PSEUDO-RANDOM PULSED IV CHARACTERISATION SYSTEM FOR GAAS MESFET/HEMT DEVICES

J. Rodriguez-Tellez
University of Bradford, Department of Electronic & Electrical Engineering, Bradford, West Yorkshire, BD7 1DP, England
e-mail j.rodrigueztellez@bradford.ac.uk

T. Fernandez, A Mediavilla, A Tazon
Universidad de Cantabria, Departamento de Comunicaciones, Av. De los Castros, Santander, Spain
e-mail tomas@.dicom.unican.es

ABTRACT

A novel experimental system for observing the dependence of the trapping states on electric field for GaAs MESFET/HEMT devices is presented. The new procedure employs a pseudo-random pulse characterisation system for observing the memory effect in these devices. The results indicate that the trapping effect is more serious than may be thought.

INTRODUCTION

In this paper a new measurement technique for observing the dependence of the trapping effect on electric field for GaAs devices is presented. The new experimental method also enables the dependence of the traps on self-heating or ambient temperature to be considered. The results obtained with the new procedure are compared with experimental data obtained with conventional pulsed and static IV characterisation systems. The results indicate that the effect of the trapping states in the MESFET device could be more serious than has been thought of to date.

MEASUREMENTS AND DEVICES

The measurement system employed to investigate the frequency dispersion or hysteresis effect in GaAs devices is shown in Figure 1 Fernandez[1]. The static and pulse power supplies associated with the gate-source and drain-source junctions are identical and completely independent. Through program control a wide range of different measurements can be carried out. For the purposes of this paper the most relevant are:

(i) **Static IV measurements:** These can be performed using different sweep rates to enable the extent of the self-heating effect to be observed. For the results presented in this paper a one second interval was employed for each bias point prior to measuring the drain current. This time is sufficiently long for the device to reach equilibrium conditions from a thermal point of view.

(ii) **Pulsed IV measurements:** These were performed by pulsing the gate-source and drain-source terminals from different static points. Since the pulse widths employed were of 1µs width (with a rise and fall-time of 50ns) with a period of 1ms, no self-heating effect from the dynamic bias conditions are introduced into the device Teyssier et al[2], Parker and Scott[3] and Rodriguez-Tellez et al[4]. Self-heating effects are, therefore, determined by the static conditions employed for the pulse measurements.. The drain current value obtained from this measurement is the average of 16 readings which are taken once the pulse has settled.

(iii) **Pseudo-random pulse IV measurements:** This is a novel pulse IV measurement idea which enables the true extent of the dependency of the frequency dispersion or hysteresis effect on electric field to be observed. A clearer understanding of the method used to implement this measurement can be obtained by considering a specific case. If it assumed that the static supplies are set to V_{DS}=0V and V_{GS}=-1V(the device in the off condition and therefore no self-heating effects) and the drain current at the dynamic bias point of v_{ds}=3V v_{gs}=-0.4V is to be measured then the two step process shown in Figure 1 is employed. The amplitude of the pulses denoted as $v_{ds\ random}$ and $v_{gs\ random}$ in Figure 1 are determined using a pseudo-random algorithm. The maximum and minimum values of these pulses is constrained by the user to fall within a specified bias range. For this case this could be in the 0V to 4V range for the drain-source junction and –1V to 0V for the gate-source junction. The base potential of these pulses is clearly the V_{DS}=0V V_{GS}=-1V static point. After 1µs a further pulse is launched whose base potential is the pseudo-random value and the final potential is the destination value. Once the value of the drain current is noted the pulse amplitude returns to the static bias value and remains there for 1ms. The drain current at the same dynamic point is then measured again using different pseudo-random values. If this process is repeated a large number of times then an accurate appreciation of the hysteresis effect can be obtained. For the results presented in this paper each dynamic bias point was measured in this way using a 1000 samples. This provides a reasonable statistical distribution and because of the speed by which this measurement system performs this task, it is an operation which can be performed quickly. In theory if the device is free of hysteresis effects then the value of the drain current at the point of interest should not vary since the measurement frequency is the same and the thermal conditions of the device remains constant. As will be seen, however, this is not the case and the hysteresis effect is quite significant. It is worth noting that the polarity of the pulses employed for these measurements can be positive, negative or zero. This depends on the value of the static bias point, the value of the pseudo-random bias and the final or bias value to be measured.

To demonstrate the results a 4 finger 225μm gate-width/finger MESFET device from GEC Marconi Materials Research Ltd will be used as a demonstrator. Similar results have been observed with other devices. The device above is an ion-implanted device with a 0.5μm gate-length and a pinch-off voltage of –0.8V.

