Establishment of A Full Functional Six-inch PHEMT Manufacturing Wafer Fab

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ABSTRACT

Filtronic Solid State is establishing a world-class six-inch wafer processing facility for high volume production of PHEMT products at Newton Aycliffe, UK, and a full functional six-inch R&D and MMIC prototyping wafer processing facility in Santa Clara, CA. The production facility in UK has 310,000 sq ft facility with over 100,000 sq ft of clean room, half of which is at class 10 standard. This facility will rank among the first and largest 6" GaAs wafer processing foundries in the world. The GaAs wafer processing capabilities include MBE PHEMT material growth, stepper and E-beam photolithography, with a maximum throughput of approximately 170,000 wafers per year.

INTRODUCTION

Filtronic is in the business of designing and manufacturing a broad range of customized microwave and millimeter wave radio frequency components and subsystems. The company's products are used in wireless communication infrastructure equipment, cellular handsets, electronic warfare systems, and other wireless communication systems. Filtronic employs nearly 3,000 people around the world and has 7 sites in the UK (including the Head Office in Shipley, West Yorkshire), 4 in the USA, 3 in Finland, 1 in Australia and 1 in China.

In late 1998, Filtronic acquired Litton Solid State Division to obtain advanced MBE based PHEMT technology, manufacturing, and MMIC design capabilities. In August 1999, Filtronic plc (UK parent company) took the opportunity to acquire a complete 6" silicon DRAM facility (established in 1992) from Fujitsu, Ltd., which consists of 310,000 square feet facility with 100,000 sq ft of clean room, in which 54,000 sq ft are at class 10 standard. The phase one improvement of this plant is to provide throughput of 50,000 six-inch wafers per year, with a maximum throughput of approximately 170,000 wafers per year. This facility ranks among the largest GaAs wafer processing facilities in the world

Filtronic is currently operating one semiconductor R&D facility in Santa Clara, CA and constructing one major semiconductor production facility in Newton Aycliffe, County Durham at UK. Both facilities are equipped with a full line of state-of-the-art MBE epitaxial wafer growth and processing equipment to handle 6-inch PHEMT wafers. The Santa Clara site focuses on process development and fast MMIC prototyping, while the Durham site concentrates on mass production of high volume handset devices and ICs. The emphasis on mass-producing the advanced PHEMT devices and MMICs is mainly driven by demand of low noise and power performance with much improved reliability for future wireless handset module and wireless Internet PDA communications. With significant public enthusiasm for wireless handsets and base station applications, demands for GaAs based RF, microwave and millimeter wave devices and ICs are dramatically increasing.

Large-scale production of PHEMT based low noise and power amplifiers requires significant investment and commitment in facility, capital equipment, processing technology and production methodology [1, 2]. With the newly established Durham production 6" wafer processing facility and the already facilitated Santa Clara 6" R&D wafer processing facility, Filtronic is fully committed to be a leader in the GaAs based hetero-junction device and MMIC markets. This paper provides in-depth description of the establishment of Filtronic six-inch GaAs PHEMT wafer capability and the development of its manufacturing technology.

FACILITIZATION

The Durham 6" GaAs production wafer processing facility was originally dedicated to Fujitsu's silicon based 4MB and 16MB DRAM manufacturing with a work force

of over 500 employees. After seven years of successful operation, changes in the DRAM market caused Fujitsu to close the plant, and in 1999 Filtronic reached an agreement to acquire this facility to build up its presence in the GaAs based handset components and module business.

The Durham facility comes with its own power plant with MW line conditioning and UPS capability, and complete DI water treatment, and waste chemical handling capabilities. The building is constructed with a two-floor, three-layer structure, the class 10 wafer processing clean room area is located on the upper floor while the lower floor serves as filtered air return path and hosts all the facility and supply infrastructure; power and gas lines, DI water pipelines, waste chemical drains, vacuum and compressed air lines, etc. A central command center is equipped to monitor, control and supervise all facility related activities to ensure a smooth, un-interrupted operation. The Durham facility is shown in Figure 1.

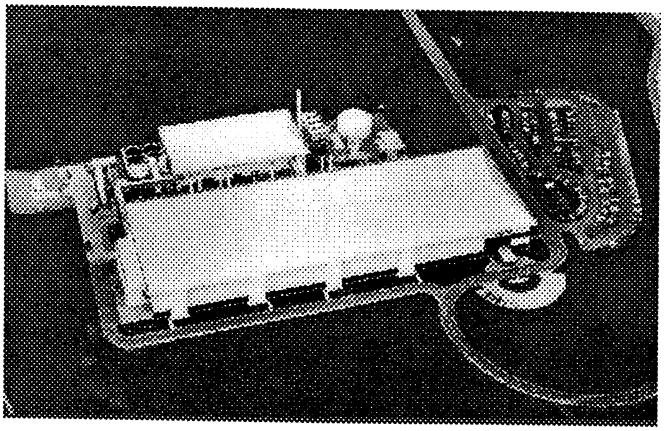

Figure 1. Bird-eye view of Filtronic 6" GaAs plant at Newton Aycliffe, Durham, UK.

The Santa Clara site is a 45,000 square foot facility with 12,000 square feet of class 100 clean room to host the semiconductor 6" wafer R&D and fast MMIC prototyping operation. The R&D operation has full range of material and wafer processing equipment, MBE and gas source MBE epitaxial growth systems, complete PHEMT based epitaxial wafer characterization instrumentation, general 6" wafer processing equipment, and multiple sub-quarter micron electron beam direct write lithography systems. The focus is to conduct advanced power PHEMT, and millimeter wave device and MMIC product development.

