GaAs Foundry: Challenges and Future

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Abstract

Since entering the GaAs industry in 1999 as a pure-play wafer foundry, WIN Semiconductors' rapid and sustained growth has confirmed that the pure-play foundry model can meet the diverse requirements of the RF/microwave markets, just as this model has worked for the Silicon industry. With over 25% of worldwide GaAs ICs now produced at foundries, outsourced manufacturing of GaAs wafers has become an indispensable link in the global RF/microwave semiconductor supply chain. It is anticipated the share of GaAs wafers produced at foundries will continue to grow along with the increasing demand for mobile content delivered to more and more smartphones and tablets, each with increasing GaAs content per device. In this presentation, the challenges and future opportunities for GaAs foundries will be discussed from various perspectives including technology, manufacturing, applications and end markets.

INTRODUCTION

The pure-play IC foundry business model started in 1987 with the establishment of Taiwan Semiconductor Manufacturing Company (TSMC) initially for the silicon CMOS logic market, and eventually blossomed in 2012 to a $40B industry. WIN Semiconductors pioneered this same pure-play business model in the GaAs RFIC/MMIC industries in 1999, at time when the majority of GaAs component manufacturers exclusively relied on internal wafer fabrication. At the time of WIN's entry into the market, established device manufacturers offered GaAs foundry services as an ancillary business line intended to absorb excess capacity in periods of low internal wafer demand. This tactical view of the foundry business resulted in significant business risk to the customer chain, as there are many instances of GaAs fabs either constraining supply as a result of capacity limitations, competitive considerations (i.e. the company competes with its foundry customers at the product level) or, worst case, exiting the foundry business entirely. Furthermore, the industry viewed GaAs technology and processes as having too many variants to enable a pure-play foundry provider to address the diverse product requirements of the entire industry. The emergence of WIN Semiconductor as a credible, high volume supplier changed these perceptions.

PRESENT SCALE OF THE GAAS FOUNDRY INDUSTRY

Soon after WIN Semiconductor established the pure-play foundry option for the GaAs industry, the RFIC/MMIC market entered a period of spectacular growth driven by the proliferation of mobile handsets, Wi-Fi and most recently by the broad adoption of smartphones and associated demand for rich mobile content (i.e. video). The growth in the GaAs component market is illustrated in Fig. 1, which shows the annual sales levels for devices, foundry services as well as the revenues recorded by WIN Semiconductors from 2002 to 2012[1].

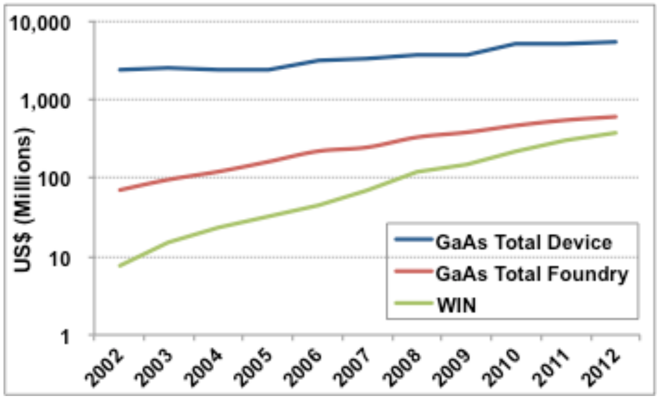

Figure 1 Worldwide GaAs Device Sales and GaAs Foundry Revenue (Source: Strategy Analytics)

Fig. 1 shows that from 2005 to 2012, total GaAs IC device revenue grew at an average annual growth rate of 12%, from $2.6 billion to $5.9 billion, and is quite robust in comparison to the 4% growth rate for the silicon IC industry over the same time period. Additionally, the chart shows that the 2002-2012 average growth rate for GaAs foundry was 21%, far greater than the 8% average annual growth rate for the overall GaAs IC industry and confirms that device manufacturers are choosing to source an increasing percentage of their GaAs wafer needs from external foundries. This figure also shows the rapid growth of WIN Semiconductors, which had an average annual growth rate of 48% from 2002 to 2012, and is now the dominant player in the GaAs foundry market, with approximately 60% market share.

VALUE OF THE PURE-PLAY FOUNDRY MODEL

As discussed above, GaAs foundry services have become an important and indispensible element of the global supply chain for the GaAs products that many markets rely on. The availability of pure-play foundry capacity and access to unrestricted process technology options provides customers with new levels of business flexibility, allowing GaAs component suppliers to adopt several manufacturing models, from hybrid (wafers both insourced and outsourced), to asset lite or completely fabless. This is unique to the pure-play model as only this approach provides a stable and reliable source of GaAs technologies *from a foundry that does not compete with its customer*.

