POSSIBILITY TO DETECT DEEP LEVELS IN ALGAN/GAN HETEROSTRUCTURES BY *C-V* MEASUREMENT

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1. Introduction

AlGaN/GaN heterostructures are still intensively studied as a basic tool for high frequency, high power and high temperature semiconductor devices. One of interesting and still open problems connected with them is influence of deep levels on electrical parameters of heterostructures. Deep levels in GaN and AlGaN layers itself are in most cases attributed to point defects as Ga [1] or N vacancies [2] and are present in GaN also as in AlGaN. To study their influence on electrical parameters *I-V* and *C-V* measurements are commonly used [3]. Between negative effects possibly caused by deep levels, we could name current collapse. These levels are also named traps. The charge in the traps on the surface, interface and/or in the bulk of the heterostructure [4] influences the two-dimensional electron gas (2DEG), causing effects such as current collapse, drain lag, gate and light sensitivity. DLTS measurement has shown that the traps are also situated at the interface [5,6].

2. Theory

To explore influence of deep levels on electrical characteristics of the structures we used drift-diffusion approximation. We have solved simultaneously Poisson and drift-diffusion equations. The population of deep levels depends on the quasi-Fermi level position. Quasi-Fermi level position depends on the charge state of the deep levels.

The problem can be solved only iteratively. A new loop must be given into the computational algorithm. The solution of equations is the potential and charge carrier concentration in the whole structure.

We studied influence of both types of traps, donor-like - neutral when occupied and positive if empty and also acceptor states that are neutral when empty and negative when occupied. Donor-like levels are placed in the lower part and acceptor-like traps in the upper part of the bandgap. We assumed discrete peak distribution of traps in energy with 0.9 eV energy distance from the appropriate band edge.

Simulated AlGaN/GaN heterostructure consists of 25 nm thick AlGaN layer and 75 nm GaN layers. Schottky barrier height at the metal/AlGaN interface was set to 1.3 V. The doping concentrations used were $1x10^{18}$ cm^{-3} for AlGaN layer and $1x10^{17}$ cm^{-3} and $1x10^{16}$ cm^{-3} for GaN buffer layer. The sheet carrier concentration of 2DEG was $8x10^{12}$ cm^{-2}.

The *C-V* characteristics were then calculated as

$$C = \frac{dQ}{dV}, \qquad (1)$$

from the change of the charge in the structure for two very close voltages. