Mass-Production of High-Voltage GaAs and GaN Devices

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Abstract

We have developed 28V-operation high voltage GaAs and 50V-operation GaN devices and successfully moved to mass-production. Our flexible wafer process line utilizing Light-Wave products process line can handle small size SiC wafers the same as the matured 4-inch GaAs wafer process line. The device performance of high Voltage GaAs and GaN devices from mass-production line is well controlled. We have released full line-ups for W-CDMA and WiMAX base station systems from 10W to 180W devices as products from mass-production line.

INTRODUCTION

Eudyna has been dedicated to compound semiconductor devices since early seventies.

Recently our main focus was high power devices for base station applications such as W-CDMA. We believe high voltage operation is the most efficient way to meet the requirement of modern wireless base station systems.

We have successfully developed 28V operation GaAs FETs for W-CDMA application and released device line-up from 4W driver to 180W output device into mass-production in May 2004. Following high voltage GaAs devices, we developed 50V operation AlGaN/GaN HEMTs and successfully released 10W to 180W devices to mass-production in February 2006.

In this paper, we address some of key issues we had to overcome to realize the mass-production of high voltage GaAs and GaN devices.

DEVELOPMENT AND MASS-PRODUCTION OF 28V OPERATION GAAS FETS

We expanded the well-established conventional 12V operation GaAs Quesi-Enhancement mode technology to 28V operation FETs with optimization of gate structure and gate-to-drain distance to relax the electric field around the gate electrode. Fig 1 shows the schematic cross section of 28V operation GaAs MESFET structure. The key parameters were overhanging length (L_h) and the gate-to-drain distance (L_{gd}) to improve the gate-to-drain breakdown voltage (BV_{gdo}). Through the optimization of the values of Lh and Lgd in view of both performance and repeatability in mass-production, we have achieved BV_{gdo} of over 80Vwhich is enough for 28V operation [1].

In-line process control for several key process parameters was critical for the mass-production. Fig. 2 and 3 shows the process control charts for gate-to-overgate and gate-to-ohmic pattern alignment. We control misalignment less than 0.2um. Fig. 4 shows BV_{gdo} trend chart of process control monitor (PCM) measurement. As the result of tight control of the key parameters, we can keep stable yield in production.