Historically, GaAs device manufacturers owned their wafer fabs, which have large capital requirements and high fixed costs. To provide added overhead absorption, these companies routinely established foundry business lines to sell some of their excess wafer capacity to external customers. This arrangement can (and did) create substantial business risk as the foundry customers often developed competing products for the same markets as those offered by their GaAs wafer supplier. Clearly, when faced with the choice of enabling or damaging a direct product competitor (who is also a foundry customer), the fab owner will always make the choice that favors their internal business objectives over those of the competitor/foundry customer. There are many examples where, for competitive reasons, access to fab capacity and/or differentiated GaAs process technologies have been curtailed or restricted for "external customers" and in extreme cases, supply relationships have been terminated. Even when product-level competition does not exist between the wafer foundry and customer, during periods of peak fab-loading competition for available capacity can create a similar business conflict. The inevitable result is that excess fab capacity sold to an external foundry is reallocated to internal product needs resulting in long and unpredictable cycle times. Clearly, this arrangement creates an unacceptable level of business risk, and is made more acute by the overall growth in the GaAs device market as demand for these products are now dominated by large consumer/infrastructure product companies (manufacturers of smartphones, tablets, Wi-Fi and network gear) and the consequences of a supply disruption are typically quite severe and long-lasting.

The emergence of credible pure-play GaAs foundries, led by WIN Semiconductors, completely eliminates the potential business conflict due to foundry-customer/foundry-supplier competition at the product level. The pure-play model clearly establishes the foundry as a provider of fab capacity and GaAs process technology, and not a supplier of RFIC/MMIC *products*. This clear delineation also enables the foundry to achieve greater manufacturing scale and offer its complete portfolio of transistor platforms (HBT, pHEMT, BiHEMT etc.) and technology options (enhanced moisture protection, Cu pillar bumps) to all customers, providing the maximum flexibility to design, develop and commercialize highly differentiated GaAs-based products.

Furthermore, GaAs product companies that utilize external foundry services gain a long-term business advantage in that these companies are not burdened with the capital requirements, R&D investment and fixed overhead costs associated with wafer fab ownership. For the foundry customer, the cost of the outsourced wafer becomes entirely a variable cost, which is incurred only as wafers are needed. The variable nature of this cost avoids the fixed overhead and depreciation expenses associated with fab ownership. This model has multiple benefits for the entire range of foundry customer demand levels, from 10s of wafers to 10s-of-thousands of wafers per year. For low volume customers (tens of wafers per year), fab ownership is simply not economically feasible, yet this customer accesses the benefit of manufacturing scale and years of technology investments made by the pure-play foundry, accessing the highest performance technologies to support their markets. For the high volume customer, the pure-play foundry provides installed capacity that can be accessed quickly during periods of peak demand while avoiding the profit draining fixed/overhead costs during periods of low wafer requirements. The adverse profit impact of under-utilized wafer fabs can be readily observed in the recent financial reports of several companies in the RFIC/MMIC industry.

Finally, as a true sign of GaAs industry maturation, the availability of competitive/superior GaAs technology on a foundry basis has leveled the playing field for all the product companies in the GaAs device industry, and now places a premium on innovation at the product level. Just having a fab with good technology is no longer a differentiator and the real value to the end customer lies in the product, who is technology agnostic. This is the model that enabled the silicon microelectronics industry to grow to an unprecedented scale, and GaAs is following that same path.

CHALLENGES

Pure-play foundries face ongoing challenges in the areas of operations and technological competition, and like any successful business, must continually invest, evolve and adapt to remain competitive.

In the operations area, the GaAs wafer foundry is often confronted with large, unforecasted fluctuations (both up and down) in customer demand. In both situations, production levels have to be adjusted and, in the event of a demand ramp, factory output has to respond in time to satisfy customer deliveries. The nature of the markets served by WIN Semiconductors is extremely competitive, and usually every PA or Wi-Fi socket in a smartphone or tablet is at least dual sourced. Thus when handset production increases, the product demand must fulfilled otherwise the shortfall will be immediately made up by the alternative product supplier. In most cases, the shortfall quantity cannot be made-up on future deliveries and the associated revenue is lost.

