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THE RELATIONSHIP OF MAGNETOTRANSCONDUCTANCE MOBILITY PROFILES AND RF PERFORMANCE OF GaAs FETs

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ABSTRACT

The mobility profiles of FET channels were measured on fabricated low noise and power GaAs MESFETs, using the recently developed magneto-transconductance technique. The results are used to study the correlation between the RF performance and the material parameter.

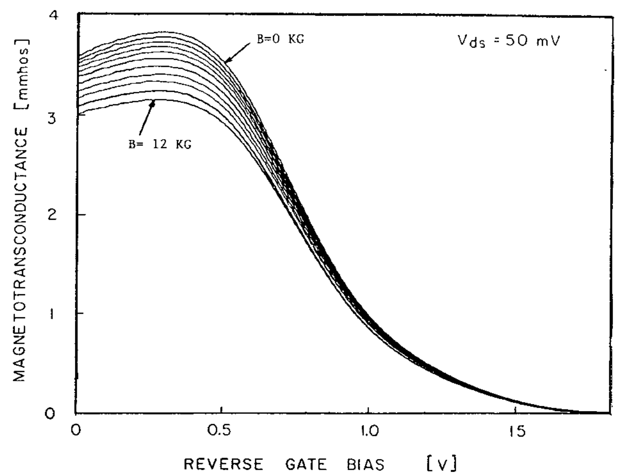
INTRODUCTION

The mobility of majority carriers in the channel of a GaAs MESFET is one of the intrinsic parameters which significantly affect the microwave performance of the device. Device parameters such as the cut-off frequency, minimum noise figure, and maximum available gain are dependent on the transconductance which is directly related to the carrier mobility. However, despite the obvious importance of this parameter, a direct relationship between the mobility and the device performance has not been sought seriously. One of the main reasons was that conventional mobility profiling has to be done either on specially made Hall samples or on FAT FET patterns distributed at various places on the wafer. As a result of non-uniformity across the wafer, it is difficult to seek direct correlation with these indirect measurements. In this paper, we report the use of the magnetotransconductance method [1] to determine the mobility profiles of fabricated FETs mounted on carriers. Since RF measurements on each specific device can be made and correlated with the mobility data, a much more meaningful relationship can thus be sought.

The magnetotransconductance mobility profiling method does not involve capacitance measurements and thus is more accurate at high gate bias. The magnetotransconductance of a FET is resulted from the magnetoresistance of the channel, which increases with the square of the magnetic field perpendicular to the direction of the current flow. The magnetic field dependence of the transconductance is then given by

$$g_m(B) = \frac{g_m(0)}{1+\mu^2 B^2} \quad (1)$$

where μ is the local mobility of the channel just below the depletion region at the gate bias that $g_m(B)$ is being measured. This relationship is valid for a parallel channel with a length-to-width ratio <<1.



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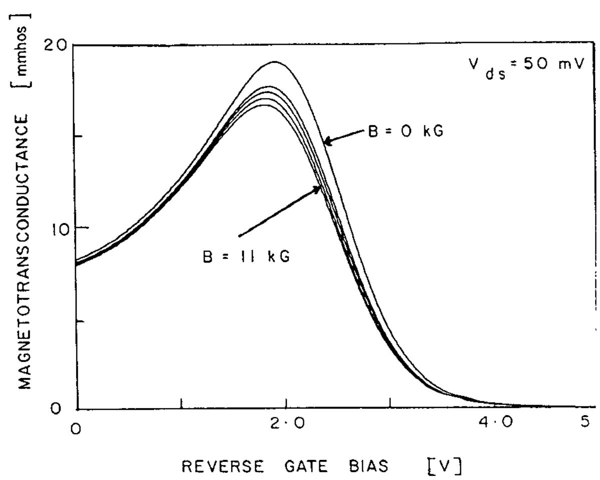

(b)

Fig. 1 Typical magnetotransconductance of (a) low noise and (b) power device.

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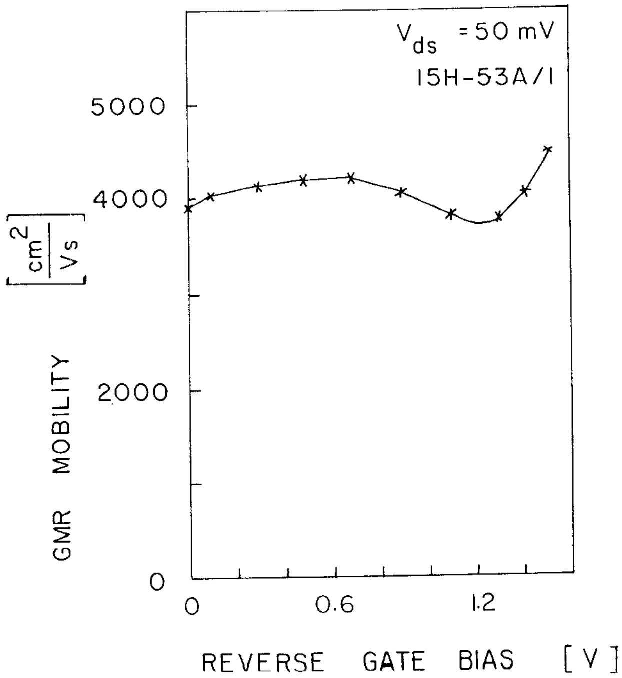
It is well known that the measured transconductance g_m^* is always smaller than the ideal value as a result of degradation due to parasitic resistances. Since measurements are conducted in the linear region in order to maintain a parallel channel, the measured g_m^* is related to the ideal g_m by

