GaAs DEVICE ACTIVITIES IN EUROPE

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ABSTRACT

An overview on the current activities in Europe on GaAs and related devices is presented. The highlights include: high performance GaAs FET devices, opto-electronic circuits, GaInAs FETs and theoretical investigations on MESFET performance.

INTRODUCTION

The GaAs device and circuit activity on the R + D level in Europe can be characterized as follows:
- continued improvements of the high frequency performance of MESFET devices and MMICs;
- exploration in the area of GaAs and GaInAs FET's and circuits for integration with opto-electronic devices;
- significant work on improvements in substrate material growth and processing technology for MMICs and opto-electronic devices.

The strong activities on materials and processing become obvious at the 14th International Symposium on Gallium Arsenide and Related Compounds in Heraklion. In this paper a summary on R + D - highlights in the area of GaAs MESFETs, GaInAs JFETs, HEMTs, δ-doped GaAlAs/GaAs FETs is presented. Significant work is going on in the area of GaAs MMICs, this activity however, will be reviewed in the paper by J.Magarshack at this conference.

GaAs FETs

The GaAs MESFET device, although an established microwave device and in production in single devices and MMICs, is still getting improved. In particular the possibility of growing well defined channels with molecular beam epitaxy, and improved lithographical tools, in particular direct E-beam exposure, has precipitated in improved transconductance values and higher transit frequences f_T. The IBM Zurich Research Lab has published a GaAs MESFET with a gate length of 0.5 μm with a recessed channel structure on a channel grown with molecular beam epitaxy. (1)

The transconductance was 400 mS/mm. With the same process an integrated GaAs opto-electronic receiver has been implemented (2). The photodetector of the circuit is an interdigitated Schottky barrier diode on the semiinsulating substrate with an outstanding response time to a short optical pulse of only 4.8 ps FWHM. The GaAs MESFET preamplifier is implemented as DC coupled transimpedance amplifier with enhancement/ depletion MESFETs. For the combination of the Schottky barrier detector and the transimpedance amplifier a 3dB bandwidth of 5.2 GHz has been measured (Fig.1).

An optimization of the GaAs MESFET in a different direction has been reported by Telettra from Italy (3). In order to improve high power MESFETs, the gate and drain contacts have been arranged in a comblike structure with a finger width of 150 μm. The individual source island are interconnected with an air-bridge metallization across the source and drain contacts. This structure resulted in a MESFET device area of 0.2 mm^2 for a total gate width 2.4 mm. In particular the gate metallization resistance could be reduced by a factor of 30 with respect to a conventional finger structure. At 11 GHz a power added efficiency of 40% was measured.

A new and promising GaAs FET structure is being pursued at the Max-Planck-Institute, Stuttgart, FRG: the δ doped GaAs FET (4,5). The δ doped FET channel consists of a single atom layer of dopant material, mostly Silicon, in high resistivity Gallium Arsenide. This δ shaped doping profile generates a V-shaped potential well with a quasi 2D electron gas, similar to the 2D electron gas of a HEMT structure. The δ doped channel has a sheet donor density of N_D = $2..4.10^{12}/cm^2$, which is higher than the electron density in the HEMT structure. Moreover the channel can be very close to the Schottky gate, which would result in a high transconductance. The first preliminary experimental data show a transconductance of 240 mS/mm for a gate

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length of 0.5 μm. According to the theory, the transconductance should get close to 400 mS/mm for a gate length of 1 μm. (Fig.2)

