Current Developments in Epi Foundry Services for Advanced Wireless Applications

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Abstract

The wireless industry continues to grow strongly in terms of its size, breadth of applications and its penetration. As it matures it is also undergoing significant structural change, with a strong move toward the use of outsourced foundry services. This paper explores the current developments relating particularly to epi foundries and how they are continuing to help drive both efficiencies and materials technology alike, to the wider benefit of the wireless industry.

INTRODUCTION

Over the last decade the wireless industry has grown very strongly, driven by the explosion in mobile communications, and a wide diversity of other applications. The top ten wireless chip companies now have combined annual revenues of over US$6 billion. As it has matured, the indiustry has undergone some significant structural change, moving in the direction of more mature industries where outsourcing and focus on more efficient industrial manufacturing strategies becomes the norm. In particular, the last decade has seen the growth of Compound Semiconductor Chip Foundries, in much the same way that the Silicon Industry developed in the 1990's with the rapid evolution and eventual dominance of Chip Foundries such as TSMC, UMC, Chartered Semiconductor and Global Foundries. However, unlike the Silicon industry, where epitaxy is not a key step in the chip manufacturing process, the wireless industry has also seen very strong growth in foundry services for epitaxy, which is a critical step in the manufacture of compound semiconductor wafers for wireless devices and chipsets.

WIRELESS INDUSTRY STRUCTURE

Initially, the wireless industry was dominated by vertically intregrated device companies, such as RFMD, Alpha, Conexant, Avago and several Japanese companies who had the full vertical chain from epitaxy through to full chip processing. However, as the inexorable downward pressure on pricing became more intense, driven by consumerisation of the end markets, companies were forced to look at the cost efficiency of their manufacturing strategies and determine the appropriate balance between in house pre existing IP, ongoing materials development costs, capital spend allocation between epitaxy and chip manufacturing (their core competency), and fab utilization. This has led to a highly significant change in the overall structure of the industry today, where most epitaxy is now done by dedicated outsourced epi foundries, and a number of significant outsource chip foundries have emerged, particularly in Taiwan, following the successful Silicon Chip Foundry model of TSMC and UMC.

The key drivers behind such moves can be summarized as follows;

Epi Foundries

When a chip company uses only internal epitaxy, although it has full control of the epi process and the output, the company must bear the entire overhead of the epitaxy unit on its own. As end demand, and therefore epi tool utilization fluctuates, the manufacturing cost of the epi (a significant part of the end chip cost) also fluctuates. When the epi plant is fully utilized, the epi cost is low, when the epi plant is only partly utilized, the epi cost can be very high, leading to a rapid deterioration in the competitiveness of the vertically integrated company. In addition, the vertically integrated chip company must bear all of the development costs of new materials structures, and bear all the capital costs of installing new epi tools. Since each new epi tool delivers a discrete amount of capacity (and potentially quite a large amount), it is inevitable that the vertically integrated company will ALWAYS have under utilization of its resources. When the new tool comes on line, only a portion of the capacity will be used, and until demand is such that the tool becomes heavily utilized, (and another new tool has to be installed), the vertically integrated company will always be investing significantly ahead of when it can fully utilize epi equipment.

On the other hand, epi foundries serve many customers and can therefore make much more efficient use of their capacity and resources, leading to lower epi costs. In addition, since it is (generally) their sole focus, the development costs of new materials can be spread over potentially many customers and many applications. The larger epi foundries also have significantly more purchasing power for raw materials, such as substrates, OMs and metals than a vertically integrated chip company would have, and because of the focus of their business on epi production, are in a much stronger position to work with epi tool companies to further develop the capabilities and improve the throughput of their epi tools. In

Table 1: Structure of Wireless Industry

Epi Foundry	Chip Foundry	Module manufacturers	Systems Users
IQE	WIN Semiconductors	RFMD	HTC
KOPIN	AWSC	SKYWORKS	NOKIA
VPEC	GCS	ANADIGICS	SAMSUNG
HITACHI	Wavetek microelectronics	TriQuint Semiconductor	BlackBerry
SUMITOMO ELECTRIC		M/A-COM	MOTOROLA MOBILITY
IntelliEPI		Avago Technologies	Sony Ericsson
EPIWORKS		Panasonic	SIEMENS
Picogiga		RENESAS	LG
		TOSHIBA	BROADCOM
		SONY	ALCATEL
		Eudyna	SANYO
		MITSUBISHI ELECTRIC	BenQ
			HUAWEI
			FUJITSU
			QUALCOMM
			intel

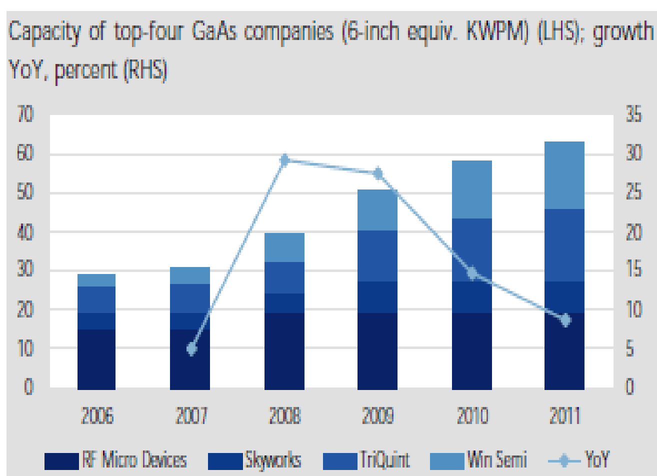
all, this makes the epi foundries a very attractive alternative to in house epi manufacture, allowing the chip companies to not only avoid the capex and R&D expenditure on epi, but are also able to exactly match their external epi purchases to their internal wafer demand. Overall, this leads to a much more cost effective and efficient approach than in house manufacture of epi by vertically integrated chip manufacturers. It is therefore hardly surprising , given these clear benefits, that most wireless chip companies have chosen to outsource their epi production and development to the larger epi foundries.

Wireless Chip Foundries

There has also been a very strong growth in the wireless chip foundry space, where a number of significant players have emerged, following the highly successful models of TSMC and UMC. In fact recently UMC have set up a subsidiary company WaveTech, to concentrate on GaAs Chip Foundry Offerings, in part to utilize smaller diameter wafer processing equipment (e.g.150mm), as the Silicon industry moves to ever larger wafer diameters. The other major GaAs Chip Foundries, such as WIN Semiconductor and , AWSC are also located in Taiwan, in addition to TriQuint, GCS and other smaller players located around the globe. The key drivers for the emergence of the GaAs chip foundries are for fabless chip design houses to make wireless chipsets, in addition to existing wireless chip manufacturers making efficient use of external foundries to ensure their own fabs are running at full capacity, and therefore at the lowest cost point. However, some IDMs consider their own chip IP to be so critical that not all use this route. Table one shows the current structure of the wireless chip industry, together with the major player in each segment.

Figure 2 below illustrates how quickly the largest of the Wireless Chip Foundries has grown relative to some of the other chip companies. Note that between them, the four companies below are estimated to have a wafer capacity of over 60K 6” wafers per month in 2011, or over 720K wafers per annum

