J. Chem. Chem. Eng. 8 (2014) 324-326

The Effect of Defects on the Mobility of HEMT Transistors Based on AlGaN/GaN

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Received: November 29, 2013 / Accepted: December 18, 2013 / Published: March 25, 2014.

Abstract: A phenomenological low-filed mobility model is developed to describe the dependence of the carrier mobility on the gate to source bias applied for AlGaN/GaN high electron mobility transistor. The results show excellent agreement with experimental data, when compared thereby proving the validity of the model. In the proposed work the temporal evolution of the mobility degradation shows a sharp decline in emission rates below 456 s^{-1}. We also note a sharp decline for large defects densities.

Key words: AlGaN/GaN, HEMT, low-filed mobility model.

1. Introduction

Radical change in microelectronics environment has occurred since the use of cell phone base stations and wireless. The reduction of manufacturing costs needs an increasing integration and use of materials at low cost. It also requires the provision of design tool integrates accurate and reliable models that can describe the physical phenomena that govern the operation of these devices.

The HEMT (high electron mobility transistor) based on AlGaN/GaN are promising candidates for power switching applications [1-4]. The authors' work focuses on the study of AlGaN/GaN HEMT transistors. These electronic components using GaN exhibit performance very attractive for microwave power applications. With a wide band gap of GaN (3.4 eV), high breakdown field, which are required for HEMT and remarkable piezoelectric properties. The study of mechanisms that limit mobility seems an essential step to improve in order to achieve an acceptable device reliability and stability under continuous high performance.

The device performance is greatly degraded by the trap-related. This condition above can be attributed to deep level in the channel or in interface of the structure. The capture and release of the electrons by traps or surface states greatly affect the free carrier concentrations and carrier transport properties, which results in the mobility fluctuation. Consequently, the behavior of defects is the main inherent cause of undesirable characteristics. These defects trap and emit electrons under an electric field influence in the area between drain-gate [5]. DLTS (deep level transient spectroscopy) measurements were used to analyze traps corresponding to surface states and bulk defects [6, 7]. The electrons in the channel are trapped when there is enough activation energy that can come from voltage or heat, they can also be detrapped if the time is long enough or they are activated again. In this work, the authors propose the study of the influence of these defects on the mobility transistors HEMT based on AlGaN/GaN.

2. Model and Mathematical Formulation

The model proposes to highlight the dependence of

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the degradation of mobility over time and depending on the concentration of defects. For this we use the following expression [8]:

$$\mu = \frac{\mu_0}{1+\frac{N}{N_d\delta}\exp(-e_n t)} \quad (1)$$

where, μ_0 is the low field mobility, N is the two-dimensional interface state density of the defect layer, N_d is the donor concentration of structure, δ a thin interfacial layer thickness and e_n the emission rate of an electron by a defect.

3. Results and Discussion

The authors study the structure [9-11] shown in Fig. 1. The parameters of this structure are reported in Table 1.

Fig. 2 shows the evolution of mobility for different emission rates. As evident from Fig. 2, the authors notice a strong dependence between mobility and emission rates for value below 465 s^{-1}. This variation is particularly marked for time lower than 20 ms. For larger time, the curve of mobility versus time is flat. On the other hand the mobility remains almost constant with emission rate for value higher than 465 s^{-1}.

Fig. 3 shows the influence of the defect density on the temporal evolution of mobility. The authors notice that the mobility in AlGaN/GaN HEMT with defects density of 5 × 10^{14} cm^{-2} is a little lower than that with defects density of 2 × 10^{14} cm^{-2}. The degradation observed is particularly marked for time below 20 ms

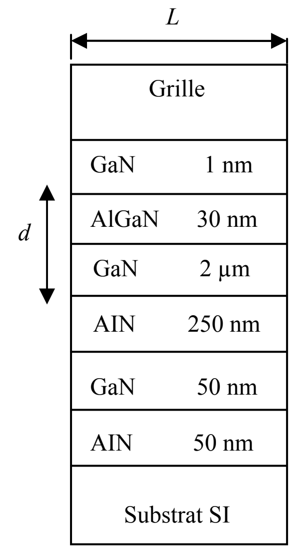

Fig. 1 Diagram of the studied structure AlGaN/GaN HEMT.

Table 1 Parameters of studied transistor.