EXPERIMENTAL RESULTS

In Figure 2 we show the measured drain current of the device at the v_{ds}=4V v_{gs}=0V dynamic point as a function of the pseudo-random drain-source and gate-source voltage. This data was measured from the static bias point of V_{DS}=0V V_{GS}=-1Vand represents 1000 samples. The large change in the drain current as the electric field is varied on either the gate-source or drain-source junctions is quite interesting. The low-pass filter type of characteristics as the drain-source junction potential changes is also worthy of note. This large change in the drain current is also true at other bias points. In Figure 3, for example, we compare the drain current of the device when measured with the pseudo-random method, the normal dc method and the normal pulsed method. For the normal pulsed method the static bias point corresponds to V_{DS}=0V V_{GS}=-1V. For the normal dc method a one second settling time was used to ensure the device reaches equilibrium conditions from a thermal point of view. In a previous article it was clearly proven that the differences between the pulsed (normal) and dc IV characteristics of the device were not entirely due to thermal but frequency dispersion effects[4]. The pseudo-random data presented here re-enforces this point and shows that the memory effect is more serious than may have been thought. A similar picture emerges when a lower drain current area is considered as is shown in Figure 4. This effect is not of course restricted to the saturation region. In Figure 5, for example, we compare the drain current as a function of the pseudo-random drain source voltage for different drain-source destination values. As can be seen in the linear region the dependency of the hysteresis on electric field is just as relevant as in the saturation region. These results indicate a large charge trapping effect in the device equivalent to a capacitance in the region of a few nF. This has been confirmed with low frequency capacitance voltage measurements on the device the results of which will be published at a later date.

The results presented above corresponds in all cases to a device which is at ambient temperature since the operating conditions employed do not introduce any self-heating effect. The dc IV characteristics are clearly exempt from this and the self-heating effect will be significant for this case. As was demonstrated in an earlier paper, however, the self-heating effect introduces small changes to the IV characteristics of the device compared to the frequency dispersion effect. The effect of self-heating on the pseudo-random pulse IV data could, of course, be investigated by simply altering the static bias point. This issue is however beyond the scope of this paper and will be considered at a later date.

SUMMARY/CONCLUSIONS

A new experimental system for observing the dependence of the memory effect in GaAs devices on electric field has been presented and compared with conventional measurement idea. The results indicate a much larger change in the device IV characteristics due to trapping effects than previously thought. This behaviour is true in the saturation and linear regions of operation.

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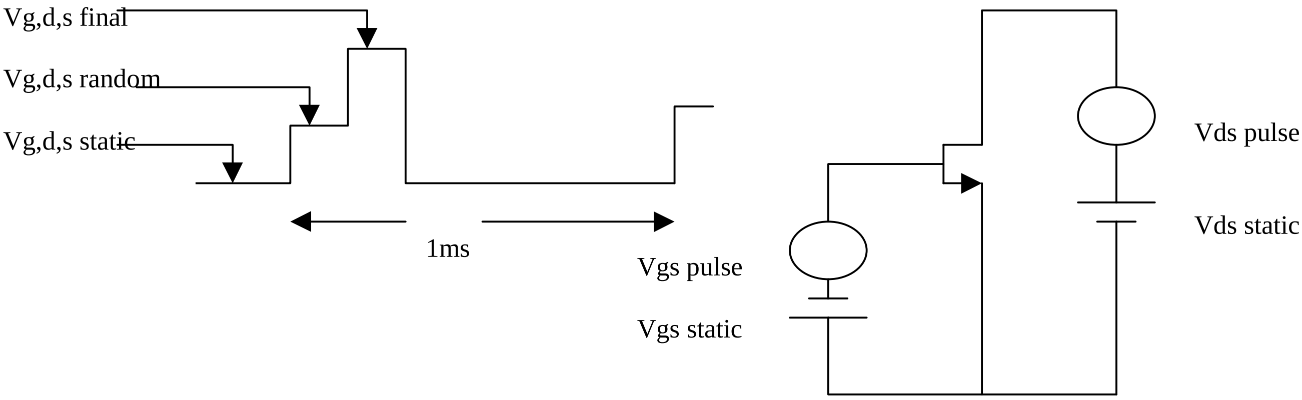