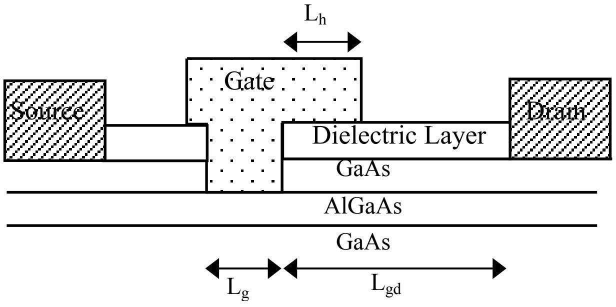

Fig 1 : Schematic cross section of 28V operation GaAs FET

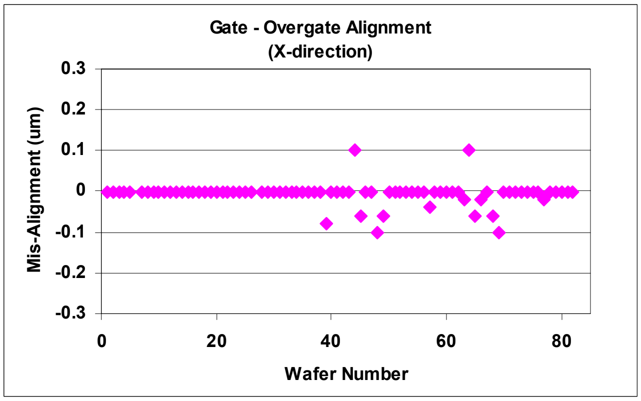

Fig 2 : SPC chart for Gate-Overgate alignment of 28V Operation GaAs FETs

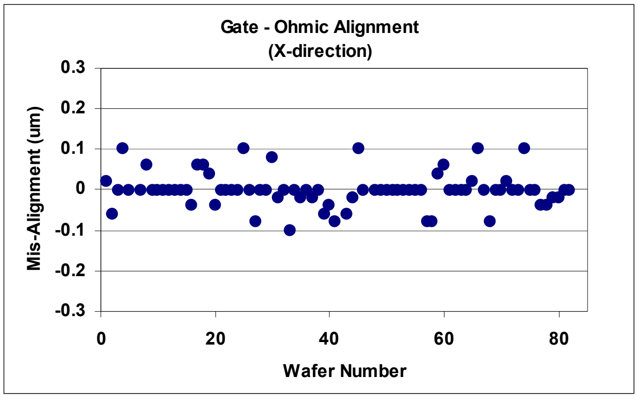

Fig 3 : SPC chart for Gate - Ohmic alignment of 28V Operation GaAs FETs

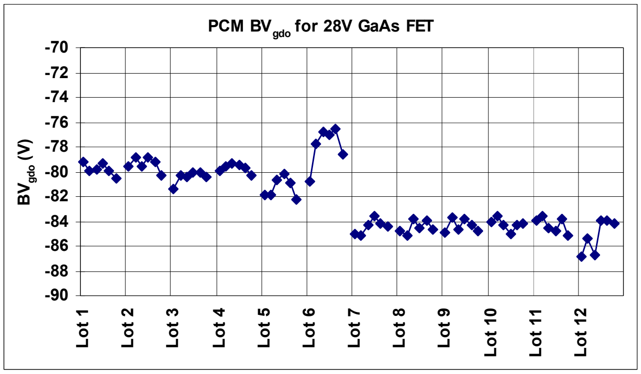

Fig 4 : Trend chart of Gate-to-Drain Breakdown Voltage of 28V Operation GaAs FETs

DEVELOPMENT AND MASS-PRODUCTION OF 50V OPERATION ALGAN/GAN HEMTS

Eudyna has been developing AlGaN/GaN HEMTs energetically in recent years in collaboration with Fujitsu Laboratories Ltd [2-4]. We have successfully developed and presented state-of-arts data at several conferences. To move AlGaN/GaN HEMT wafer process from Laboratory-level experiment line to mass-production manufacturing line, the biggest challenge was handling of small wafer size of transparent SiC substrates.

Our production GaAs wafer process line is 4-inch wafer process line. To handle 2/3-inch wafers currently available for semi-insulating SiC substrates, we developed special tools/trays which can handle 2/3-inch wafers in our 4-inch wafer process equipment. (Fig 5) In some of the critical processes like lithography or dry etching; we use another wafer process line currently manufacturing Light-Wave products, which is specialized for 2/3-inch wafer process.

Table 1 shows the process step list of 4-inch line or 2/3-inch Light-Wave process line equipments. Roughly 70% of process steps can be done by 4-inch line equipment. It means we can move GaN HEMT process into full 4-inch process easily when 4-inch wafers become available.

At some of the equipment, it was hard to detect transparent wafers with the wafer sensors. The optimization of sensors allowed detecting transparent SiC substrates.

Using a flexible combination of 2/3-inch Light-wave process line and 4-inch wafer process line, we established GaN mass-production line. Fig 6 and 7 shows the trend chart of the device performance from production wafers. The data shows the device performance is well controlled.

Fig 5 : Tray for Evaporator

Process line/Equipments	Process Step
2/3-inch process using Light-Wave process equipments	Stepper process, Photoresist Coating and Developing, Dry Etching (Batch process),
4-inch process using 4-inch equipments with tools/trays	Evaporation, CVD, Sputtering, Ion Implantation,
4-inch process equipments without special tools/trays	Back Grinding, Dicing, On wafer DC probing (PCM, 100% die DC test)

Table 1 : Process step list using 2/3-inch or 4-inch line equipment

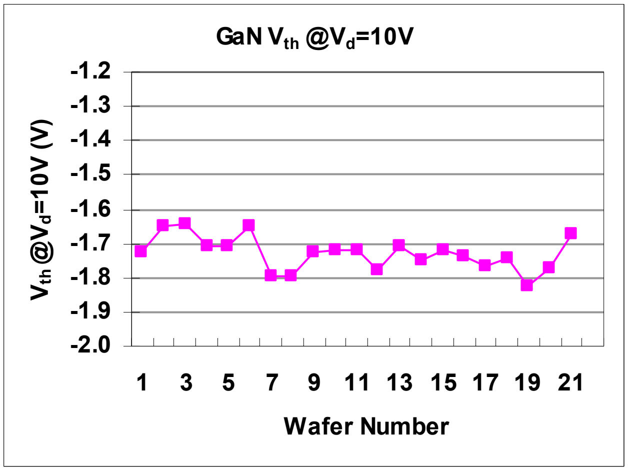

Fig 6 : Trend Chart of Vth for GaN HEMT

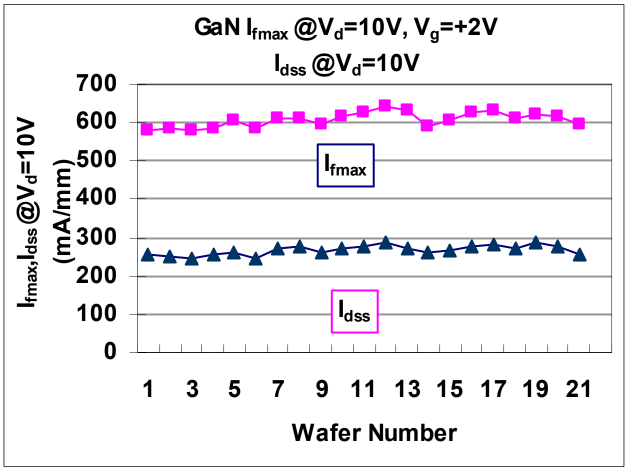

Fig 7 : Trend Chart of Idss/Ifmax for GaN HEMT

HIGH VOLTAGE DEVICE LINE-UP AND PERFORMANCE

For 28V GaAs device, we have line up of unmatched 4W to partially matched 135W single-ended and 180W push-pull type FETs suitable for W-CDMA application. (Fig 8)

