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Mass Production Technology of MOVPE for InP, GaN and Progressed GaAs Related Materials

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1. Introduction

GaAs devices for microwave application have been used as key devices in the multimedia era and in real mass production since the 1990's. The ion-implantation technique was mainly used at the beginning of mass production, but it gradually changed to epitaxial growth technology in order to achieve a higher device performance. MOVPE is one of the key techniques used for high volume production of epitaxial wafers[1]. In this paper, recent MOVPE technology applicable to mass production is introduced. It's properties and potential for use in mass production of newly developed compound semiconductor materials, for the next generation of devices, are also described.

2. Material Trends for Microwave Application

Fig.1 shows the main systems that use the compound semiconductor devices together with present devices. Each system requires higher performance for their next generation. For example, PA for cellular phone needs better linearity with higher power efficiency for the third generation system of wide band CDMA.

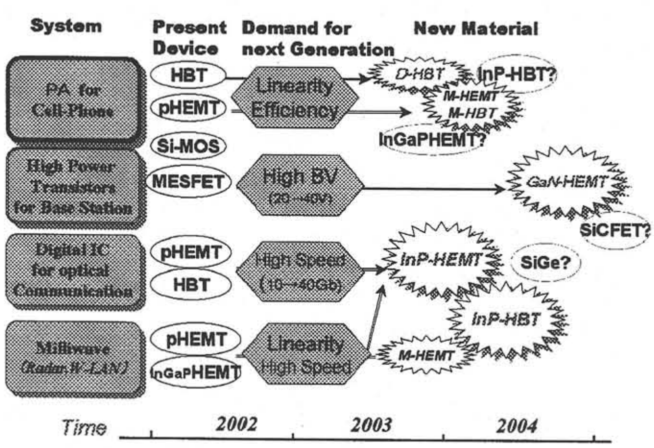


Fig.1 Trend for Ⅲ-V Microwave Devices

There are two ways to progress:

a) Improvement of conventional devices, HBT, pHEMT or Si-MOS in case of PA: It uses a circuit and module design technique. From a material standpoint, improvement of crystal quality and that of uniformity in a wafer and also in wafer to wafer is necessary.
b) Using the new materials: Many new materials have been reported in these applications and InP; GaN, and metamorphic material show a high possibility to be put to practical use at this stage.

Recent improvements are discussed in the next section from viewpoints of a) and b).

3. Improvement of conventional technique

3.1 Uniformity improvement

The planetary type reactor with a face-down system[2] has enabled us to achieve excellent uniformity with very good surface (no particles, etc.) at high throughput. Fig.2 shows uniformity of current gain across a wafer of 150mm in diameter InGaP-HBT, where sheet resistivity of base layer was 250ohm/cm^2. Relative standard deviation is very low at 0.5%. This value can be obtained in mass production. In case of pHEMT, standard deviation pinch-off voltage of less than 20mV in a 150mm wafer has been achieved.

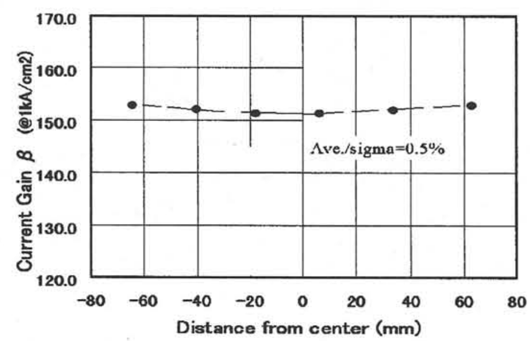
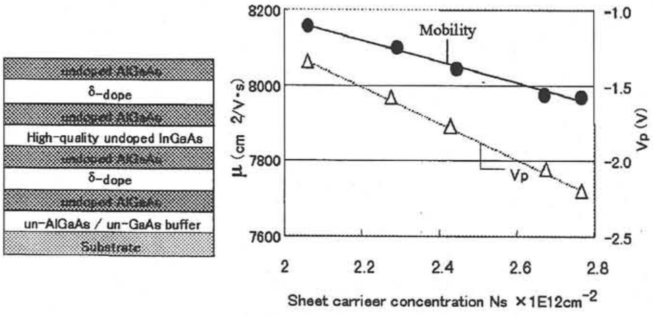


Fig.2 Uniformity of current gain of 150mm diam. InGa-PHBT grown by face-down planetary MOVPE system

3.2 High mobility pHEMT with conventional epi-structure

Double doped type pHEMT as shown in Fig.3(a) has been widely used for PA of digital cellular phone and switch application. In general the mobility of this structure grown by MOVPE was around 6000cm^2/vs. (About a 10% higher value is obtained from MBE.)

