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Extremely Low-Noise InP-Based Lattice-Matched HEMT Grown by MOCVD

Shinobu Fujita, Takao Noda, Aki Wagai, *Shigehiro Hosoi, and Yasuo Ashizawa

Research and Development Center, Toshiba Corporation, 1 Komukai Toshiba-cho, Saiwai-ku, Kawasaki, Japan, Facsimile: 044-555-2074, Phone: 044-549-2141
***Microelectronics Center, Toshiba Corporation, 1 Komukai Toshiba-cho, Saiwai-ku, Kawasaki, Japan**

The authors have successfully fabricated MOCVD-grown InP-based lattice-matched HEMTs (LM-HEMTs) with excellent noise performance: a minimum noise figure(F_{min}) lower than 0.3dB with an associated gain(G_a) of 15dB at 12GHz. This is the first report on noise performance of MOCVD-grown LM-HEMTs.

InP-based HEMTs have exhibited extremely low F_{min} of 0.8dB at 63GHz[1] and 0.3dB at 18GHz[2] on LM-HEMTs, and 0.23dB at 12GHz[3] on pseudomorphic channel HEMTs. These devices are all fabricated on MBE-grown layers. On the other hand, there has been no report on noise performance of MOCVD-grown HEMTs.

It is essential to reduce noise associated with gate leakage current. By examining Schottky diode characteristics on undoped InAlAs, the reverse leakage current has been revealed to increase largely with residual donor concentration(N_D) in InAlAs, as shown in Fig.1. In the growth of InAlAs by MOCVD, it has been difficult to achieve low donor concentration, since reactive Al sources easily attract unintentional impurity atoms, mainly oxygen and silicon. The authors have succeeded in growing InAlAs layers with N_D of $1x10^{15}cm^{-3}$ by optimizing growth conditions[4], which resulted in reduction of gate leakage current.

A uniformly doped (UD) structure and a planar doped (PD) structure were grown for device fabrication, as shown in Fig.2. Hall electron mobility and sheet concentration of both structures without n-InGaAs cap layers were $10000cm^2/Vs$ and $2.5x10^{12}cm^{-2}$ at room temperature. HEMTs with 0.3- and 0.13-μm-long T-gate on the UD structures, and HEMTs with 0.13-μm-long T-gate on the PD structure were fabricated. These devices have 180-μm gate width. Alloyed ohmic contacts consisting of AuGe/Ni/Au exhibited a typical contact resistance of 0.15 Ωmm. Gate contacts consisting of Pt/Ti/Pt/Au were formed using electron beam lithography and lift-off technique. The devices were fully passivated with silicon nitride by plasma-enhanced CVD. The S-parameters and noise figures were measured using on-wafer probing system, which comprises HP network analyzer, HP8970A noise meter, and Cascade wafer probes.

Table I shows the device performance of the 0.3- and 0.13-μm T-gate HEMTs. Each extrinsic transconductance was a little low, owing to relatively low donor concentration of Si-doped InAlAs. The gate leakage current lower than 10μA/mm at a gate voltage of -1V was obtained for all structures. Cut off frequencies of 140-155GHz are comparable to those reported on MBE-grown HEMTs[1,2]. The 0.3μm T-gate HEMT exhibited excellent noise performance, such as the F_{min} of 0.37dB with a G_a of 14.3dB at 12 GHz. For both of the 0.13-μm HEMTs, the F_{min}s lower than the measurement limit of 0.3dB were obtained, as shown in Fig.3. To the authors' knowledge, these F_{min}s are the lowest ever reported on LM-HEMTs, and are comparable to those of MBE-grown InP-based pseudomorphic HEMTs[3]. This excellent performance is due to the purification of InAlAs layers grown by MOCVD.

References:

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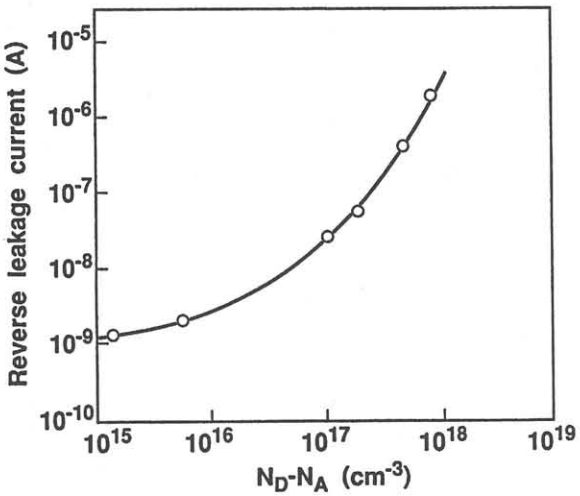

Fig.1 Donor concentration dependence of reverse leakage current of Schottky diodes on undoped InAlAs layers. Diameter of Schottky metals is 200μm.

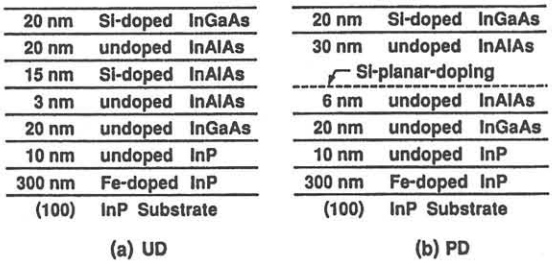

Fig.2. Schematic cross-sectional view of uniformly doped (UD) and planar-doped (PD) structures for HEMT devices.

Structure	UD	UD	PD
Gate Length (μm)	0.3	0.13	0.13
Transconductance (mS/mm)	550	650	700
Unity Current Cut Off Frequency (GHz)	65	140	155
Minimum Noise Figure at 12GHz (dB)	0.37	≤0.3*	≤0.3*
Associated Gain at 12GHz (dB)	14.3	≈15	≈15

Table I
Performance of the uniformly doped (UD) and planar-doped (PD) HEMTs grown by MOCVD. (*The measurement limit of the noise meter HP8970A is 0.3dB.)

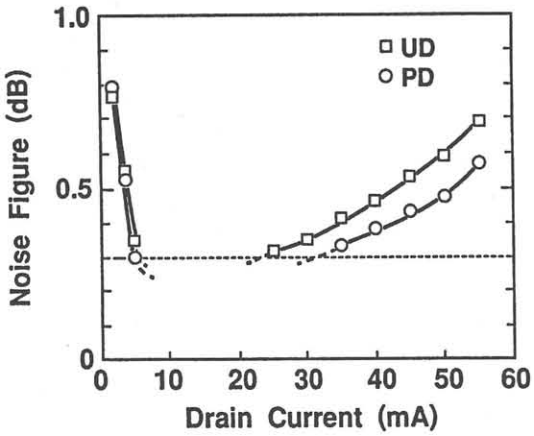

Fig.3. The noise figures at 12GHz of the UD HEMT and the PD HEMT with 0.13 x 180 μm2 T-gate as a function of drain current at the drain voltage of 1V. The measurement limit of the noise figure is 0.3dB.