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Comparison of electrical characteristics of metamorphic HEMTs with InP HEMTs and PHEMTs

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1. Introduction

Metamorphic InAlAs/InGaAs HEMTs[1-3] (MHEMTs) fabricated on a GaAs substrate have exhibited superior performance in ultra-high frequency applications. However due to the lattice mismatch between the active layer ($In_{0.53}Ga_{0.47}As$) and the substrate, there is some concern about the existence of defects which would limit the performance for circuit applications. Even though there are many reports which studied the high frequency performance, there are few reports which studied the effects of defects on the MHEMTs' performance in the low-frequency (LF) regime. In this report, we compared the LF noise and the side-gate effect of MHEMTs with those of InP-matched HEMTs (InP HEMTs) and pseudomorphic HEMTs (PHEMTs) on GaAs substrate. MHEMTs have shown superior characteristics to InP HEMTs and PHEMTs.

2. Experiments

MHEMTs are fabricated on $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ heterostructure grown on a GaAs substrate. InAlAs instead of InGaAs was used as a buffer layer to realize high electrical isolation (Fig 1). The step-graded buffer layer (d_{step}=50 nm, In step=0.05) accommodates the lattice mismatch between the active layer and the substrate. The transconductance of MHEMTs was about 500 mS/mm (almost same as that of InP HEMTs).

Figure 2 shows noise power spectral density of MHEMTs, InP HEMTs and PHEMTs with 1.5-μm gate at frequencies below 1MHz. While 1/f noise is observed for MHEMTs, the bulge which reflects the existence of deep level is superimposed on the 1/f noise for InP HEMTs and PHEMTs (as shown by vertical arrows). Moreover, the magnitude of the noise power spectral density of MHEMTs was smaller than that of InP HEMTs and PHEMTs. These results suggest that MHEMTs are better than InP HEMTs or PHEMTs in the view point of transient behavior which is dominated by deep levels. Figure 3 shows Arrhenius plots of the time constant obtained from the temperature dependence of the noise bulge of InP HEMTs and PHEMTs. The activation energy of the noise bulge was 0.38 eV for InP HEMTs and 0.50 eV for PHEMTs, respectively.

Figure 4 shows the side-gate effect of MHEMTs, InP HEMTs and PHEMTs. Drain current was plotted as a function of the voltage of the side gate which was placed about 100-μm away from the channel. The drain current of MHEMTs and InP HEMTs was affected little by the side-gate voltage, as shown in the figure. This is important because the devices can keep almost same characteristics in the integrated circuits without being affected by the voltage of neighboring devices and interconnections. Figure 5 shows the comparison of the side-gate effect of MHEMTs and InP HEMTs. The side-gate effect of MHEMTs is smaller than that of InP HEMTs. Step graded InAlAs buffer layer with high registivity probably plays an important role in attaining small side-gate effect and small LF noise.

The cut off frequencies of the MHEMTs were 210 GHz, 142 GHz and 114 GHz for the gate length of 0.1-μm, 0.2-μm and 0.3-μm, respectively, as shown in Fig 6. These values are one of the highest among the MHEMTs to our knowledge.

3. Summary

In summary, MHEMTs showed superior performance at low and high frequencies opening up the possibility of applying them to high-speed communication systems.

4. References

1) W.E.Hoke, et al.; J.Vac.Sci.Technol. B 17(3), May/Jun (1999) 1131

2) Katsuhiko Higuchi, et al., IEEE Electron Devices, Vol. 46, No. 7, July (1999) 1312

3) D.C.Dumka, et al., IEEE Electron Devices Lett Vol. 22, No. 8, August (2001) 364

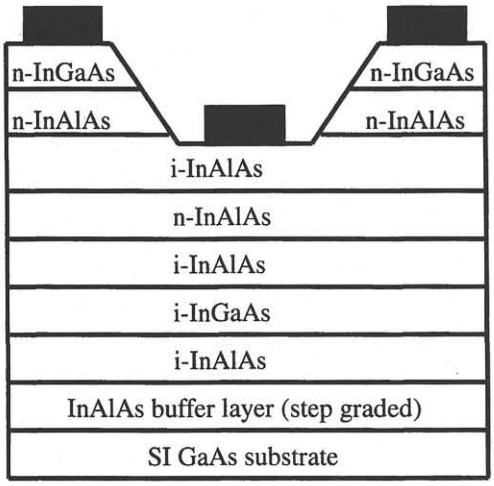

Fig 1. Schematic cross section of MHEMTs.