GaInAs Junction Field-effect Transistors

A special highlight at the Int. Symposium on Gallium Arsenid and Related Compounds was the strong activity on GaInAs junction FETs (JFET). Schottky barrier contacts on GaInAs show a rather low barrier hight of approximately 0.3V. Therefore the gate contact is mostly implemented as a p^+n junction.
The following organisations presented papers on the subject:
(a) CNET, Bagneux, France (6)
(b) Thomson CSF, Orsay, France (7)
(c) University of Duisburg, FRG (8)
(d) Siemens, Munich, FRG (9)
The GaInAs JFET is lattice matched to the InP substrate, which is also the substrate for opto-electronic devices for the 1.3 -1.55 μm wavelength range. For the application in opto-electronic integrated circuits the Ga InAs JFET is in competition with the GaInAsP heterojunction bipolar transistor HBT. The technology for the JFET is simpler than for the HBT. In Ref. (8, 9) normal liquid phase epitaxy (LPE), in (6) molecular beam epitaxy (MBE) and in (7) metal-organic vapor phase exitaxy (MOVPE) was used for the growth of the vertical structure. In (8, 9) the p+ is obtained with a Zn diffusion, whereas in (7) the p+n junction was epitaxially grown. The following normalized transconductances, which compare very favorably to MESFET transconductances, have been reported:

gate length	transconductance gm	
0.5 μm	235 mS/mm	(7)
0.6 μm	330 mS/mm	(8)
1 μm (normally off)	430 mS/mm	(9)

In (6) an integrated PIN/JFET photoreceiver is reported with a sensitivity of -33dBm at 140 Mb/s with a bit error rate BER of 10^{-9}.

The microwave properties of the GaInAs JFETs are not yet fully characterized. In (10) a 2 μm gate GaInAs JFET is compared with a 1 μm gate GaAs MESFET (Fig.3):
1 μm MESFET : f_T = 13GHz fmax = 24GHz
2 μm JFET : f_T = 8GHz fmax = 20GHz

These figures indicate, that the GaInAs JFET will show better microwave performance than the MESFET for the same gate geometry.

GaAs HEMT

At LEP, France a detailed investigation on the noise performance of HEMTs has been made (11).The devices have been grown by MOVPE and MBE and similar performance has been found for both devices (12):
MOVPE-HEMT: gate length: 0.55 m, gm=420 mS/mm
NF = 0.84dB, G_{ass} = 9.7dB at f = 12GHz
MBE - HEMT: gate length: 0.5μm, gm=430 mS/mm
NF = 1.02dB, G_{ass} = 9.2dB at f = 12GHZ
These are among the best noise figures reported in the literature (Fig.4).

GaAs FET Device Simulations

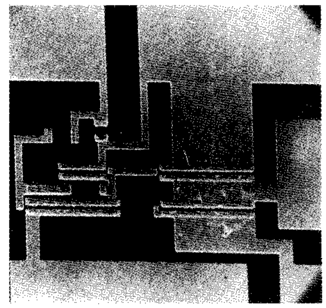
From the University of Lille,France, a number of publications have appeared on the subject of 2 D Monte Carlo simulations of FET devices with very short gate lenghts (13).The results confirm the qualitative behavior of the transconductance on channel geometry, which is known from the simple 1 D analysis. In addition quantitative results on the output conductance and the pinch-off voltage as a function of channel thickness and the subchannel doping are presented.

CONCLUSIONS

The survey of the European GaAs device activities shows a strong focus on GaAs MESFETs, HEMTs and GaInAs JFETs. In all areas significant progress is noted, which can be attributed to advanced processing methods. In the case of the GaInAs JFET, outstanding device results have been presented. The technology, however, is presently suited for very simple integrated circuits only. With the introduction and perfection of tools and processes similar to the established MESFET processes, it can be anticipated that similar levels of integration will be feasible.

(1) B.J. Van Zeghbroeck et al, "Submicrometer GaAs MESFET with shallow channel and very high transconductance".