Acknowledging this market dynamic, along with the inherent shortcomings of customer forecasts, WIN Semiconductors has always chosen to strategically add capacity while constantly increasing operational efficiency, improving yields and reduce cycle times such we are able to react to nearly every customer demand spike and meet our customer's requirements. This approach requires a significant financial and operational commitment to the industry and can only be achieved though adequate business and manufacturing scale, as well as operational discipline. Furthermore, our broad customer base provides a deep view into the global GaAs device market, enabling WIN to evaluate trends and rapidly recognize technology and market shifts, altering our investments in such a manner as to never constrain our customer's ability to deliver products or address a new product opportunity. Additionally, our sheer scale and majority share of the GaAs foundry market is a result of a broad customer mix, and provides a high level of revenue diversification to keep our fab running efficiently even during the seasonal low periods for consumer markets.

Technological challenges faced by GaAs Foundries are twofold; First of which is that foundries must continue to invest in device and process technologies that enable customers to rapidly develop and produce new products to meet the ever increasing performance demands of the mobile data transport market. Global mobile data traffic increased 70% in 2012, and the availability 4G services and compatible handsets will drive even greater increases in data consumption. Figure 2 illustrates a recent projection by Cisco Systems, that predicts monthly global mobile data traffic growing from 0.9EB to 11.2EB (1EB=10^{18} bytes) by 2017, which is a 66% CAGR in mobile data consumption! Furthermore, the majority of this data will take the form of video and be delivered over a 4G-enabled smartphone[2].

To support content delivery to/from these advanced mobile data terminals, GaAs process technology has to continually provide improved power efficiency, higher linearity and lower noise figure. In addition to meeting the performance requirements of 4G RF front-ends and Wi-Fi connectivity for smartphones, GaAs foundries also have to provide solutions on the infrastructure side with cost effective, ultra high performance technologies to enable high capacity backhaul networks operating at E-Band and above. These high data rate microwave radios will rely on production-ready advanced transistor technologies such as

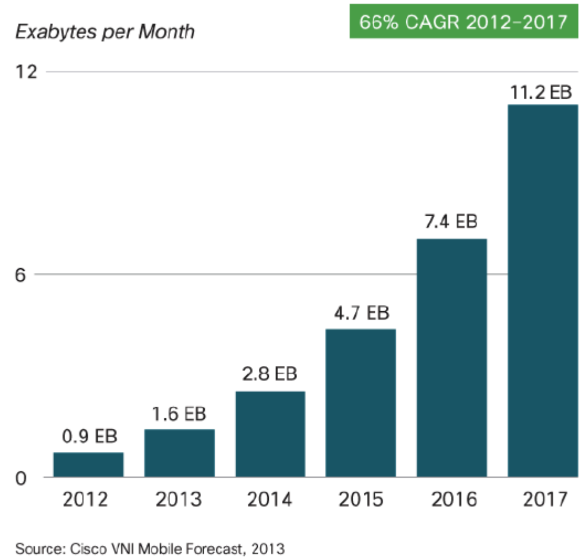

Figure 2 Global Mobile Data Traffic, 2012-2017

the WIN 0.1µm technology platform, PP10, which is the only production 0.1µm pHEMT available on 150mm substrates. Only a few GaAs foundries have achieved the requisite business size and manufacturing scale to address such diverse and demanding performance requirements across so many markets, as the capital and R&D investments required to do so exceed the capabilities of most companies.

The second technological challenge faced by GaAs Foundries is the threat posed by high performance RF silicon and SOI technologies as applied to various functions in the RF chain. The continuous improvement in the high frequency performance of silicon has been nothing short of remarkable, with SOI significantly eroding the market share of GaAs in the switch function, and RF silicon now being used to realize 2G and 3G power amplifiers. The continuous technological advancement of the established Silicon foundries certainly is a threat to GaAs's dominance in the RF front-end, however there is still an element of fundamental physics that favors GaAs technology for these functions. The higher electron mobility, and ability to leverage bandgap engineering of the materials system provides GaAs technology with more degrees of freedom to achieve superior power amplifier figures of merit (linearity, PAE, f_t*BV, etc.) and will help preserve GaAs as the preferred technology for 3G and 4G RF front-ends. As evidence of this outcome, Fig 3 shows the market share of GaAs and Si in the Handset PA function from 2000 through 2011 as published by Strategy Analytics[3]. Despite the advances in RF silicon technology, the share of Si handset power amplifiers *has actually declined* over time, from more than 20% in 2000, to ~5% in 2011. There are many reasons for the erosion of Si share of the handset PA, and it is likely that Si will serve the most cost effective solution for the 2G PA that provides backward compatibility for most handset.