Figure 1 Pulse characterisation system

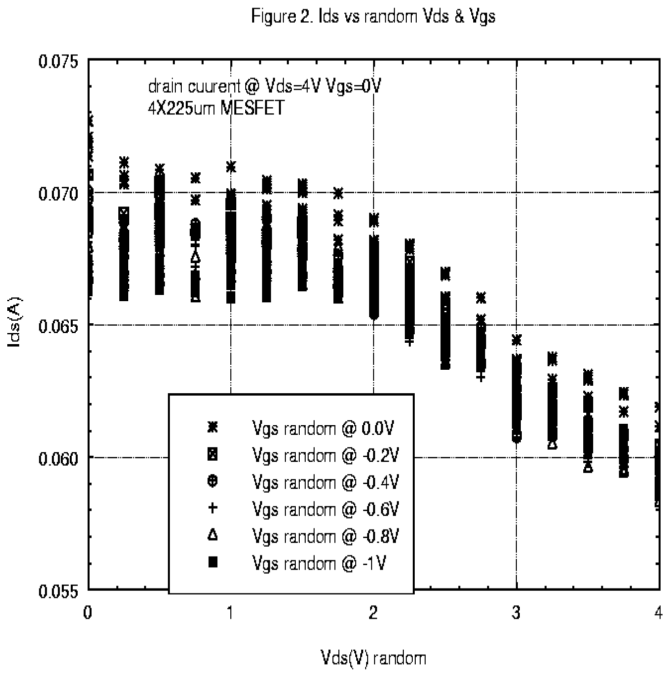

Figure 2. Ids versus random Vds & Vgs

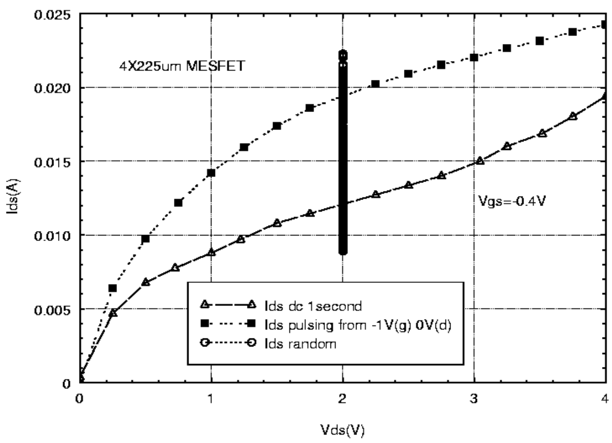

Figure 3 . Comparison of Ids for the Vgs=-0.4V curve

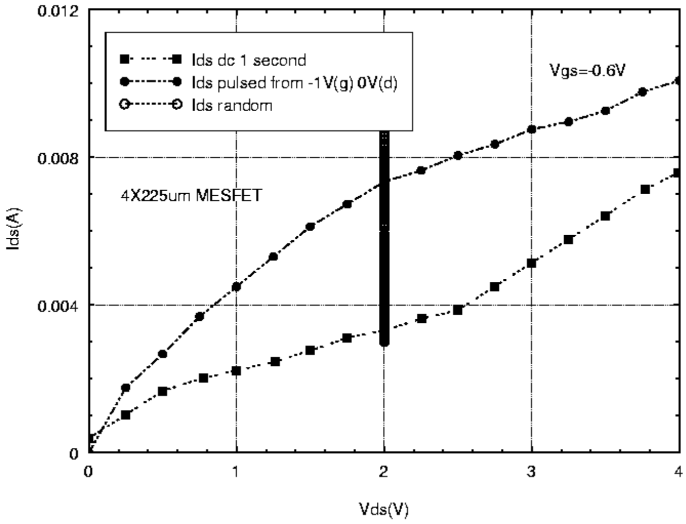

Figure 4. Comparison of Ids for the Vgs=-0.6V curve

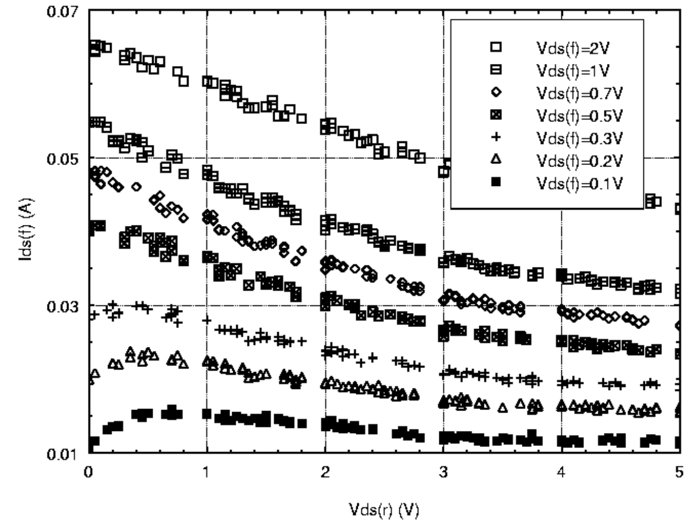

Figure 5. Ids vs random Vds for various Vds destinations