$$g_m = g_m^*[1 + \frac{R_p}{R_c}]^2 \qquad (2)$$

where R_p is the total parasitic resistance including the intrinsic source and drain resistances, and lead resistances; R_c is the channel resistance. The correction factor is particularly significant for devices with large gate width and at low gate bias when R_p and R_c have comparable magnitudes.

EXPERIMENT

For the FET to maintain a nearly parallel channel at all gate bias, a constant low drain-source voltage, V_{ds} = 50 mV, was chosen for all the measurements. g_m^*(B) was measured directly with a modulated gate bias. Since g_m^* is a very weak function of magnetic field but increases linearly with the drain voltage, care must be taken in maintaining a stable and constant drain voltage such that the magnetic field dependence will not be affected by the variation of V_{ds}. Shown in Fig. 1 are typical transconductance versus gate voltage plots with the magnetic field as a parameter. The significant difference between (a) and (b) is a result of the different total gate width. Fig. 1(a) is the characteristics of a 0.3 mm low noise device and Fig. 1(b) represents a 2 mm power device. For a large device, though the parasitic resistance is small, the channel resistance is even smaller and results in a large degradation factor, as expressed through eq. (2). As the gate bias is increased, the channel resistance increases and becomes much larger than R_p. g_m^* peaks at a gate voltage that R_c>>R_p and $g_m^* \rightarrow g_m$. Data read from the plots were used to calculate the mobility at various gate bias. Measurements were also made at fixed gate biases while the magnetic field was being scanned. Mobilities deduced from both sets of data agree very well.



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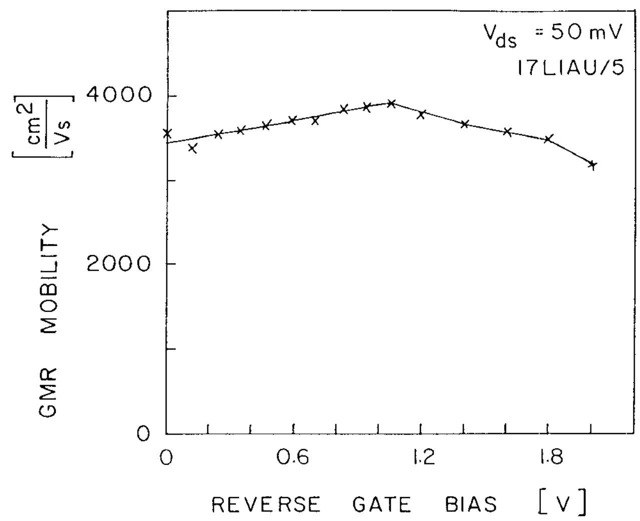

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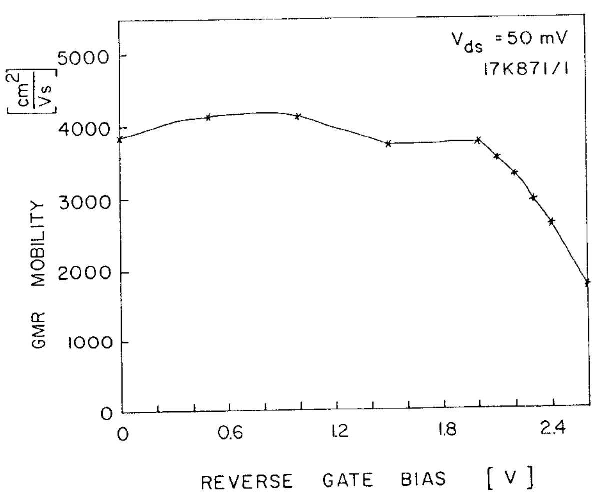


(c)

Fig. 2 Different mobility characteristics of low noise devices.