L (µm)	m (Al%)	μ_0 (cm^2/V·s)
0.15	26	1,750

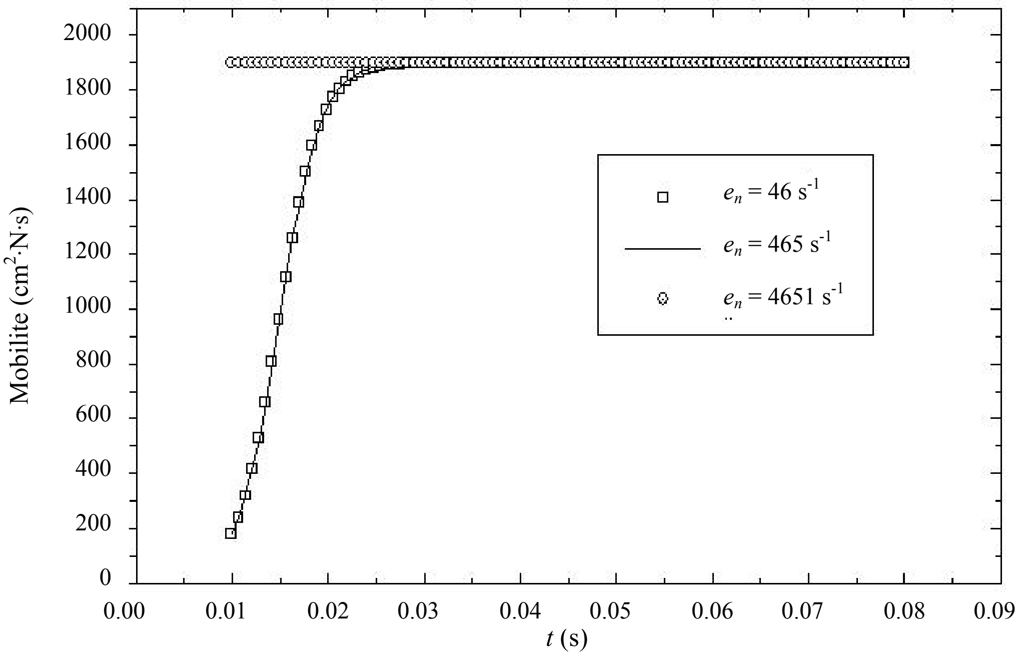

Fig. 2 The mobility evolution versus time for different emission rates.

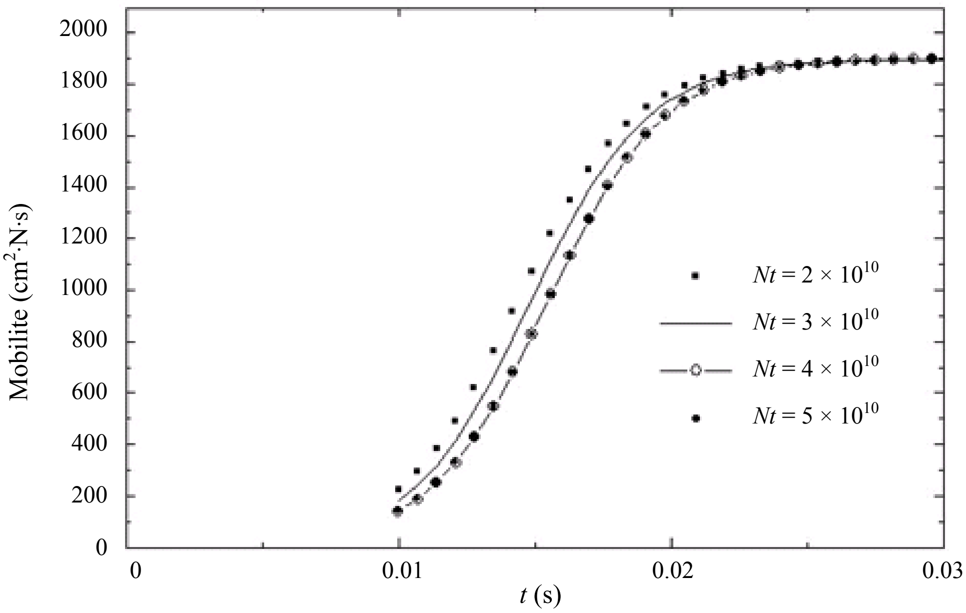

Fig. 3 The evolution of mobility versus time for different defects density.

with defects densities. It is normal because the more the structure has defects more their influence is remarkable.

4. Conclusions

From our analysis, it is concluded that the electrons interact with traps, and the change of emission rate is limiting mechanism of the transport and electron mobility. The decrease of the mobility due to the defects effect is drastically marked for time below 20 ms. For larger time, we observe non-dependence of the mobility on the defects density. The model can be utilized as reliable predictor of devices behavior.

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