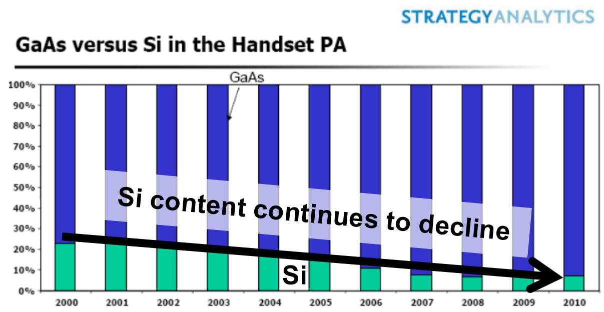

Figure 3. GaAs and Si handset PA share

As was stated above, the mobile user is consuming more and more data and this will be delivered over a high data rate network to/from 4G handsets that will rely on the most advanced power amplifier available. For smartphones and tablets to operate on these 4G networks, delivering rich content to the user, the performance benchmark is set very high and favors GaAs devices as they provide the most cost effective high performance solution for this critical function.

FUTURE

Similar to the last decade, the increasing demand for rich mobile content delivered over high-speed networks will drive continued growth in the GaAs device market. Returning to the Cisco Global Mobile Data Traffic Forecast, smartphone data consumption will continue to dominate data traffic and account for more than 67% of all data on the mobile Internet in 2017 (Fig 4). Furthermore, Cisco envisions much higher rate of data consumption for a 4G connection, accounting for 45% of data traffic, while only

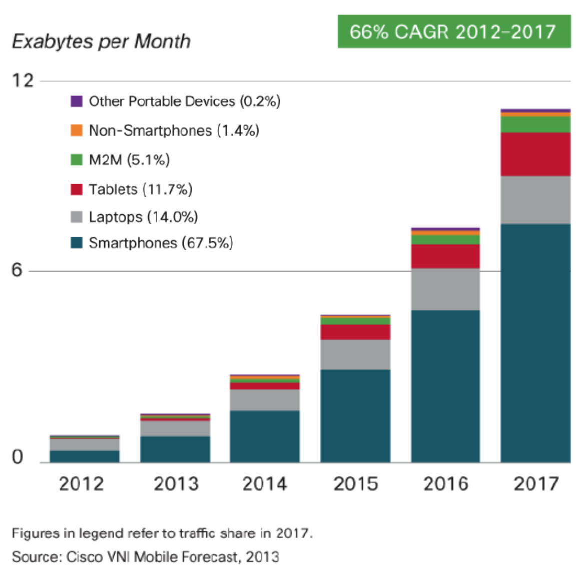

Figure 4. Projected mobile data consumption by device

comprising 10% of mobile connections. This certainly makes sense that, as a user with high-speed access (approaching 1 Gbs) will consume rich content (i.e. video) at an increasing rate and likely will be the users primary Internet connection.

This projected increase in data traffic will be enabled by continued advances in GaAs process technology to meet the increasing requirements for mobile data delivery at high speeds. From the optical components that drive data through fiber at 100Gbs, high bandwidth microwave radios to deliver content to/from the wireless infrastructure, to advanced highly linear and efficient power amplifiers for the RF front-end module and next generation Wi-Fi networks, GaAs foundries will be relied upon to develop the transistor technologies to meet the more stringent requirements of next generation transmission standards across the entire infrastructure. Additionally, as these transmissions standard evolve to incorporate additional bands and faster speeds, the number of power amplifier per cellular terminal is expected to increase. The combined growth in mobile terminals sold, and more GaAs devices per terminal, present an opportunity for significant increase in demand for the pure-play foundry capabilities and capacity.

CONCLUSIONS

The pure-play GaAs foundry market continues to grow faster than the overall GaAs device industry and is now an integral part of the global supply chain for demanding RF components used to deliver mobile content to the consumer. Pure-play foundries provide every customer with reliable access to a large installed wafer capacity and world-class technologies used across all product functions. The pure-play model clearly establishes the foundry solely as a wafer supplier and eliminates business risks associated with competition at the product level. Furthermore, these foundries led by WIN Semiconductors, enable a level of business and manufacturing scale that is necessary to drive the capital and technology investment required for high performance, cost effective RF solutions for the entire industry.

REFERENCES

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[3] Strategy Analytics RF Power Amplifier Report

ACRONYMS

BiHEMT: Bipolar and High Electron Mobility Transistor
CAGR: Compound Annual Growth Rate
HBT: Heterojunction Bipolar Transistor
MMIC: Monolithic Microwave Integrated Circuit
PA: Power Amplifier
pHEMT: pseudomorphic High Electron Mobility Transistor
RFIC: Radio Frequency Integrated Circuit
Wi-Fi: Wireless Fidelity