By repeating the above procedure for each of the 100 blocks of 16 complex vector channel responses and for each BTS and MS location, the histogram of PAS correlation bandwidth for the urban environments investigated is given in Fig. 3. For $\rho_{th} = 0.5$, the median spatial correlation bandwidth is 5MHz and for a small number of cases PAS correlation bandwidths of greater than 10MHz have been reached. For $\rho_{th} = 0.9$ the the median spatial correlation bandwidth is reduced to 412kHz.

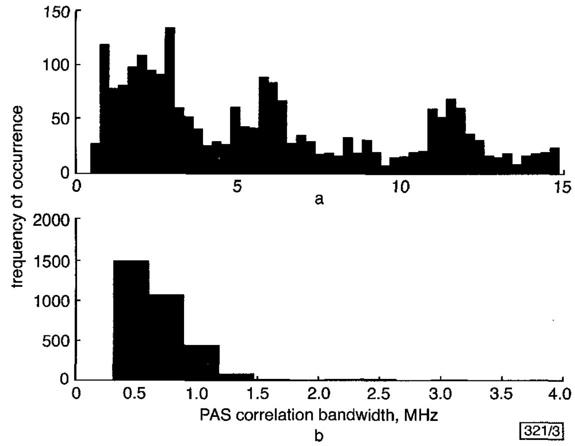

Fig 3 *Histograms of PAS correlation bandwidth for urban environments*

a $\rho_{th} = 0.5$
b $\rho_{th} = 0.9$

Conclusions: A novel metric to quantify the impact of duplex frequency spacing on power azimuth spectrum has been introduced. The analysis has immediate applications in performance appraisal of smart antenna systems deployed for systems using a frequency division duplex air interface, such as UTRA. The results from an urban spatio-temporal trials campaign have indicated that PAS become significantly decorrelated for frequency offsets of more than 5MHz for an angular resolution of 2°.

Acknowledgments: The authors gratefully acknowledge funding support under HEFCE JREI'98, and Allgon Systems AB for the loan of the antenna array.

15 September 2000

Electronics Letters Online No: 20001338

DOI: 10.1049/el:20001338

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High DC current gain InGaP/GaAs HBTs grown by LP-MOCVD

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The high current gain of InGaP/GaAs heterojunction bipolar transistors (HBTs) grown under optimised growth conditions using MOCVD is demonstrated. Large area (60μm × 60μm) samples of InGaP/GaAs HBTs are grown and fabricated for DC characterisation. These devices show Gummel plots with nearly ideal *I-V* characteristics (n_c = 1.00 and n_b = 1.09). Measured current gain of the devices with a base sheet resistance R_b of 236Ω/sq is 130 at a collector current I_c of 1mA and 147 at the collector current density of 1kA/cm^2 (I_c = 39.1mA). The current gain to base sheet resistance ratio is 0.623 at 1kA/cm^2, which is the highest value ever reported. The optimised growth condition improves the current gain in the entire range of the collector current. The current gain is as high as 92 at an I_c of 10μA. These results are the best that have ever been demonstrated with InGaP/GaAs HBTs. The data show that the MOCVD growth condition is an important factor in achieving high current gain in InGaP/GaAs HBTs.

Introduction: In recent years, InGaP/GaAs HBTs look increasingly promising as replacements for the more widely used AlGaAs/GaAs HBTs due to a number of advantages. These advantages include low surface recombination velocity, large valence band offset between InGaP and GaAs, high etch selectivity, having no DX centre problem (which occurs in aluminium containing compounds such as $Al_xGa_{1-x}As$), and superior long-term reliability [1 – 4]. To compare the HBT device performance, the DC current gain of large area HBTs is an important figure of merit reflecting the material quality of the epitaxial layers [5]. Yang *et al.* have shown that thermal annealing produces carbon-related defects and decreases the minority carrier lifetime in the carbon-doped GaAs layer [6, 7]. To minimise annealing induced degradation, low growth temperatures and fast growth rates for the emitter and the emitter cap layers are crucial in obtaining high-gain InGaP/GaAs HBTs [8]. So far the highest value of current gain to base sheet resistance β/R_b ratio has been obtained only by the group from Kopin (β/R_b = 0.6 at collector current density I_c of 1kA/cm^2) [9]. In this Letter, we demonstrate InGaP/GaAs HBTs with a β/R_b of 0.623 at I_c = 1kA/cm^2.

