999 and 2000, the handset market grew in excess of 60% for two years consecutively, but considerably slower growth, on the order of 20-30%, has been projected for the handset market in 2001. By contrast, merchant demand for semi-insulating wafers increased 20-30% per year by area in 1999 and 2000, and most of the major substrate manufacturers have announced capacity increases of 70% or more for 2001.

Although the shortage in wafer manufacturing capacity has been corrected, there will continue to be supply issues.

- Availability of gallium will limit the ability of substrate manufacturers to fill new capacity throughout 2001.
- Capacity will continue to be tight for two and three inch wafers. New capacity for the smaller diameter wafers has been minimal and demand is growing.
- Inefficiencies in distribution and preferences for specific suppliers or type of crystal are expected to produce pockets where supply will be inadequate.

Gallium Shortage

Worldwide capacity for gallium is not adequate to meet the needs for newly constructed wafer capacity, and gallium prices have risen sharply. Table 1 shows gallium extraction plants around the world. Some capacity expansion for extraction is underway, notably at Great Wall Aluminium in China. Planning for additional new sources of gallium is know to be underway, and announcements are expected.

Table 1
Worldwide Gallium Extraction Capacity, 12/2000

Primary Producer (extraction)	Capacity Tons/yr
GEO Gallium (Germany)	30
Pavlodar Alumina (Kazakhstan)	20
Dowa Mining (Japan)	20
Pikalevo Alumina (Russia)	10
Shandong Aluminum (China)	8
Hungarian Aluminum Co.	8
Slovakian Government	8
Great Wall Aluminum (China)	6
Nikolayev Alumina (Ukraine)	5
Other , Russia	9
Other, China	6

Source: USGS

Newly extracted gallium accounts for less than 50% of the material used for GaAs crystal growth. Recycling of gallium has long filled the gap between demand and virgin gallium supply. Faced with the need to wait for new gallium extraction capacity to materialize, substrate manufacturers have put substantial effort into increased recycling. At Sumitomo Electric, gallium recycling efforts have extended beyond our traditional recycling of waste ingot and broken wafer scrap. We now also routinely recycle sludges from slicing and polishing operations. Substrate manufacturers have also increasingly been approaching device manufacturers to purchase gallium containing scrap, including broken wafers, sludge from wafer thinning and waste from epitaxial source material. We estimate that we internally recycle 40% of the gallium used for crystal growth, retrieving an additional 20% of gallium from device manufacturers. Additional efforts may allow an additional 20% of the starting material to be reclaimed, bringing the total to near 80%.

Table 2
Worldwide Gallium Purification Capacity, 12/2000

Purification Company	Capacity tons/yr
Dowa Mining (Japan)	50
Sumitomo Chemical (Japan)	35
GEO Gallium (France)*	30+
Other (Japan) *	36
Recapture	9
Eagle-Picher	7

Source: USGS & *internal estimates

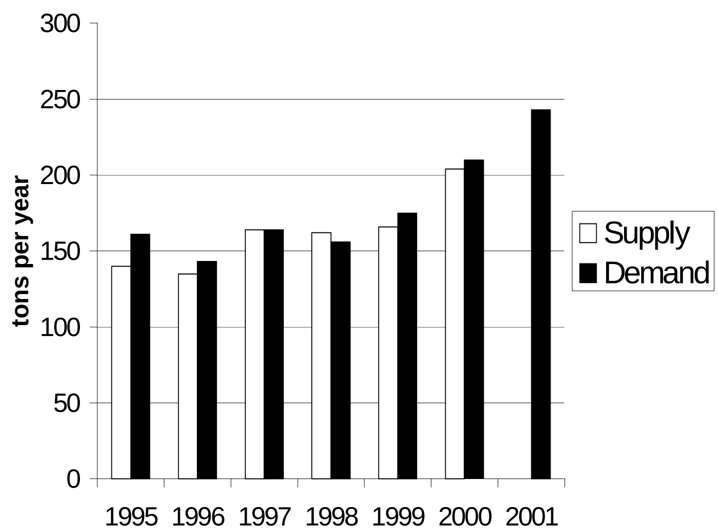

Figure 1. Gallium Supply & Demand, 1995-2001
Source: Kinzoku Jihyo

Mercifully, the severity of the gallium shortage will in part be mitigated by the softness in handset sales in the first half of 2001.

Managing the Supply Chain in a Turbulent Market

The recent wafer capacity tightness has been followed by the inevitable pleas for improved forecasting. It is certainly necessary to continue to improve the communication between device and material manufacturers. Wafer manufacturers must keep current on trends in handset and other end markets, as well as technology changes at the device level. However, it is also necessary for us to approach management of capacity with an understanding of the nature of high technology markets. Product life cycles are short. Product introduction and rapid growth are often followed closely by decline with little or no period of product maturity. These characteristics can be seen in handset markets. To better serve a market with these characteristics, wafer manufacturers need to improve their speed of reaction to market changes. Sumitomo Electric has re-directed its crystal growth strategy from high pressure LEC to VB in part to shorten lead times for new capital investment. We have also shifted our six-inch polishing lines to single wafer polishing, allowing us to add capacity incrementally. While there are quality improvement and cost reduction benefits from these technology changes, we also realize the value of being able to react more quickly to the needs of the market.

Conclusions

The shortage in wafer capacity is no more; an end to the gallium shortage is not yet apparent. With gallium in short supply, the industry needs to focus on doing more with less. Both wafer and device manufacturers will need to further intensify recycling efforts and work on yield improvement to offset material price increases.

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