On the equipment side, a total of $45M, in addition to the facility cost, has been invested in major process and test equipment for the first phase of 6" PHEMT wafer production. These include multiple multi six-inch wafer MBE systems, a full range of material characterization systems (PL, X-ray, Hall measurement, Polaron profiler, Surfscan, etc.), multiple I-line steppers, wafer tracks, SEMs, RTAs, E-beam evaporators, sputtering systems, nitride PECVD systems, ICP-RIE systems, complete in-line CD, topology, and stress measurement systems, PHEMT device characterization, reliability test stations, and microwave test systems.

PROCESS START-UP AND DEVELOPMENT

The 6" PHEMT processes, which have been transferred or developed, are categorized into the following focused areas:

- Six-inch GaAs substrate qualification
- MBE growth and characterization of 6" PHEMT wafers
- Stepper based 0.5 micron lithography
- E-beam based direct write sub 0.25 micron lithography
- Silicon nitride passivation and MIM capacitor
- TaN resistor
- Air bridge interconnect process
- Wafer grinding and chemical thinning processes
- RIE via hole process
- Wafer back-end, demounting, taping processes
- Die separation process
- Automated PCM and RF testing

The two areas of process development, which are considered to be high risk, are (1) securing six-inch GaAs substrate and epitaxial wafer supplies, and (2) maintaining wafer integrity during thinning, via etching, and subsequent handling. Since the epi-ready GaAs substrates are not widely available from commercial vendors, Filtronic is experiencing some delays in delivery and uncertainty in substrate and epitaxial wafer quality. This situation should be improved quickly as vendors advance on the learning curve. However, the stability and quality of the PHEMT epitaxial wafers remain to be proven at this time. The risk factor is this area is relatively high considering the quantity of demand (approximately 50,000

wafers per year) and short delivery time schedule. The other high-risk area is the wafer thinning, via hole etching, and the subsequent handling of the 6" wafers. This is an area of great interest to Filtronic and a big challenge to all backside equipment vendors. Of course, not all of the intended GaAs handset products require wafer thinning and via hole etching, which gives some breathing room for the process development requirements.

Even though Filtronic has existing PHEMT processes on both three-inch and four-inch wafers, doing it for the first time on six-inch wafers is a unique and very different experience. First it is a true global effort to build two six-inch facilities at the same time, one in Santa Clara, CA for prototyping and development, and one in Durham, UK for handset product production. Not only do we have to conduct all the new automated 6" equipment evaluation, purchasing, installation, and process development; all the handing and carriers, fixtures, tools, and holders are also specially designed and ordered. Each process step began processing live wafers for process development while at the same time trying to get the equipment qualified to vendors' specifications, so often when a vendor's field engineer came to work on the system in the morning for acceptance qualification, Filtronic engineers started to run the system for process development in the afternoon. It is by no means an ideal way to conduct the needed engineering tasks and to perform the development work, but it became the only way to meet the aggressive schedule. Most of the individual steps of the six-inch processes were first demonstrated in the Santa Clara facility and were, within days, transferred to the Durham facility. Regular conference meetings among process team members between Santa Clara and Durham facilities are held almost daily in order to keep all tasks coordinated and managed.

PLAN INPLEMETATION AND RESULTS

Seven months after announcing the six-inch wafer project (which was first revealed in September 1999), Filtronic is processing complete 6" PHEMT wafers under pilot run capabilities, thanks to everyone's efforts. Figure 2 shows a front side processed, six-inch, PHEMT wafer with 0.5-micron gate geometry. The uniformity of the drain saturation current (i.e., Idss) achieved on the first 6" PHEMT wafer is 250 +/- 45 mA/mm, which is about a factor of 2 degradation from the 4-inch wafer result and reflects possible uniformity issues with the large scale production of MBE wafers as well as the gate etch used for the first lot of 6" wafers. It was surprising how many problems, both technically and non technically, one can run into on both 6" epi-ready GaAs substrates and 6" MBE PHEMT wafers when large quantity requirements are made. However, rapid improvements on both substrate and epitaxial wafer quality and delivery have been achieved, even though the final device performance and overall physical parameters (e.g., Idss, gm, ft, etc.) uniformities remain to be comprehensively evaluated and determined. Results of the findings will be given at the conference.

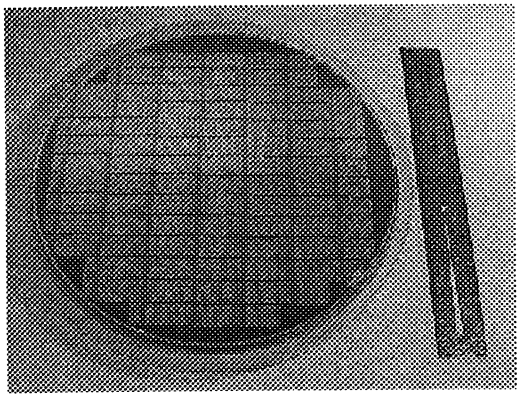

Figure 2. Processed 0.5-micron six-inch PHEMT wafer.

CONCLUSIONS

Filtronic is conducting a major global GaAs semiconductor expansion across two continents. The intended wafer fabrication capacity, once the Durham UK facility is fully utilized, will provide almost one third of the total world wide capacity for GaAs related handset products. The company believes that GaAs will have the same impact on the information technology and communication revolution as silicon has had in the past.

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