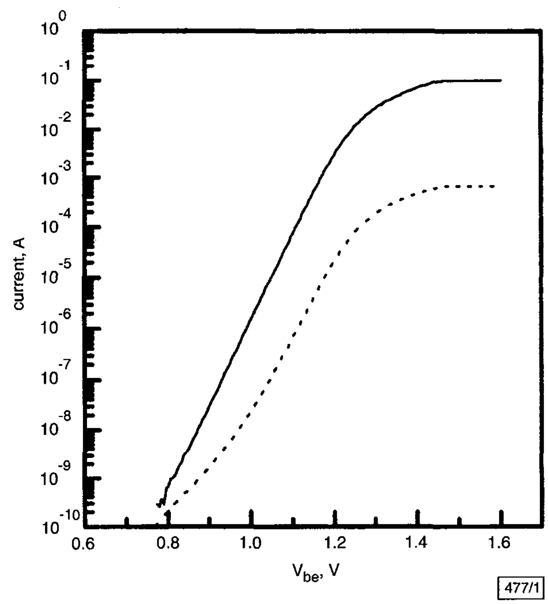

Fig. 1 *Gummel plot for 60 × 60μm emitter device*

——— I_c
– – – – I_b

Material and fabrication: The material for this work was grown using an Emcore DS-125 vertical flow MOCVD reactor. The chamber pressure was kept at 76Torr. TMGa, TEGa and TMIn were used as group III precursors, and AsH_3 and PH_3 were used as group V precursors. Si_2H_6 was used as an *n*-type dopant source, and carbon was used as the p-type dopant. The HBT epitaxial structure consists of a 5000Å GaAs subcollector, a 150Å InGaP subcollector etch-stop, a 3750Å GaAs collector ($n = 3 \times 10^{16}cm^{-3}$), a 700Å C-doped GaAs base ($p = 4 \times 10^{19}cm^{-3}$), a 700Å InGaP emitter ($n = 5 \times 10^{17}cm^{-3}$), a 2300Å heavily doped GaAs emitter cap, and a 600Å graded layer from GaAs to $In_{0.5}Ga_{0.5}As$. An InGaP etch-stop thickness of 150Å is designed to provide a reliable etch-stop layer for subcollector metal deposition and for the collector undercut in our high-frequency process to reduce the base-collector capacitance. The substrates used in the experiment were semi-insulating GaAs, 2° misoriented off (100) towards the (110) direction. The samples were cleaved into 1 × 1cm squares for DC large area HBT processing. The devices tested in this study have an emitter area of 60 × 60μm. Nonalloyed TiPtAu was used for emitter, base and collector contacts.

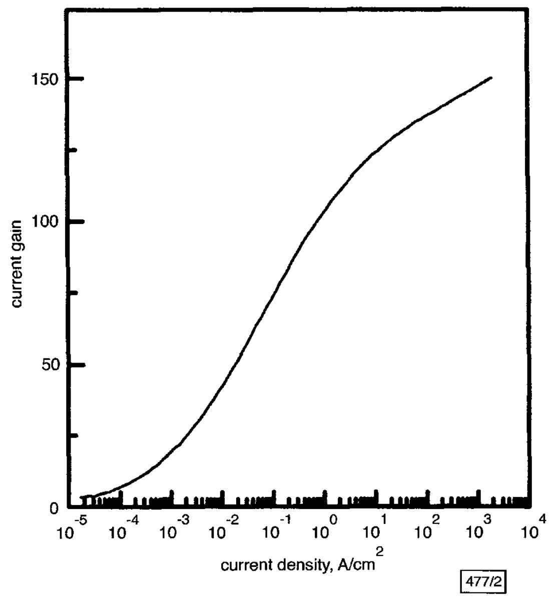

Fig. 2 *DC current gain of annealed HBT against collector current density*

Results and discussion: A Gummel plot of a large-area device is shown in Fig. 1. The base ideality factor is 1.09, while the collector ideality factor is 1.0. The base ideality factor shows that the emitter-base heterojunction is of good quality and the recombination in the space-charge region is negligible. As the base-emitter voltage V_{be} reaches 1.3V, both the collector and base currents begin to saturate. When V_{be} rises above 1.3V, the series resistance begins to dominate the collector current and the DC current gain begins to saturate as well. Fig. 2 shows the DC current gain against collector current density up to 2kA/cm^2 of the device. For collector current density $J_c < 10^{-2}$A/cm^2, the DC current gain β is limited by the space-charge recombination in the emitter-base depletion region. As J_c goes above 10^{-2}A/cm^2, β increases dramatically since the current gain is limited mostly by the recombination in the base layer. When J_c rises above 10A/cm^2, series resistance begins to dominate and β starts to flatten out.

Conclusion: We have demonstrated high current gain InGaP/GaAs HBTs grown by MOCVD. The DC current gain exhibits a maximum value of 147 at a collector current density of 1kA/cm^2 (R_b = 236Ω/sq). The base ideality is calculated to be 1.10, showing the emitter-base heterojunction to be of high quality. The current gain to base sheet resistance ratio is the highest DC current gain ever reported for InGaP/GaAs HBTs grown by MOCVD.

Acknowledgment: The authors would like to acknowledge funding support from the DARPA VLSI Photonics project (DAAG55-98-1-0303).

28 July 2000
Electronics Letters Online No: 20001321
DOI: 10.1049/el:20001321

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InGaP/GaAs camel-like field-effect transistor for high-breakdown and high-temperature applications

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A novel InGaP/GaAs camel-like field-effect transistor (HFET) has been fabricated successfully and demonstrated. Because of the use of an n^+-GaAs/p^+-InGaP/n-GaAs camel-like gate and GaAs/InGaAs double channel, the gate barrier height and carrier confinement are improved. Therefore, low-leakage and high-breakdown characteristics are obtained. Experimentally, this device provides high-breakdown characteristics and good device performances over a wider temperature operation range of 30–210°C. Therefore, the studied InGaP/GaAs structure is suitable for high-power and high-temperature applications.

Recently, the InGaP/GaAs material system has attracted significant interest for high-speed digital and microwave circuit applications owing to its superior performance [1]. The advantages of the InGaP/GaAs material system, as compared to AlGaAs/GaAs or InAlAs/InGaAs, include: (i) high etching selectivity, (ii) absence of DX centres, and (iii) low reactivity with oxygen. Therefore, the uniformity and device performance can be improved. In addition, for automotive, aircraft, space technology and other applications, high-power and high-temperature devices are needed [2]. An important factor to limit the power application is the breakdown voltage. The breakdown voltage can be improved by reducing