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Effects of Deep Level Centers on Microwave Frequency Characteristics of GaAs Schottky Barrier Gate FET

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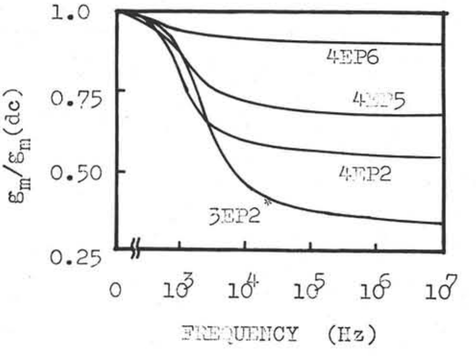
It has been shown that the GaAs Schottky barrier gate FET (SBFET) is a device capable of microwave application and even outperforms Si npn transistors.[1,2] So far, maximum frequency of oscillation as high as 30-40 GHz has been reported.[1,2] The active region of a SBFET usually consists of a very thin (a few tenth of a micron) epitaxial film, which is liable to include unwanted defects and impurities. Therefore, it is important to have high quality epitaxial material in order to realize high frequency FET's. In this paper we report several anomalous phenomena observed in GaAs FET's in the audio frequency range, which can be attributed to field-dependent trapping centers in the epitaxial films. The transconductance g_m is reduced at higher frequencies due to the trapping of conduction electrons, resulting in deterioration of microwave characteristics. Precautions to avoid incorporation of heavy metal impurities have resulted in FET's with satisfactory high frequency characteristics.

GaAs FET's were fabricated using n-type epitaxial layers grown in GaAs/$AsCl_3/H_2$ vapor transport system on semi-insulating substrate. Carrier concentration ranged from 2 to 4 x 10^{16} cm^{-3}, and thickness from 0.2 to 0.46 μm. Source and drain contacts were alloyed Au/Ge/Ni. The Schottky barrier gate was evaporated Mo-Au double layer, 2 μm wide, being spaced 2 μm apart from either source or drain. The aspect ratio Z/L = 250.

Static characteristics of an FET showed hysteresis loops when displayed on an ordinary transistor curve tracer. Such a hysteresis has already been known in GaAs MOSFET and ascribed to deep-lying centers at insulator-semiconductor interface.[3] In contrast to the case of MOSFET,[3] g_m decreased with increasing frequency and approached a high frequency limit at about 10 KHz, as shown in Fig. 1.

Drain saturation current I_{DSS}, pinch-off voltage V_p, and g_m were measured under various biasing conditions. The results obtained for a typical sample are summarized in Table 1. Drain current and pinch-off voltage are considerably larger for pulsed biases than for dc.



* : an FET with 3 μm gate

Fig. 1 Frequency dependence of normalized transconductance

The anomalous characteristics can not be explained by a simple deep donor (or acceptor) model for the trapping centers. Such trapping centers would give rise to I_D and g_m larger and V_p lower at higher frequencies (or for pulsed bias). The nature of the trapping centers responsible to these anomalies is such that continuous (or dc) application of high field (due either to V_{DS} or V_{GS}) results in reduction in the number of conducting electrons. Therefore, the so-called field-enhanced trapping centers4) have to be called for to interprete the experimental results consistently. Furthermore, strongly field-dependent 1/f noise has been found, which provides another evidence for field-enhanced trapping centers.

The unilateral power gain given by

$$U = g_m^2 / \omega^2 C_{gs} g_d R_{eff}$$

is an important figure-of-merit, where g_d is the channel conductance, C_{gs} the gate input capacitance, and R_{eff} the sum of all resistances in series with C_{gs}. Considerable deterioration in U results from reduction in g_m due to the field-enhanced trapping. The high frequency characteristics are correlated with the low frequency anomalies as shown in Table 2.

For the purpose of improving quality of crystal and thereby the high frequency characteristics of FET's, we have employed EDTA treatment and vapor phase etching prior to growing epitaxial films. An FET fabricated on improved crystal, 4EP6, has been relatively free from the effects of deep level impurities and shown an f_{max} (frequency at which U = 1) of 15 GHz.

V_{DS}	dc	dc	pulse
V_{GS}	dc	pulse(hf)	pulse
g_m (m℧)	26	18	22
I_{DSS} (mA)	80	-	120
V_p (V)	4.8	5.2	6.0

Table 1. g_m, I_{DSS}, and V_p under various biasing conditions

sample	$g_m(hf)$ / $g_m(dc)$	f_{max} (GHz)	
		max.	typ.
4EP2	0.58	11.0	6.5
4EP5	0.69	11.0	9.0
4EP6	0.90	15.0	12.0

Table 2. Correlation between f_{max} and the degree of low frequency anomaly (as represented by $g_m(hf)/g_m(dc)$)

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2) K. E. Drangeid et al., Electronics Letters, 6 228-229 (1970)

3) H. Becke et al., Solid State Electron., 8 813 (1965)

4) B. K. Ridley and T. B. Watkins, J. Phys. Chem. Solids, 22 155 (1961)