Mobility profiles of some low noise devices (1 μm x 300 μm) are shown in Fig. 2. They were deduced from the slopes of straight line plots of

$$\sqrt{\frac{g_m^*(0)}{g_m^*(B)} - 1} \text{ vs B}$$

with the measured magnetotransconductances. In these small size devices, we found that parasitic degradation of the resulting mobility profiles is not significant and no correction was made. 15H53A/1 (Fig. 2a), a device with high gain and high power added efficiency, has a mobility profile that most of the channel mobility is ~4000 cm^2/V-sec, with a slight dip just before rising towards the active layer-buffer interface. Shown in Fig. 2b is the characteristics of a device with low gain and poor efficiency. 17K871/1 (Fig. 2c), a device with high gain at low gate bias but poor gain and very noisy at high gate bias, can be correlated with the profile of reasonably good mobilities at most of the channel and sharp degradation as the interface was approached.

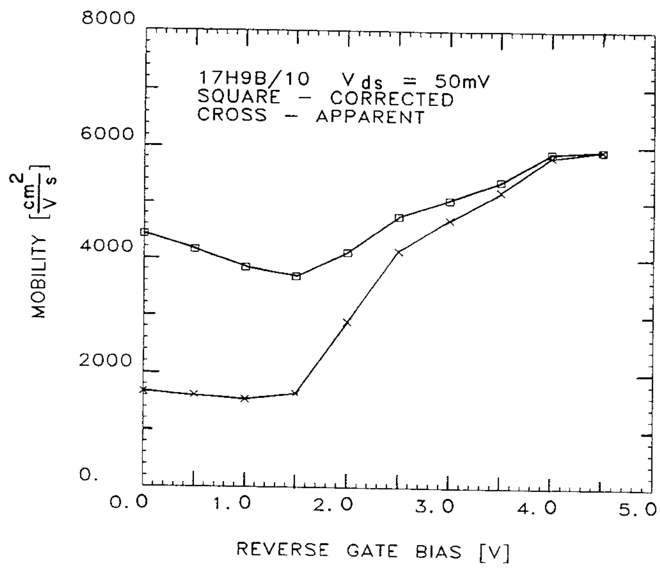
We also studied some 2 mm gate width power FETs for 20 GHz applications. Shown in Fig. 3 are the mobilities deduced from the measured g_m^*, as well as the corrected $g_m^*(B)$. To correct the measured g_m^*, we determined R_D and R_G with the measured transfer characteristics. Without parasitic corrections, the mobilities at low gate bias are so low that little information can be inferred from these profiles. The corrected profile in Fig. 3(a) represents a device with 1 W output power, 4 dB gain, and >20% power added efficiency at 20 GHz. Fig. 3(b) typifies the mobility of a poor device with low gain and power output.

CONCLUSION

We have demonstrated that the magnetotransconductance is a viable technique for measurement of mobility profiles in GaAs MESFETs. It has the advantage over other techniques that measurement can be made on a fabricated device, which makes correlation of material and device parameters much more meaningful. Furthermore, without any capacitance measurement involved, results at high gate bias are more reliable.

For a complete corrected mobility profile, measurements required are transconductances and transfer characteristics. Both can be obtained with high accuracy throughout all gate bias range with appropriate measurement set up. For devices of periphery larger than 300 μm, it is necessary to correct for parasitic resistances before any interpretation of the profiles.

Based on the results we obtained thus far, we may conclude that a device with good RF performance is normally associated with a mobility profile that in most of the channel $\mu \geq 4000 cm^2/V\text{-}s$ and has a rising trend near the active-buffer layer interface. We believe that the increasing profile is not a measurement artifact as in the case of some other measurement techniques.



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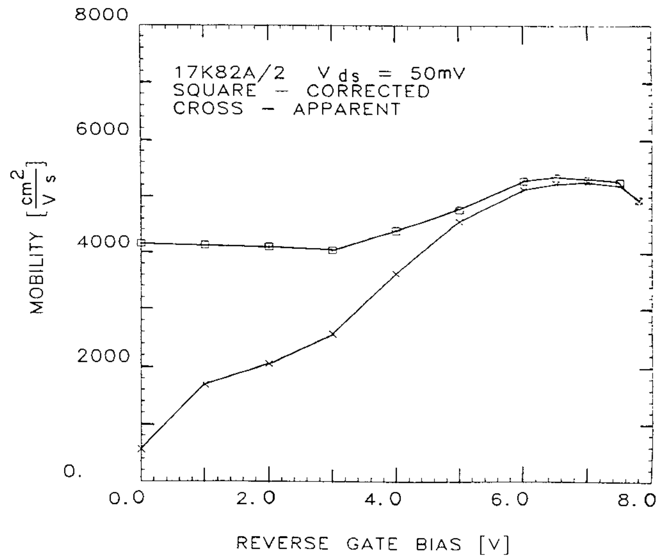

(b)

Fig. 3 Uncorrected and corrected mobility characteristics of power devices.

REFERENCES

[1] P.R. Jay and R.H. Wallis, IEEE Trans. Electron Dev. Lett. EDL-2, 265 (1981).