0.06µm Gate Length Metamorphic $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ HEMTs on GaAs with High f_T and f_{max}

S. Bollaert, Y. Cordier, M. Zaknoune, T. Parenty, H. Happy, S. Lepilliet, A. Cappy
Institut d'Electronique et de Microelectronique du Nord
Département Hyperfréquences et Semiconducteurs
Cité Scientifique, Avenue Poincaré, BP 69
59652 Villeneuve d'Ascq Cedex, France
sylvain.bollaert@iemn.univ-lille1.fr

Recently, metamorphic $In_xAl_{1-x}As/In_xGa_{1-x}As$ HEMTs on GaAs (MM-HEMTs) have demonstrated their potential for high performance low noise and power applications [1-2]. 0.1µm gate length MM-HEMTs on GaAs exhibit f_T of 225GHz [3]. MM-HEMTs presents comparable performance than InP-based HEMTs with the cost advantage of GaAs substrate. Future communications systems will require devices with f_T and f_{max} higher than 300GHz. This can be achieved with sub-micrometer gate length HEMTs. In this paper, we report the first 60nm gate length MM-HEMT on GaAs substrate using a conventional electron beam lithography process for the T-gate definition.

HEMT epitaxial layers were grown on GaAs substrate by MBE using an inverse-step graded buffer to accommodate the lattice mismatch between the substrate and the active layers [4]. Indium content in the active layers is close to 0.5 (figure 1). The T-shaped gate devices were fabricated as follows. First, the mesa was defined by wet chemical etching using $H_3PO_4:H_2O_2:H_2O$ solution. To form ohmic contacts, Ni/Ge/Au/Ni/Au metalization was evaporated and followed by rapid thermal annealing at 310°C for 60 seconds. Typical ohmic contact resistance is 0.15 Ω.mm. The 0.06µm T-shaped gates were defined by electron beam lithography using a bilayer PMMA/P(MMA-MAA) resist scheme and a 100keV LEICA EBPG-5HM machine. Selective gate recess etching was performed using a solution of Succinic Acid, resulting in 50nm side undercut etching. The gate metalization consists of Ti/Pt/Au.

Figures 2 and 3 present DC characteristics of a $0.06x100µm^2$ MM-HEMTs. Pinch-off voltage is –0.8V. The device exhibits excellent I-V characteristics with a slight increase of output conductance at high V_{ds}. A peak extrinsic transconductance gm of 850mS/mm and a maximum drain current I_{ds} of 600mA/mm have been obtained. S-parameter measurements were performed up to 50GHz. –6dB/octave extrapolation of extrinsic $|H_{21}|^2$ and unilateral gain U give respectively a f_T of 260GHz and a f_{max} up to 490GHz (figure 4). To our knowledge, these are highest values ever reported for HEMTs on GaAs substrate.

[1] C.S. Whelan et al, IPRM 2000, pp337-340.
[2] S. Bollaert et al, Solid State Electronics 44 (2000), pp1021-1027.
[3] K.C. Hwang et al, IEEE Electron device Letters, vol.20, n°11, Nov 1999.
[4] Y. Cordier et al, IPRM 2000, pp102-105.

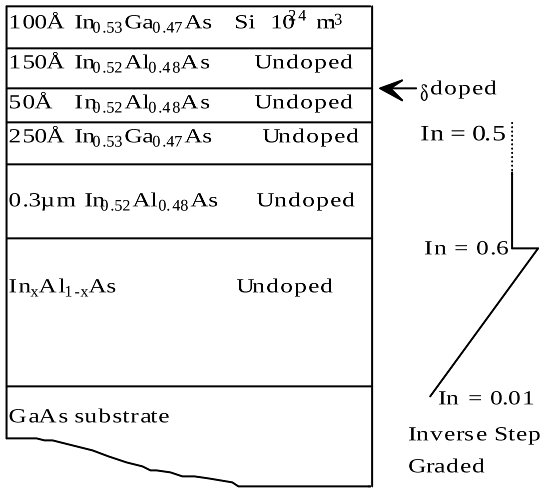

Figure 1: Epitaxial layer structure of the metamorphic HEMT. Indium content in the channel is 0.53.

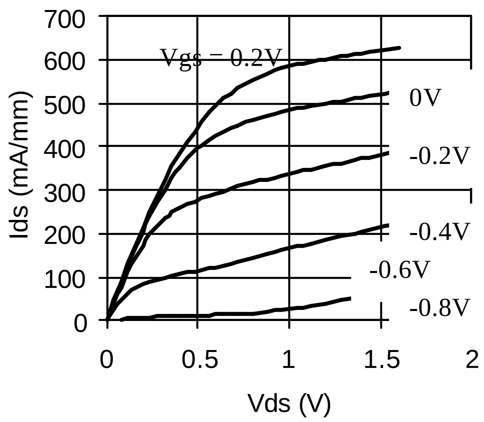

Figure 2: I-V characteristics of 0.06µm gate length metamorphic HEMT. Width is 2x50µm.

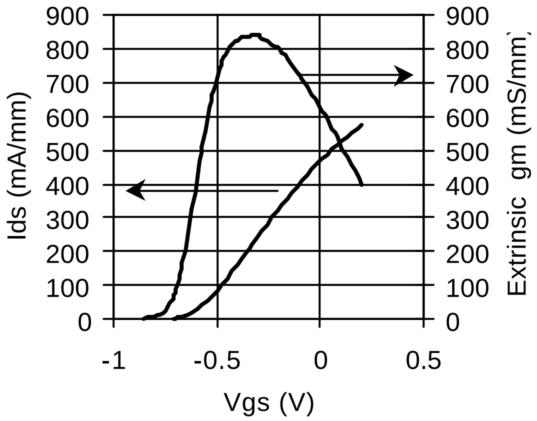

Figure 3: Extrinsic transconductance gm and drain current I_{ds} versus gate-to-source voltage V_{gs}. Drain-to-source voltage V_{ds} is 1V.

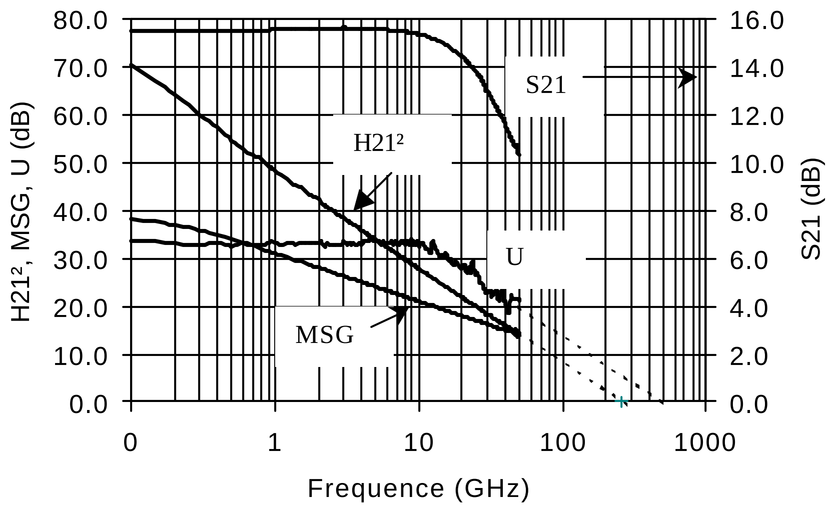

Figure 4: Gain of the 0.06µm gate length metamorphic HEMT. Width is 2x50µm. Darin-to-source volatge V_{ds} is 1V. Gate-to-source voltage V_{gs} is –0.2V