Trap Characterization at Different Temperatures in AlGaN/GaN/Si HEMT Structure by the Conductance Method

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1. Introduction

Wide band gap materials, in particular, nitride semiconductors have a potential for applications in power electronics, optoelectronics and microwave communications [1, 2]. Recently, the High Electron Mobility Transistors (HEMT) based on gallium nitride became more useful in intense research and investigations. In addition to their wide band gap, the GaN have excellent electronic properties such as a very high breakdown field, high electrons velocity saturation and good transfer ability [3-5]. In AlGaN/GaN HEMTs, the surface traps on top of AlGaN layer can act as a source of electrons in the channel. In addition to the surface traps, the electron traps can be found in different locations in the device structure including the barrier or channel layers, the barrier channel interfaces or the metal semiconductor interface. The nature and formation of the trap states depend on the material quality and the device fabrication technology. In this context, we are interested in the characterization of the local electrical properties of active layer in order to quantify the effect of the defects. The work presented in this paper consists of an analysis of the traps at various temperatures without illumination in Al₀.₂₅Ga₀.₇₅N/GaN hetero-structure field effect transistors using the conductance method.

The sample used for the present investigation is an Al₀.₂₅Ga₀.₇₅N/GaN hetero-structure, which was grown on a very resistive (111) silicon substrate by Molecular Beam Epitaxy. The gate-source capacitance and conductance measurements used a HP4284A LCR meter in the frequency range from 100Hz to 1MHz. Measurements were performed without illumination at various temperatures from 100K to 430K.

2. Results

In Figs.1 and 2, we show the measured gate-source capacitance and the conductance as a function of the frequency.

We noticed that at low frequency the value of the capacitance increase with the temperature. Dispersion has been observed for all temperature measurement between 100K and 430K. We can also see that in high frequencies for all values of the measured temperatures, the curves converge towards a constant value in the order of 2 pF. However, the measured conductance has an opposite behavior, so the dispersion is clearly observed at high frequencies. We can also notice that at high frequency the conductance increases with the measurement temperature.

Fig. 1 shows curves Gp/ω as a function of pulsation ω calculated from the measured capacitance and the conductance at various temperatures. The examination of the parallel conductance Gp/ω curves show, for all the measured temperatures, a symmetrical shape. We have noticed that the peaks amplitude decreases when the temperature increases, but beyond 310K their values tend to be nearly constant with a shift position towards the high frequencies.
3. Conclusion

Taking into account only one energy level, the fitting results may also be obtained from the conductance data. Results obtained here are in good agreement with \( G/\omega \) curves. The density \( D_i \) and the trap time constant \( \tau \) have been calculated for different values of the temperature. We notice that a time constant and the density of traps, respectively, of the order of 2 \( \mu \)s and \( 10^{12} \) \( \text{cm}^{-2}\text{eV}^{-1} \) were calculated.

References