GaAs Industry in Europe – Technologies, Trends and New Developments

Wolfgang Bösch

CTO Filtronic IP, Shipley UK, wolfgang.bosch@filtronic.com

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Abstract

Driven by the wireless handset market the GaAs industry has seen an immense growth in recent years. The wireless markets will continue to grow. In addition an emerging mmW market with applications in automotive, defense and optoelectronics will further drive the demand for GaAs components. The two biggest European GaAs foundries, Filtronic and UMS, are very well positioned to address globally the high volume low cost and the higher margin and more specialized niche markets. An overview of the process and design capabilities and new product developments of both companies is provided.

INTRODUCTION

The world-market for GaAs components is predicted to grow steadily for the next five years reaching $ 4.5b in 2010. The key drivers are the cellular handset and WLAN market characterized by low cost and very high volumes, next to the growing optoelectronic and mmW markets with higher margins but reduced volumes. Figure 1 shows the overall growth in GaAs devices forecasted recently by Strategy Analytics.

The European GaAs industry is very well prepared to address the high volume markets and also the more niche mmW markets that continuously are growing. The two biggest and dominant GaAs manufacturing companies in Europe are Filtronic and UMS. Their achievements, product portfolio and strategic positioning are discussed in the following paragraphs.

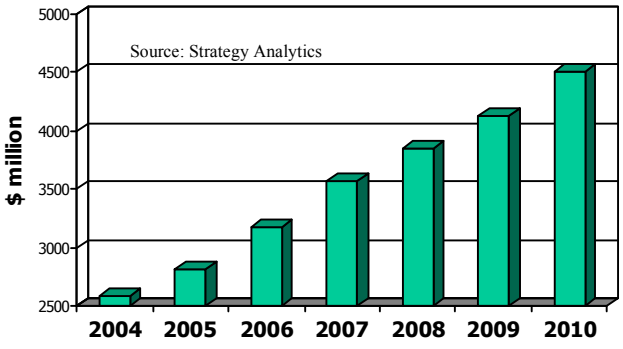

Figure 1. Global GaAs device market

FILTRONIC

Filtronic Compound Semiconductor Ltd. (FCSL) is a wholly owned subsidiary of Filtronic plc and operates from the Newton Aycliffe facility in the North East of England. The factory comprises a total of 310.000 square feet of which 100.000 square feet are clean room space capable of Class 10 air quality. Their highly automated GaAs manufacturing line is based 0.5µm and 0.25µm stepper lithography on 6" wafers. The supply of EPI substrates is secured by two in-house GEN2000 MBE tools and several external qualified suppliers. The business supports several pHEMT processes optimized for specific applications. FCSL is the biggest and the only 6" GaAs wafer fabrication site in Europe.

The worldwide market for wireless devices has been growing at an unprecedented rate. Within this year more than 1billion new handsets will be sold. The convergence of multiple services and functions into a single portable radio demands highly complex switches. Even though the complexity and functionality is increasing, the average selling price for handset microwave components is eroding year by year. Multithrow pHEMT switches are implemented in the majority of handsets meeting the performance and cost objectives for the required complex transmit/receive and band-select switching functions.

FCSL had recognized the switch business opportunity since long and has substantially invested in a high volume low cost pHEMT manufacturing line. Most challenging was the very steep ramp up of switch production volume in the last 24 months (Figure 2).

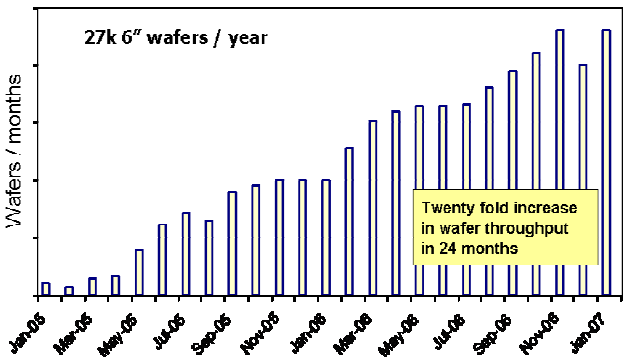

Figure 2. FCSL 6" GaAs wafer throughput

FCSL plans to level off their production capacity at the end of 2007. The high volume switches are manufactured on a 0.5µm pHEMT process, with an optimized number of layers, no VIAs and airbridges. Figure 3 shows the FMS2028, a SP6T switch for a quad band GSM handset application that is manufactured in many millions per months. The insertion losses are better than 0.5dB on transmit, TX-RX isolation is better than -40dB and the harmonic performance is better than 70dBc at transmit powers of 35dBm. The overall production yield is well above 90%.

