A-4-1 (Invited) MBE-Grown GaAs/N-AlGaAs Heterostructures and Their Application to High Electron Mobility Transistors

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A high electron mobility transistor (HEMT)[1-5] is one of the most promising candidates for post-silicon devices for application to future computers, since it shows excellent high-speed performance at an economically feasible temperature of 77 K. This is principally due to a characteristic feature of mobility enhancement of electrons at low temperatures in a MBE-grown selectively doped (SD) GaAs/N-AlGaAs heterostructure material of this device.[4]

In this report, we describe electrical properties of high quality SD GaAs/N-AlGaAs heterostructures grown by MBE and device characteristics of a recently developed HEMT.[5]

Figure 1 shows a schematic diagram of an SD GaAs/N-AlGaAs heterostructure. Electrons originating in N-AlGaAs transfer to an undoped GaAs region and form quasi-two-dimensional electron gas (2DEG) accumulating at the heterojunction interface. Electron mobility parallel to the interface increased surprisingly with decreasing temperature as shown in Fig. 2 (together with data of sheet electron concentration), which is mainly due to spacial separation between electrons and their parent ionized impurities in this structure. We obtained mobilities of 8,030 cm^2/Vs at 300 K, 117,000 cm^2/Vs at 77 K and 244,000 cm^2/Vs at 5 K with sheet electron concentration of about 4.9×10^{11} cm^{-2}. The mobility at 5 K is much higher than any yet reported for MBE-grown semiconductor materials including similar GaAs-AlGaAs heterostructures. Even at 77 K, electron mobility is almost 25 times as high as that of GaAs with a typical carrier concentration for MESFETs.

Figure 3 shows a structure of the cross section of an enhancement-mode HEMT with a short gate (gate length L_G = 2 μm, gate width W_G = 300 μm). The doping concentration of Si in N-$Al_xGa_{1-x}As$ (x = 0.3, 0.06-μm-thick) and n-GaAs (0.05-μm-thick) layers was about 2×10^{18} cm^{-3}. Current-voltage characteristics of the E-HEMT at 300 K and 77 K are shown in Fig. 4. An apparent increase in transconductance, g_m, was observed at 77 K even when the device was operated in the high electric field region (an average field in the gate region is about 4 kV/cm) where the velocity saturation effect could be significant in GaAs. The value of g_m was as high as 409 mS/mm (measured at V_{GS} = 0.7 V and V_{DS} = 1.5 V) at 77 K, which is, to our knowledge, the highest one reported so far for field effect transistors. Consequently, HEMTs have potential for application to high-speed and low-power dissipation intergrated circuits which would be almost comparable in performance with Josephson junction devices.

References

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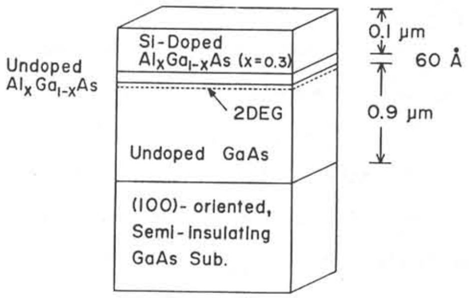

Fig. 1 Schematic diagram of a selectively doped GaAs/N-AlGaAs heterostructure.

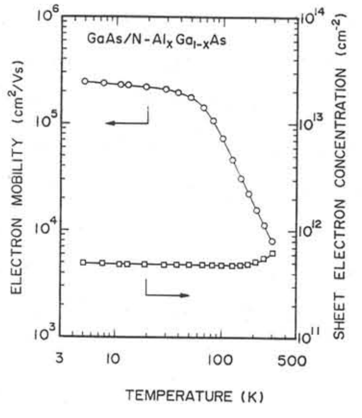

Fig. 2 Electron mobility and sheet electron concentration in GaAs/N-AlGaAs versus temperature.

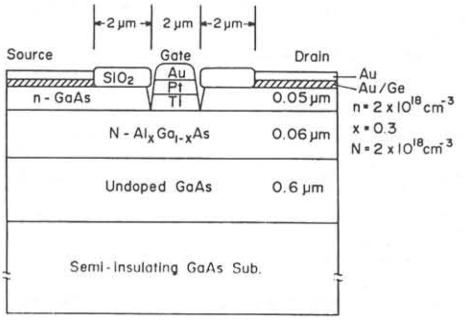

Fig. 3 Structure of the cross section of a short-gate E-HEMT.

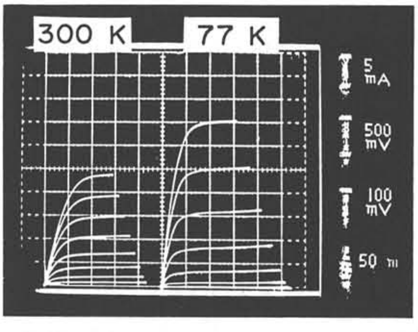

Fig. 4 Current-voltage characteristics of the E-HEMT at 300 K and 77 K: drain current I_{DS}, 5mA/div.; drain voltage V_{DS}, 500 mV/div.; gate voltage V_{GS}, 100 mV/step.