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B — 5 — 7 MOCVD GaAlAs Hetero-Buffer GaAs Low-Noise MESFETs

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<u>Introduction</u> One of the important factors for performance improvement in GaAs low noise and high power MESFETs is to introduce a good buffer layer between a GaAs active layer and a semi-insulating substrate. GaAlAs is more suitable for the buffer layer material than GaAs itself because the GaAlAs electron affinity is smaller than that of GaAs so that electrons can easily be confined in the GaAs active layer. Power GaAs MESFETs with a GaAlAs buffer layer were reported before[1]. However, high microwave performance was not obtained. The mobility degradation near the buffer layer interface was problematic. In respect to the crystal growth, on the other hand, metal-organic chemical vapor deposition (MOCVD) is a powerful method for GaAs/GaAlAs epitaxial growth, and has higher potentiality in mass-production than molecular beam epitaxy (MBE). However, a high quality GaAs on GaAlAs structure for microwave devices has not been reported yet. Furthermore, this high quality structure is difficult to be grown even in MBE systems at present.

This paper reports that low noise MESFETs on MOCVD GaAs(active)/GaAlAs(buffer) layers exhibited high microwave performance for the first time. It is also noticed that the remarkable transconductance (g_m) increase was observed by cooling those FETs, in spite of the highly doped active layer.

<u>Device Description and Performance</u> Fabricated MESFETs were 0.5 μm-gate flat-structure low-noise FETs (NE388 stile)[2] as shown in Fig.1. Gate width is 280 μm. Two kinds of buffer layer were adopted. One is an oxygen doped semi-insulating $Ga_{0.7}Al_{0.3}As$. Another is a thin deplèted n^+-$Ga_{0.7}Al_{0.3}As$ on an undoped $Ga_{0.7}Al_{0.3}As$ for more electron accumulation near the interface than the former, like the two-dimensional electron gas structure[3]. The carrier concentration of GaAs active layers was about $3 \times 10^{17} cm^{-3}$. These layers were grown successively by MOCVD using TMG, TMA and AsH_3. The active/buffer interface quality was good and the electron mobility did not decrease near the interface.

Figure 2 shows the drain current dependences of the noise figure (NF) and the associated gain (Ga) at 12GHz for an FET with the n^+-GaAlAs buffer layer. The associated gain is considerably high even at the low drain current. This corresponds to large g_m near pinch-off owing to good active/buffer interface quality. Noise figures obtained were 1.15dB (11.6dB gain) at 4GHz and 2.7dB (8.2dB gain) at 12GHz. O-doped GaAlAs buffer FETs also exhibited mostly the same performance. Although these performances are in the same level with conventional GaAs-buffer FETs prepared by halogen transport VPE, such high performances are obtained for the first time for the GaAlAs-buffer MESFET. Furthermore, the distinguished effects regarding GaAlAs buffer layer introduction were revealed in the substrate bias effects (or backgating effects). Drain current modulation with the substrate bias was scarcely observed, especially in O-doped buffer FETs.

Although the expected characteristics, such as smaller drain conductance, higher g_m for the n^+-GaAlAs buffer, and microwave performance superior to conventional FETs have not been achieved yet, this performance is promising for application of GaAlAs buffer layers by the MOCVD technique to practical devices. Further performance improvement can be expected by optimizing device design and growth conditions.

Low Temperature Characteristics Another interesting phenomenon was observed in the low temperature operation of fabricated MESFETs. It is well known that n-GaAlAs/high-purity-GaAs modulation-doped structures enhance the low temperature mobility[3),4)]. In this work, in spite of highly doped GaAs active layers, MESFETs with both kinds of GaAlAs buffer layer exhibited remarkable increase in g_m as shown in Fig.3. Comparison is shown in DC characteristics at room temperature (left) and at 77K (right) for an FET with the n^+-GaAlAs buffer layer. In Table I, source resistance R_s, g_m and its intrinsic value g_{mo} at room temperature and at 77K are compared with those of a conventional GaAs-buffer FET. No matter how the GaAlAs buffer layer was doped, the increase in g_m by cooling was remarkable, compared with that in a conventional FET. This can't be explained by the increase in the low field mobility because the amount of the decrease in the source resistance was small and less than that for the conventional FET. The velocity saturated region probably occupies a large part of the channel region under the gate in such a short channel device, so that the high field transport properties, rather than the low field characteristics, possibly affect that large increase in g_m.

The above results indicate that, except for devices with the modulation-doped structure, MESFETs described here are also foreseen for applications to low temperature equipment.

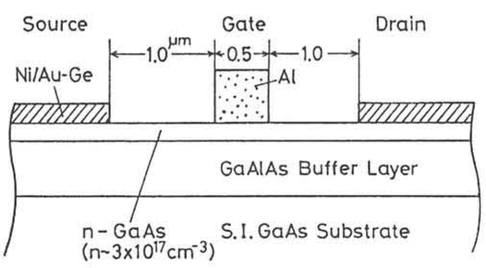

Fig.1 MESFET structure with GaAlAs buffer layer

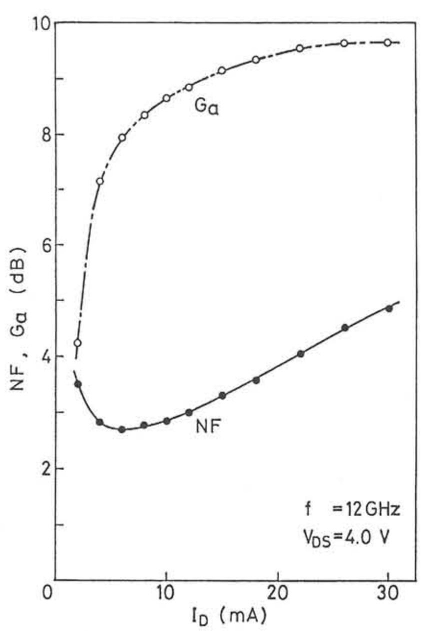

Fig.2 Drain current dependences of NF and Ga

References

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3) T. Mimura et al.; Jap. J. Appl. phys., 19, L225 (1980)
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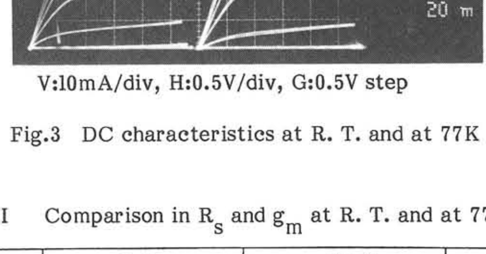

V:10mA/div, H:0.5V/div, G:0.5V step

Fig.3 DC characteristics at R. T. and at 77K

Table I Comparison in R_s and g_m at R. T. and at 77K

Buffer	R. T.			77 K			$g_{mo(77K)}/g_{mo(R.T.)}$
	R_s (ohm)	g_m (mS)	g_{mo} (mS)	R_s (ohm)	g_m (mS)	g_{mo} (mS)	
n^+-GaAlAs	5.5	33	40.3	4.6	45	56.7	1.40
S.I.-GaAlAs	7.2	32	41.6	7.2	40	56.2	1.35
i-GaAs	8.0	30	39.5	6.0	33	42.2	1.07

$g_{mo}=g_m/(1-R_s \cdot g_m)$