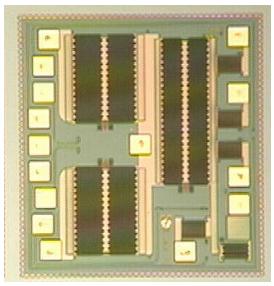

Figure 3. FMS2028, quad-band GSM - SP6T switch, 852 x 990 µm

FCSL is also focusing on other business areas to widen their product portfolio. Specifically they are addressing the wireless infrastructure market with integrated LNA gain stages, the military market with wide bandwidths and power products and the point to point market with transceiver chip sets; in addition they serve the merchant market with a selected product portfolio.

The designs cover applications from 1GHz to 40GHz and the products range from high power MMICs (10W @ 10GHz and 2W @ 38GHz), low noise figure MMICs (less than 1dB @ 2GHz and 3.5 @38GHz) and highly integrated MMICs.

In recent years the point to point radios for the cellular backhaul market have migrated from initial product offerings using discrete transistors, to a set of single function MMICs mounted in bare die form onto a soft substrate. The next step in the evolution is to replace the single functions by highly integrated multifunction MMICs (MFMMICs), mainly to reduce cost and size. Figure 4 shows an integrated receiver MMIC designed to operate between 17-23GHz. Five circuit functions (LNA, attenuator, driver amplifier, mixer and LO-amplifier) are integrated on a single die. In the future further cost savings for the point to point radios can be realized when mounting these MFMMICs into surface mount plastic packages.

FCSL has developed MFMMIC receive and transmit chipsets to cover all radio bands between 4GHz and 40GHz. A few years ago MMIC implementations of that complexity would not have been economical because of very poor line yields.

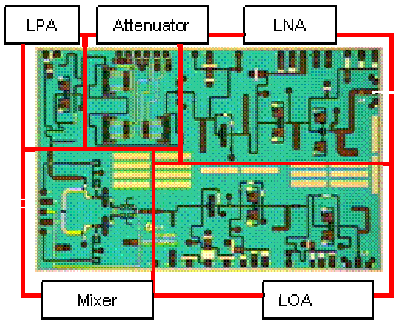

Figure 4. Highly integrated receiver operating between 17-23 GHz

There is an increasing demand for high performance GaAs technologies at mmW for military and commercial applications. Exploiting the low cost base and process stability of its volume manufacturing line, FCSL has recently developed 0.3µm and 0.15µm pHEMT processes.

The double delta doped 0.3µm pHEMT technology is based on an AlGaAs/InGaAs/GaAs structure grown by MBE on semi-insulating GaAs. The epitaxy has been designed to optimize output power, operating voltage and to reduce process sensitivity. The transistor has the maximum drain current of around 490mA/mm with pinch off voltage of –1V. The off-state gate drain break down voltage for the process is greater than 25V and a typical maximum stable gain (MSG) of 17dB at 10GHz with drain bias of 12V is achieved.

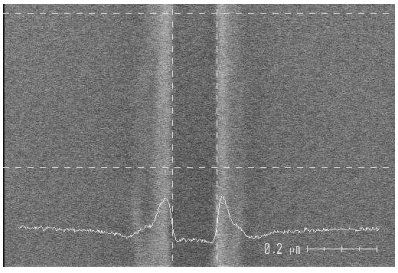

Figure 5. SEM image of the gate dimensions in resist before and after it has been shrunk to 128nm

Symbol	Parameter	Typical	Units
I_{DSS}	Saturated drain current	320	mA/mm
I_{MAX}	Maximum current	550	mA/mm
V_P	Pinch off voltage	-1.5	V
BV_{GD}	Break down voltage	-15	V
R_{ON}	On resistance	1.7	Ohm.mm
G_M	Transconductance (intrinsic)	640	mS/mm
F_T	Transition frequency	85	GHz

Table 1. Typical transistor characteristics from the 0.15µm process

Usually 3"or 4" wafer GaAs device manufacturing utilizing E-beam lithography is used to obtain the required performance mmW frequencies. FCSL is exclusively using optical stepper technology on 6" GaAs wafers for their pHEMT processes and has demonstrated superb performance on their new 0.15µm transistors. The gates are exposed with a deep UV stepper and then a spacer process is used to shrink the gate length to 0.15µm as shown in figure 5. The device fabrication uses a selective dry etch to define the double recess and to achieve uniform pinch-off across the wafer. Typical DC and RF data are summarized in Table1.