Much higher mobility, however, was obtained after optimization effort of growth condition and epi-structure especially in the channel region. One example was shown in fig.3.Very high mobility over 8000cm^2/vs was obtained with enough high sheet carrier concentration over 2.5x10^{12}cm^{-2} and with proper pinch-off voltage. (The wafer has 30nm thickness undoped AlGaAs Shottkey layer in this case.) This high mobility means a higher quality of the crystal and it is also useful for getting low series resistance from devices that give high efficiency and good linearity..



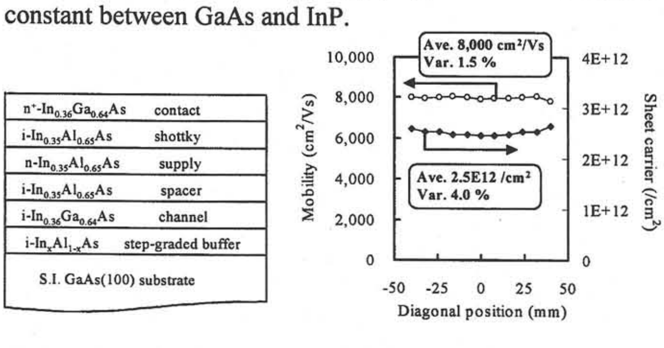
(a) Structure (b) Property

Fig.3 High mobility pHEMT

4. New Type of Material

4.1 Metamorphic materials on GaAs substrates

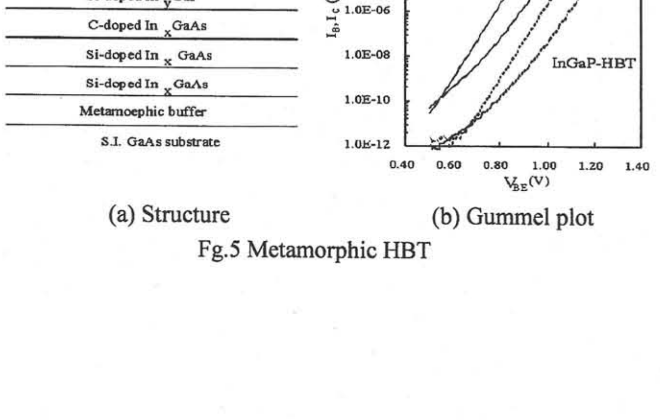
Metamorphic materials were originally developed to use the GaAs substrates, instead of InP, by using the metamorphic buffer layers where lattice constant is changed from that of GaAs to InP. It was started by MBE[3] but MOVPE was also able to be applied to this technique recently[4][5] Now it can be used not only for replacement of InP substrate, but also for applying material with lattice constant between GaAs and InP.



(a) Structure (b) Properties

Fig.4 Metamorphic HEMT

Fig.4 shows MOPVE grown metamorphic HEMT, where InGaAs channel of 35% in composition was used[4]. This composition gives us high mobility and saturation velocity with proper breakdown voltage. The sheet carrier concentration is very high as single doped HEMT structure. These properties are very useful to get good device performance of PA for the next generation and milliwave application.



(a) Structure (b) Gummel plot

Fg.5 Metamorphic HBT

This technique was also applied to HBT[6]. The 15% of Indium composition of InGaAs base layer was used in metamorphic HBT shown in Fig.5, where 200mV reduction of turn-on voltage (Vbe) .was recognized on metamorphic HBT in comparison with conventional InGaP HBT with GaAs base. This reduction enabled us to lower the supplied voltage of the battery in case of PA for cellular phone.

Reliability of the device is the biggest concern for metamorphic material to be applied practically. It will take more time to get enough results, but no negative results have been obtained so far.

4.2 New Material

Epiwafer on InP substrate is a very promising material especially for driver ICs for optical fiber communication systems. InP-HBT can be said to be the biggest candidate for a 40Gb system, however unfortunately activity has rapidly dropped due to a serious downturn in the fiber business.

GaN-HEMT has much higher breakdown voltage compared with conventional devices such as MESFET and Si-MOS for high power application. It also has very high carrier concentration as shown in Fig.6 (a). The GaN-HEMT realizes very good performance on high power application with high input voltage at 40V especially by using SiC substrate whose thermal resistance is very low.

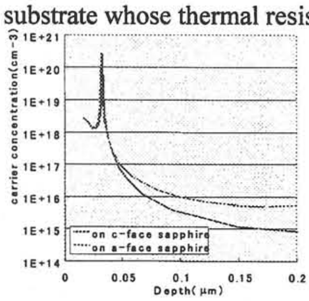


Fig.6 Carrier profile of GaN-HEMT

This material has very high potential, but still has some issues to be considered before going to real mass production. SiC substrates are very expensive and their diameter still remains at 50mm. Stable growth technology at very high temperature over 1100C (500C higher than GaAs growth) is also necessary. Currently great efforts are being focused on this concern.

5.Summary

Improvements of conventional materials and progress of new materials have been carried out for mass production of multi-media system devices. Many promising results were obtained to see improvements in the next generation of mass produced devices.

References

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