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Growth and Characterization of AlGaAs/InGaAs/GaAs P-HEMTs Grown by LP-MOCVD Using Inverted Double Channel Structure

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1. Introduction

The conventional single hetero-junction high electron mobility transistors (SH-HEMTs) have shown excellent microwave performance. However, the SH-HEMTs suffer from their low current density, which should limit the power handling capability of device. Recently, a double channel pseudomorphic-high electron mobility transistor (P-HEMT) has demonstrated a promising potential as a microwave power device due to their high current driving capability[1]. Additionally, the transconductance enhancement has been also reported from the inverted structures[2,3]. In this work, we report an $Al_{0.25}Ga_{0.75}As/In_{0.25}Ga_{0.75}As/GaAs$ inverted double channel HEMT structure. This heterostructure was grown with the use of optimized low-pressure metalorganic chemical vapor deposition (LP-MOCVD) growth conditions and quantum-well design. We have also successfully fabricated 1.8 μm-gate power HEMT and systematically characterized the device performance.

2. Experimental

An AlGaAs/InGaAs/GaAs pseudomorphic epilayer was grown on a (100)-oriented semi-insulating GaAs substrate by LP-MOCVD. The chamber pressure was kept at 76 torr. Trimethylgallium (TMG), Trimethylaluminum (TMA), ethyldimethylindium (EDMIn), arsine(AsH_3), and silane(SiH_4) were used as the Ga, Al, In, As sources and n-type dopant, respectively. The cross section of the sample structure is shown in Fig. 1. In designing the upper channel (channel 1), the Si-delta doping was not inserted in 250 Å -thick undoped AlGaAs layer on top of the channel to improve the breakdown voltage characteristics and the Si-delta-doped GaAs layer was introduced below the InGaAs channel. For the case of the lower channel (channel 2), the isolation of the delta-doped layer from GaAs buffer layer results in improved carrier-confinement in the channel. Also, by carefully controlling the InGaAs layer within the critical thickness, a dislocation-free pseudomorphic heterostructure was obtained with a 80 Å InGaAs channel layer. In order to

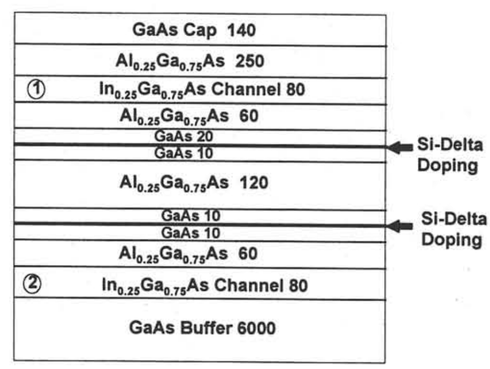

Fig. 1. The schematic diagram of the proposed inverted double channel HEMTs structure (unit: Å).

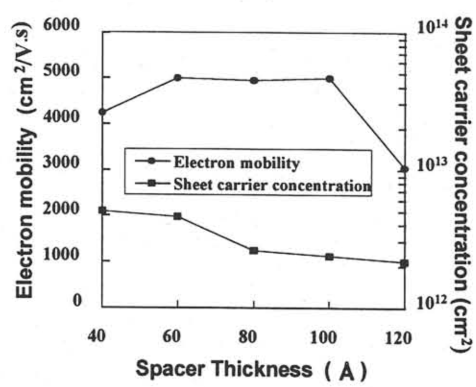

Fig. 2. The electron mobility and 2-DEG sheet carrier density versus spacer thickness.

determine the optimum spacer thickness in the AlGaAs/InGaAs/GaAs heterostructure, different spacer thicknesses were grown and their effects were investigated. Figure 2 shows the electron mobility and 2-DEG concentration versus the spacer thickness. The highest 2-DEG sheet carrier density without degrading the electron mobility was obtained at a spacer thickness of 60 Å. Hall measurements showed carrier mobility of 5010 $cm^2/V \cdot s$ at 300 K with corresponding sheet carrier density of 4.53 $\times 10^{12} cm^{-2}$. Conventional photolithography and lift-off techniques were employed for the device fabrication. Alloyed Au/Ge/Ni metal was used for source and drain contacts. Gold was evaporated as the Shottky contact metal. The gate dimensions are $1.8 \times 200\ \mu m^2$.

3. Results and Discussion

The measured current-voltage characteristics of this device at 300 K are shown in Fig. 3. Good saturation characteristics of drain current are obtained. Figure 4 shows the saturation current density and extrinsic transconductance versus gate voltage at room temperature. A maximum drain current as high as 820mA/mm was achieved. This value is comparable to that of single AlGaAs/InGaAs P-HEMTs with similar gate length[4]. The maximum extrinsic transconductance of 320 mS/mm is achieved at 300 K. In addition, it is to be noted that large value of g_m is sustained over a wide range of gate voltage from -2.0 V to 1.8 V. The high drain current and the wide range gate voltage swing are attributed to the high sheet carrier densities and the operation of double channel,

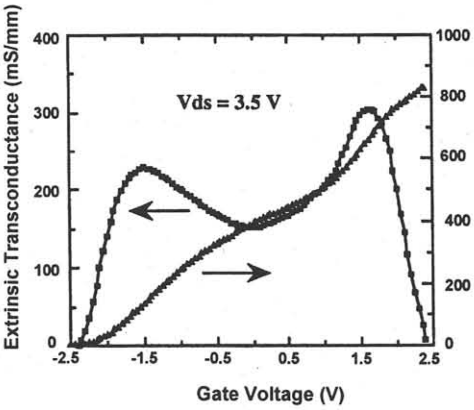

Fig. 4. Extrinsic transconductance and saturation current density versus gate voltage at 300 K.

respectively. Compared with the single channel structures, the inverted double channel P-HEMT in this work exhibits higher power performance.

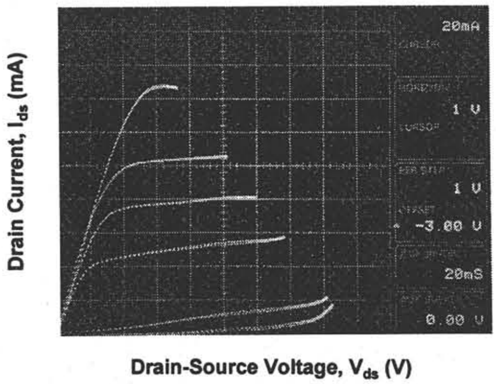

Fig. 3. Measured current-voltage characteristics of the inverted double channel P-HEMT with a gate dimension of $1.8 \times 200\ \mu m^2$ at 300 K.

4. Conclusions

An AlGaAs/InGaAs/GaAs P-HEMT structure has been grown and characterized. The sheet carrier concentration and the electron mobility at 300 K were $4.53 \times 10^{12}\ cm^{-2}$ and 5010 $cm^2/V \cdot s$, respectively. The fabricated $1.8 \times 200\ \mu m^2$ device exhibited the high maximum current of 820 mA/mm. Additionally, the maximum extrinsic transconductance was 320 mS/mm. The improved device performance is attributed to the increased 2-DEG sheet density with corresponding large mobility resulting from the inverted double channel structure. These observed performance characteristics make this device a promising candidate for microwave power device applications.

References

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