ASM-HEMT DC Geometry Scaling Development

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1. Introduction

High electron mobility transistors based on GaN materials have recently attracted great interest for power and radiofrequency applications [1]. These components can operate under severe environmental conditions in terms of power and temperature. Their physical and structural properties allow them to have a high breakdown electric field (~3.3 MV/cm), high electron mobility up to 2200 cm^2/V [2], high sheet carrier concentrations up to 2×10^{13} cm^{-2} and finally good thermal conductivity. All these properties make this component very attractive and highly demanded in research and industry. In order to use these devices in circuit design and applications, compact modeling of GaN-HEMT based devices is becoming increasingly important. Recently, several standard models are available and have been endorsed [3]. Among these models, there are models which are physics-based (ASM-HEMT), empirical (Angelov-GaN) and artificial neural network-based models (DynaFET). In this paper, the ASM-HEMT physics-based model is evaluated and the DC geometry scaling was improved by introducing additional parameters in the model.

2. Abstract

Physics-based models have several advantages over other modeling strategies. They are scalable in width/length. Excellent fit of DC/S-parameters characteristics could be achieved. Unlike empirical models, physics-based models could correctly predict the behavior of large signal behavior and finally a very good simulation robustness could be implemented. ASM-HEMT model which has been accepted as a standard CMC physics-based model combines all these advantages. Following the extraction procedure of the ASM model, as shown in Figure 1, a very good DC fit between simulations/measurements could be resulted. The device under test consists of 25 nm of $Al_{0.25}GaN_{0.75}$ unintentionally doped layer deposited on a 1µm GaN buffer layer. These layers were grown on a (111) silicon substrate in the $\overline{[0001]}$ orientation. The device is 100nm of length and 25µm of width with two fingers.

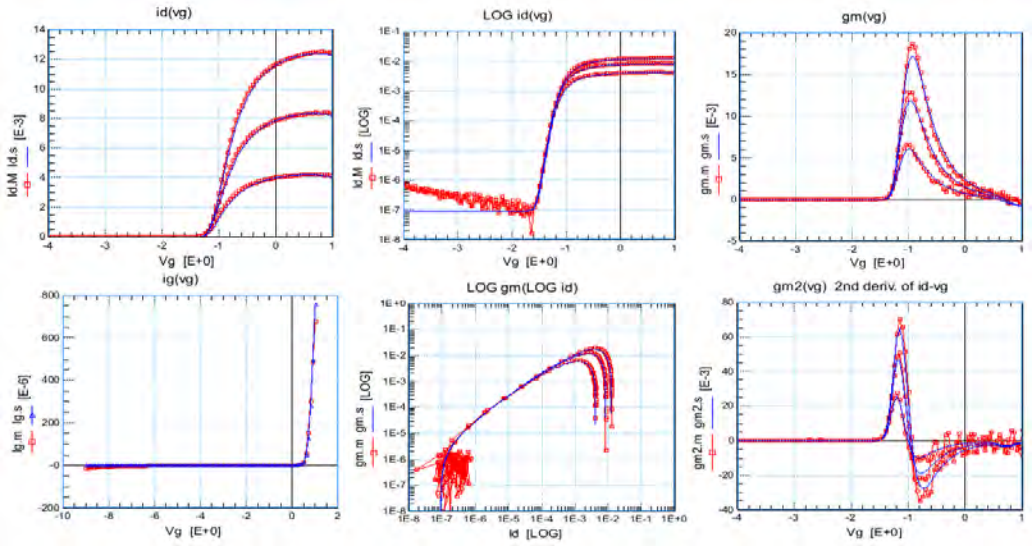

Figure 1. Simulation (in blue) andmeasurement (in red) comparison for different DC linear characterisitics: Ids, Igs, gm and gm derivative as a function of Vgs.

Despite DC characteristics for a single geometry showed a very good agreement, the ASM model shows some weaknesses in the scope of geometry scaling. As shown in Figure 2, we tested the geometry scalability of the model by comparing simulation/measurements for different widths (35µm and 18µm) and an important mismatch is observed. However, this may be due to imperfect geometry scaling that could not be modeled accurately. The non-perfect scalability could be the consequence of several approximations in the model, among these approximations, one could mention the low field mobility, which is geometry independent, the electric field is then considered as completely homogeneous with width variation. Thereafter, parameters such as channel length modulation/saturation velocity are completely considered as geometry

independent. These assumptions may not be very accurate. The doping density inhomogeneity occurs frequently with geometry scaling and especially for non-mature technologies. This last could lead to changes in the different model parameters.