Figure 2 : Capacity of top four wireless chip manufacturers



Source: KGI Research

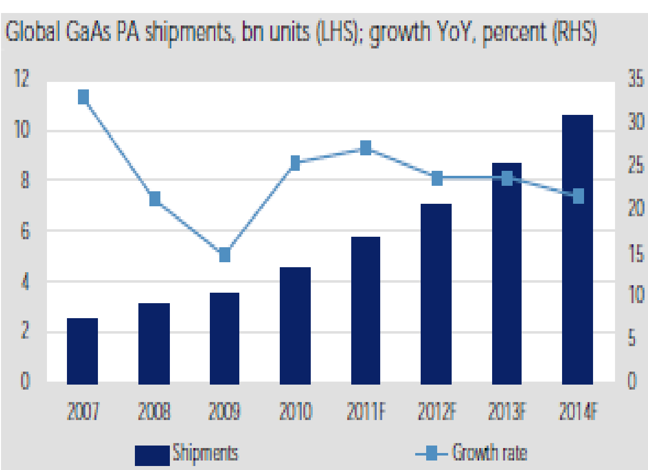
GROWTH DRIVERS

There are multiple growth drivers propelling the wireless industry forward, including mobile communications, satellite communications, point to point communications, airborne, naval and ground radar, electronic warfare, cable TV, digital video broadcast, Very Small Aperture Terminals (VSAT), portable radio, industrial, scientific and medical, smart metering, to mention just a few.

In terms of volume however, the largest is clearly the dramatic increase in the use of mobile handsets and WiFi applications.

Compound Semiconductors are used almost exclusively today in the RF Front End Modules (FEMs) of handsets, which provides the device with its key communication abilities. The key devices used here are Heterojunction Bipolar Transistors (HBTs) for power amplifiers, Pseudomorphic High Electron Mobility Transistors (PHEMTs) for Low Noise Amplifiers (LNAs) and switches to switch between different communication bands, Field Effect Transistors (FETs) for circuit control, and BiHEMTs/BiFETs which are combinations of the aforementioned devices. As the industry moves from 2G to 3G and 4G/LTE, the number of devices per handset increases substantially due to two factors (1) phones need to be able to communicate over many more frequency bands for both backward comparability and because the newer technologies operate over more bands worldwide, and (2) the most recent handsets have much more in built functionality for GPS, WiFI, WiMAX, radio etc. As an example, simpler GSM phones have less that $1 of front end content, typically a small number of PA,s and simple switches, whereas the most advanced 4G handsets now have over $10 of compound semiconductor content and multiple numbers PA's, LNA's and complex switches. This is driving a rapidly growing demand for compound semiconductor devices as illustrated by figure 3.

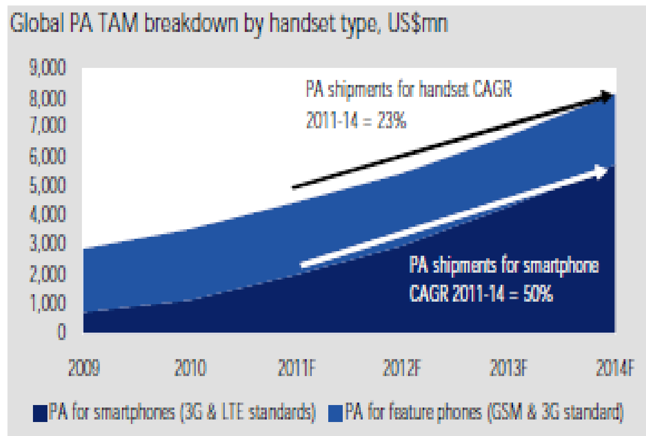
Fig 3 Global GaAs PA Shipments



Source: KGI Research

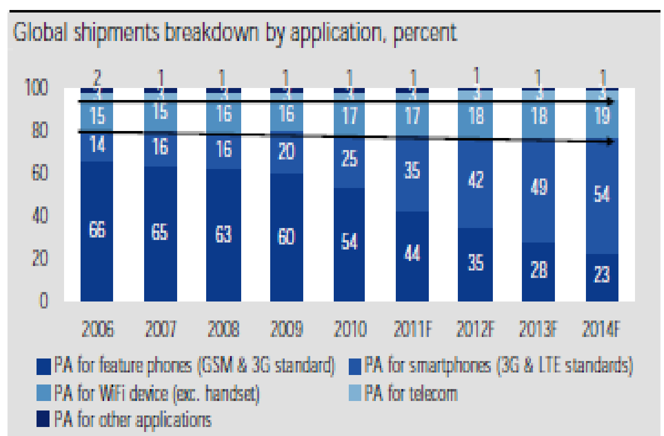
This growth is represents almost 50% compound per annum, much larger than growth in handsets. Figures 4 and 5 below show the growth in PAs vs handsets but also demonstrates how the recent introduction of 802.11ac standard, which uses many more PAs than existing WiFi standards will impact PA growth.