(2) B.J. Van Zeghbroeck et al,"5.2 GHz monolithic GaAs optoelectronic receiver", Int. Electron Devices Meeting, 1987, paper no. 10.3.
(3) G.P. Donzelli et al, "Very high performance GaAs microwave MESFET power devices", European Microwave Conference 1987, Rome.
(4) K. Ploog, "Delta doping in MBE-grown GaAs and $Al_x Ga_{1-x}$ As/GaAs device structures". 14th Int. Symposium on Gallium Arsenide and Related Compounds, paper I(2).1.
(5) E.F. Schubert et al, "The delta-doped field-effect transistor (FET), IEEE Transactions on Electron Devices", Val. ED-33, No.5, May 1986 pp 625-632.
(6-9) 14th International Symposium on Gallium Arsenide and Related Compounds:
(6) J.C. Renand et al, "Monolythic photoreceiver integrating InGaAs PIN/JFET with diffused junctions", paper DO.6.
(7) J.Y. Raulin, "Microwave characteristics of an InGaAs junction field effect transistor grown by MOCVD", paper DE(4).4.
(8) K. Steiner et al, "High transconductance submicron self-aligned InGaAs JFETs" paper DE(4).5
(9) H. Albrecht et al, "DC-characterization of normally-off InGaAs/InP:Fe junction field-effect transistor inverters", paper DE(4).6.
(10) H. Albrecht et al,"Microwave performance of $In_{0.53}Ga_{0.47}As$, InP: Fe junc - tion field-effect transistors" to be published in Archiv der Elektrischen Uebertragung AEU.
(11) A.Cappy,"Noise modeling and measurement Techniques," IEEE Transactions on MTT, Vol. 36, No.1, Jan. 1988, pp 1.
(12) L. Hollan, LEP, private communication.
(13) R. Fauquembergue et al,"The GaAs submicronic recessed gate MESFET, a Monte Carlo study".



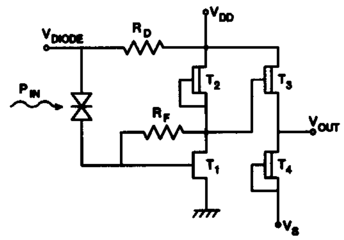


Fig. 1a,b Integrated Schottky barrier photodetector and transimpedance amplifier with enhancement/depletion MESFETs (2).

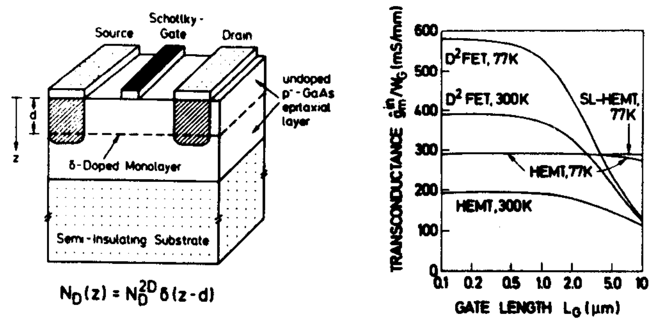
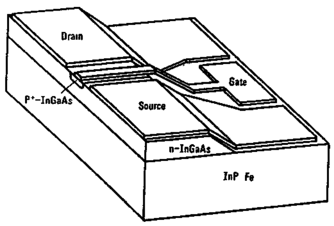


Fig. 2 δ-doped GaAlAs/GaAs FET (4). Device structure and calculated transconductance vs. gate length.



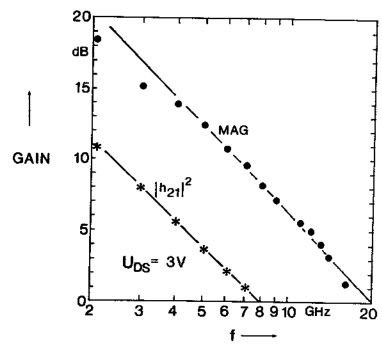


Fig. 3a,b 2 μm GaInAs Jfet: Device structure, (9, 10) $|h_{21}|^2$ and MAG vs. frequency.

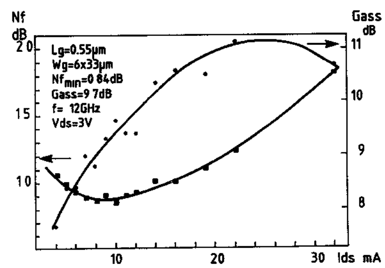


Fig. 4 GaAlAs/GaAs HEMT (11, 12). Gate length 0.55 μm, MOVPE grown channel: noise figure and associated gain vs. frequency.