Large signal load pull measurements were performed on a 200µm FET at different drain biases. The devices were optimized for gain at the input and power at the output. With VDS=8V, the process is able to give PSAT of over 1W/mm which to our knowledge is the highest reported power from a 0.15µm GaAs pHEMT process. This is mainly due to the FETs ability to operate at 8V on the drain.

UNITED MONOLITHIC SEMICONDUCTORS (UMS)

United Monolithic Semiconductors (UMS) is a company equally owned by Thales and EADS Deutschland. The intention of the UMS foundation was the secured supply of GaAs and now GaN based electronics for the both mother companies. Since 1996 UMS supplies GaAs based MMICs and has based its success on the evolving markets of telecom and automotive and the general trend to higher frequencies and integrated MMIC based solutions replacing more and more hybrid module and system architectures.

Today UMS employs 220 people. In Orsay (France) the customer support, the product design, and the MMIC on wafer and in package testing takes place. The manufacturing is located in Ulm (Germany) in a 1000 m2 class 1-100 clean room. The wafer size is 4", which is well suited to supply the targeted niche markets. The high-resolution gate processes are performed with a mixed optical and electron beam lithography. In the frame of 2007 it is targeted to transfer the single recess technologies to a fully optical process to increase the throughput of the fabrication line.

UMS offers design and production capabilities based on various different in-house, as well as external fabrication processes. Since several years the evolution of the design experience of the company results in the ability to offer fully customized product solutions. Since 2006 the design expertise is also used to create products based on external SiGe processes. This is mainly driven by the predicted market increase for 24 GHz automotive short-range radar sensors and the need to reduce further more the cost basis. Therefore UMS will be also in future able to offer to their customers a competitive solution by combining different technologies with their inherent physical properties.

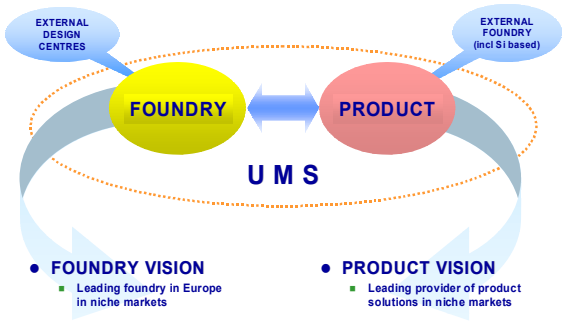

Figure 6. UMS business model showing the Foundry also accessible for external customers and the Product Line also using external processes including Silicon based technologies

Figure 6 shows the principle of the UMS business model. The foundry is used internally but is also offered to external customers providing access to most of the qualified technologies. The foundry offer includes fully scalable models. In 2006 the high number of 73 foundry runs was executed for various customers ranging from space to defense and commercial telecommunication.

UMS was one of the pioneers of microwave packaging. Meanwhile the product portfolio not only consists of bare dies but also of SMD packaged MMICs, that are easily usable in standard SMT lines. The frequency range was extended to 30 GHz and UMS is working on the next generation of standard plastic molded QFN packages, which will support frequencies up to 40 and more GHz. For the automotive 77 GHz long-range radar market multi chip packages containing complete Tx and Rx chains are available.

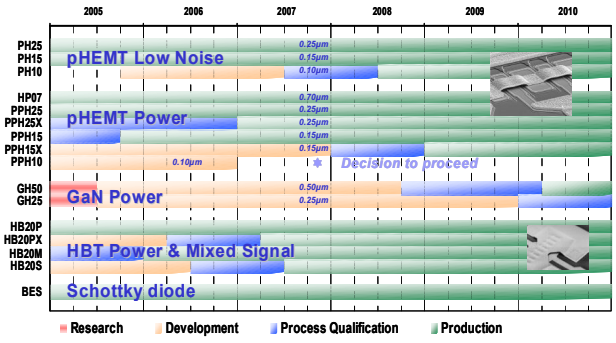

Figure 7. UMS technology portfolio. More detailed information can be found under www.ums-gaas.com

In Figure 7 the technology portfolio and the roadmap of UMS is shown. Besides the well-established low noise single recess technologies PH15 and PH25, various power technologies for different power levels and frequencies are

available. With the technologies HB20P (2 µm InGaP based HBT) and PPH25X (0.25 µm pseudomorphic HEMT) power levels up to 10 W in X-band are achievable. Examples are shown later in this paper. Since 2005 the development and industrialization of the GaN-HEMT technology takes place. It is decided to develop 2 different platforms (GH50 and GH25) for applications in defense, space and the base station power amplifier market.