Fig 4 Global Market growth for PA by handset type



Source: KGI Research

Fig 5 Global PA shipments by application



Source : KGI Research

MATERIALS AND DEVICES

As the wireless industry continues to grow and find new applications, so the number and variety of devices increases, with ever increasing demands placed on the performance of these devices and circuits. This in turn demands much tighter degrees of tolerance on the epitaxy process, and the continual evolution and application of new materials from which to make these devices. Figure 6 shows the breadth of applications and the technologies required to service them.

Figure 6 Applications, Materials Technology and Devices used in Wireless Industry

Application		Materials Technology					Device Technology			
		Si	SiGe/SOI	GaAs	GaN	TWT	HBT	pHEMT	BiFET	FET
Smart phones	RF		■	■			■	■	■	■
GSM/3G Handsets	RF		■	■			■	■	■	■
WiFi	RF		■	■			■	■	■	
WiMax	RF	■		■	■		■	■	■	
Cable TV line Amplifiers	RF			■	■		■	■		■
Cellular base station , Mast mounted PA for	RF	■			■		■	■		■
Collision warning radar	RF		■				■	■		■
Digital video broadcast	RF	■			■	■		■		■
EW / ECM	RF			■	■	■	■	■		■
industrial scientific, medical	RF			■	■			■		■
Microwave Radio	RF			■	■			■		■
Military Civil Radar	RF	■						■		■
Military Phased array Radar	RF	■		■	■	■		■		■
point to point links	RF	■		■	■	■	■	■		■
portable radio	RF			■	■			■		■
Satellite: Earth observation, / telecoms	RF			■	■	■		■		■
Very Small Aperture Terminal (VSAT),	RF			■	■	■		■		■

EPITAXY TECHNOLOGIES

The two most common technologies used to produce Compound Semiconductor materials for the wireless industry are MOCVD (Metal Organic Vapour Phase Epitaxy) and MBE (Molecular Beam Epitaxy). Generally, MOCVD has been the main technology for producing HBTs, because of its perceived advantage for growing thicker structures more quickly (higher growth rate), and MBE has been the most effective technology for producing PHEMTs, due to its ability to grow thin layers more accurately. However, there are many exceptions to these rules and both technologies have been used to grow both of the main structures. Chip companies tend to stick to the technology they know and have developed their device processing platform upon, but with new and advanced technologies continually being developed, it pays to be flexible. Both technologies now have the capacity to produce 7x6" wafers per production run, so overall it then comes down to throughput per tool type and how individual epi companies run their own proprietary epi processes. Almost all companies concentrate on a single epi technology, although IQE is the exception, and has large production capacities of both MBE and MOCVD tools, in order to serve all customers irrespective of their personal choice of platform, and to be able to serve the multitude of materials and devices now demanded by the wireless industry.

The epitaxy process has been developed strongly over the last few years and now delivers previously unthought of levels of throughput and performance.

CONCLUSIONS

The wireless industry has matured and developed rapidly over the last few years, and has undergone some powerful structural changes. The industry is now heavily focused on cost reductions throughout the supply chain in order to support continual downward pressure on cost and improvement in performance demanded by consumers of wireless devices. This has resulted in the rapid growth of both epi foundries and compound semiconductor chip foundries. In particular, epi foundries are at the heart of the drive to deliver higher levels of throughput, across multiple materials technologies , and in conjunction with the wireless chip companies, continue to drive the performance of wireless systems in order to deliver innovative solutions to satisfy dramatic growth in existing markets,as well as find new applications in exciting next generation systems. Epi foundries are clearly here to stay and make a big impact on the future of the wireless industry.

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