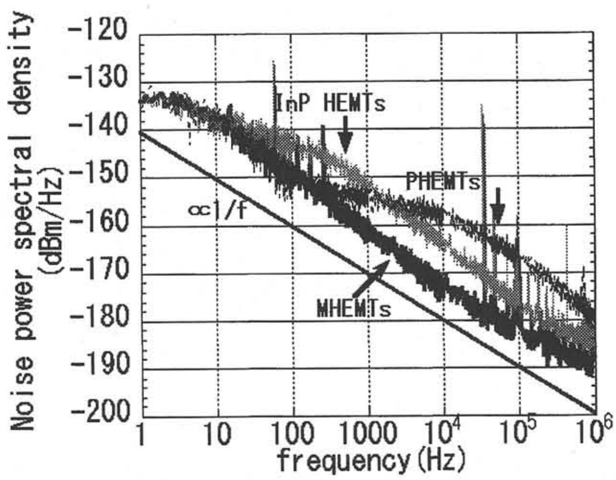

Fig 2. Noise power spectral density of MHEMTs, InP HEMTs and PHEMTs.

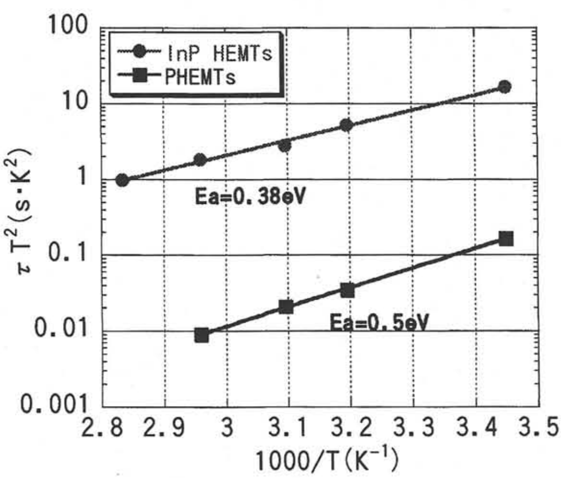

Fig 3. Arrhenius plots of InP HEMTs and PHEMTs.

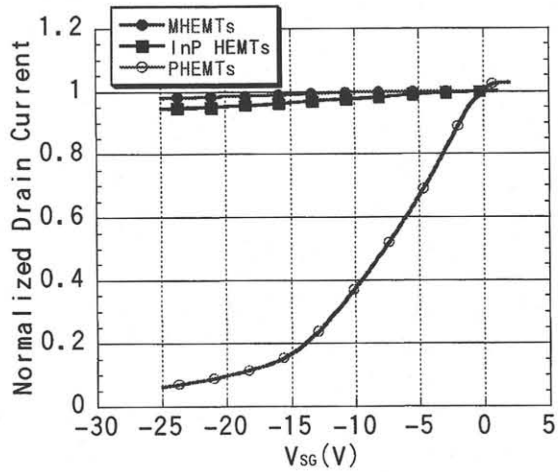

Fig 4. Side-gate effect of MHEMTs, InP HEMTs and PHEMTs.

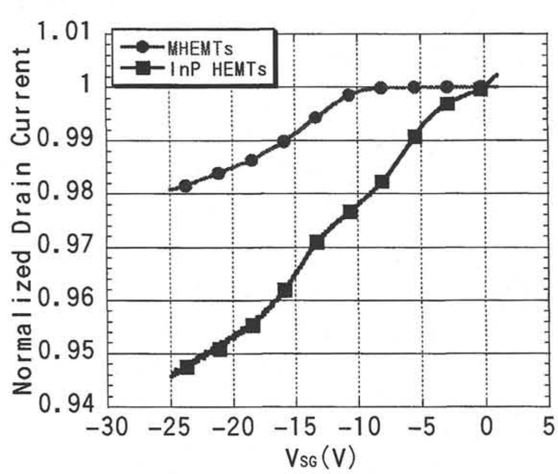

Fig 5. Side-gate effect of MHEMTs and InP HEMTs.

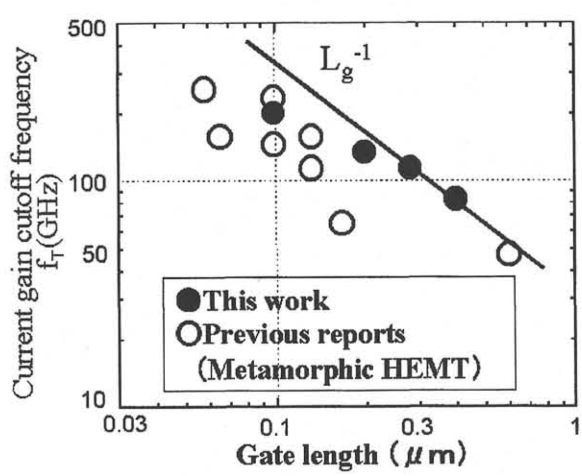

Fig 6. Cut off frequency f_T of MHEMTs.