Besides the strategic markets defense and space the main activities are in telecommunication and automotive. For the automotive market a fully MMIC based solution is available for long-range, so-called ACC radars at 77 GHz, as well as for 24 GHz short-range radars (SRR). UMS is in series production for ACC radars since 4 years for several OEMs and will start the production of 24 GHz SRR radar components in 2007 in high quantities.

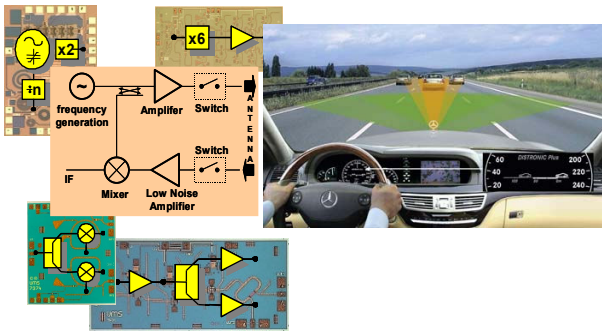

Figure 8. Typical line up of an ACC long-range radar at 77GHz based on UMS MMICs.

Figure 8 shows a typical line up of an ACC radar based on either pHEMT or HBT technology for the VCO and pHEMT technologies for the Tx chip. The mixer is designed on the Schottky diode technology BES, also available in UMS.

A recent development for the telecommunication market is a self-biased low noise amplifier that is optimized for the use in package. It covers a frequency range of 5.8 to 17 GHz, shows a gain value of above 21 dB with a noise figure of 1.6 dB. The supply voltage is 4 V with a current consumption of 80 mA.

In defense UMS is fully established in Europe. The different domains (radar, EW, communication and smart ammunition) are supplied with designs done by UMS or their customers and are based on the UMS technology platform. The different functions LNA, attenuator, phase shifter, driver and high power amplifier are available. Also the high integration of core multi function chips is achievable with very high yields based on the UMS technologies.

Figure 9 shows the performance of a X-band HPA based on the UMS HB20P (GaInP/GaAs) process. The MMIC includes a bias control circuit and a TTL interface on a chip size of 18.4 mm2. The design is very robust and allows an operation at 8 dB compression with a VSWR of 1.7:1 over a wide temperature range.

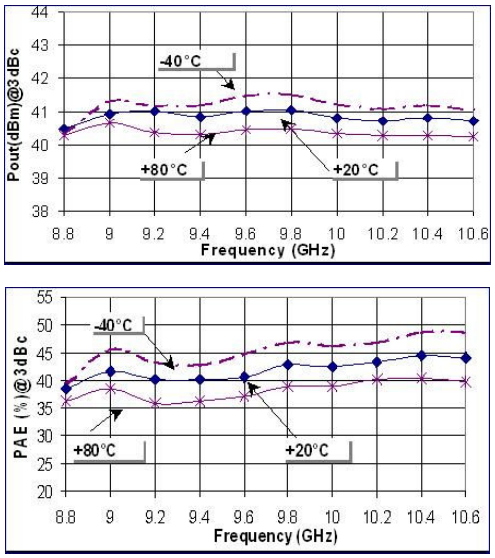

Figure 9. 11W output power X-Band MMIC for phased array applications. Output power and PAE for three ambient temperatures (-40, +20, +80degC) measured in a test jig.

Another similar new development is a 2-stage X-Band HPA based on the technology PPH25X. The chip size is 18.4 mm2. The output power is above 8 W at room temperature with a PAE close to 45 % over the frequency range 8.6 to 11.6 GHz.

CONCLUSIONS

The European GaAs industry has an impressive capability and product portfolio and is very well positioned to address the global GaAs device market covering high volume low cost applications as well as specialized high performance applications. Filtronic and UMS are the two major players in Europe and complement each other. Their target applications range from wireless handsets, to defense and security, automotive and other mmW applications.

ACKNOWLEDGEMENTS

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ACRONYMS

HBT: Heterojunction Bipolar Transistor
pHEMT: pseudomorphic High Electron Mobility Transistor
ACC: Automatic Cruise Control
VCO: Voltage Controlled Oscillator
LNA: Low Noise Amplifier
TTL: Transistor-Transistor Logic
PSAT: Saturated output power