For 50V GaN device, we have 10W to 180W single-ended devices for W-CDMA, 2.6 or 3.5GHz WiMAX applications, as well as unmatched devices up to 50W in small package of 0.2cc for general purpose. (Fig 9) A 10W GaN HEMT module with 30dB gain is also available for W-CDMA base station applications.

Due to high voltage operation and optimized device structure, the devices have very high efficiency and good error-correction capability with digital pre-distortion systems. As shown in Fig. 10, using commercially available DPD systems, very high efficiency of 26% for 28V GaAs

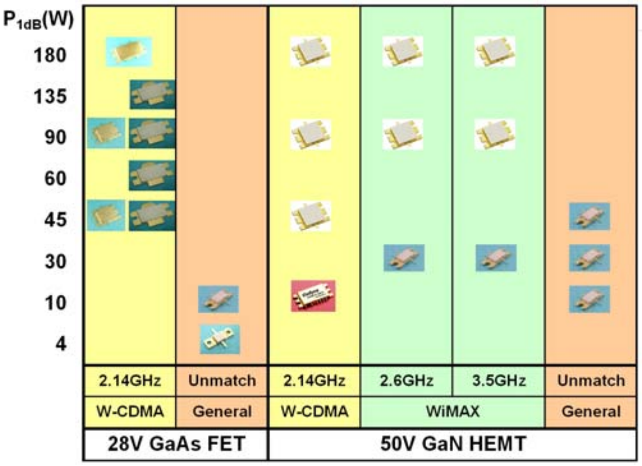

Fig 8 : Commercial Device Line up of Hi Voltage GaAs FET and GaN HEMT

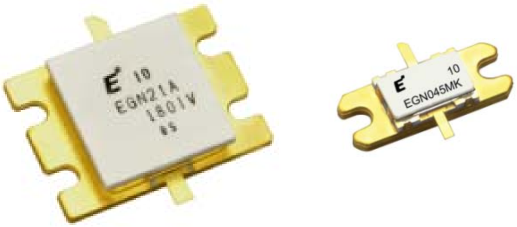

Fig 9 : Eudyna EGN21A180IV : Single-ended 180W GaN HEMT for W-CDMA (17.4 x 24.0 mm^2)
Eudyna EGN045MK : 50W Unmatched GaN HEMT (6.3 x 17.5 mm^2)

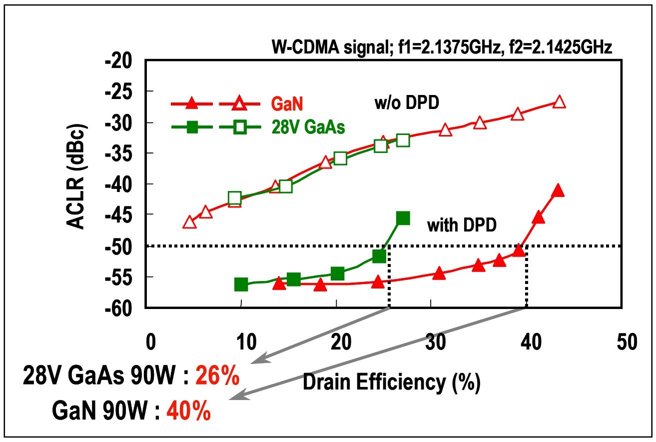

Fig 10 : Linearization performance with Digital Pre-distortion systems, W-CDMA signal, f_1=2.1375GHz, f_2=2.1425GHz, Peak/Avg.=6.5dB@0.01% Probability (CCDF);
GaAs: V_{DS}=28V, I_{DS}=700mA
GaN: V_{DS}=50V, I_{DS}=500mA

FETs, and of 40% for 50V GaN HEMTs are achieved at –50dBc of ACLR.

CONCLUSIONS

We have developed high voltage GaAs and GaN devices and successfully moved to mass-production. Our flexible wafer process line utilizing Light-Wave process line can handle small size SiC wafers the same as the matured 4-inch GaAs wafer process line. The device performance of high Voltage GaAs and GaN devices from mass-production line is well controlled and it shows high gain and very high efficiency at required linearity with digital pre-distortion systems.

ACKNOWLEDGEMENTS

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ACRONYMS

DPD: Digital Pre-Distortion
ACLR: Adjacent Channel Leakage Ratio