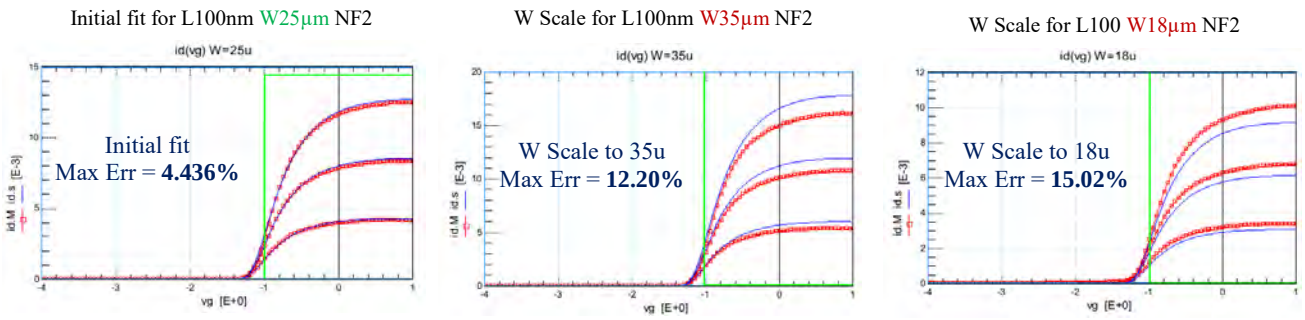

Figure 2. Simulation (in bue) and measurement (in (red) comparaisonfor DC linear characterisitics with ASM-EMT original scaling.

Consequently, the electric field/potential distribution could be considered as width dependent. In order to consider these imperfect effects, scaling rules have been implemented and are added to the ASM-HEMT model. As an example, in the original model [Eq.1], the effective mobility μ_{eff} depends only on the low field mobility $\boldsymbol{U_0}(T)$.

$$\mu_{eff} = \frac{\boldsymbol{U_{0s}}(T)}{1 + U_a.E_{y,eff} + U_b.E_{y,eff}^2} \quad (1).$$

The latter was only temperature dependent. Therefore, we introduced $\boldsymbol{U_{0s}}(T)$ [Eq.2] which is a scaling rule for $\boldsymbol{U_0}(T)$ parameter. W_{EN} presents the normalized width value and $U0VALEXP$ is an introduced fitting parameter.

$$U_{0s} = U_0(T) \times \left[\frac{W_E}{W_{EN}}\right]^{U0VALEXP} \quad (2).$$

Exponent scaling rules were sufficient to obtain a better agreement between measurement and simulation with the different widths as shown in Figure 3.

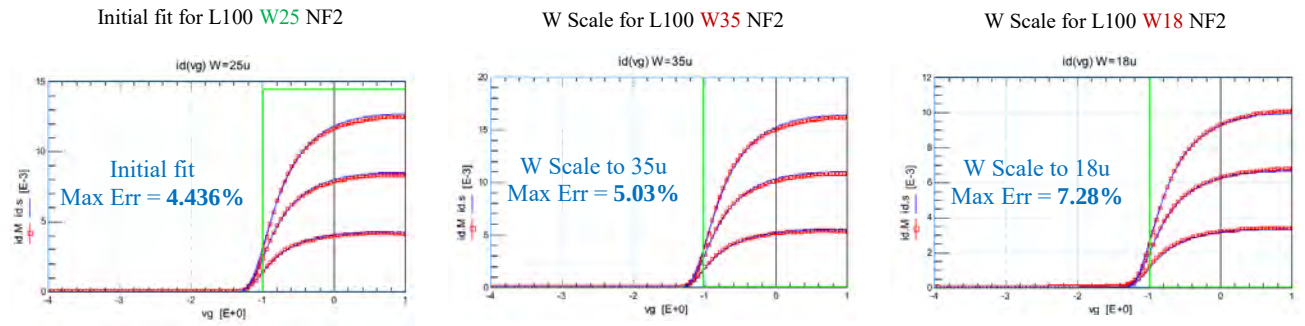

Figure 3. Simulation and measurement comparaison for DC characterisitics after scaling rule was introduced for $\boldsymbol{U_0(T)}$ parameter.

References

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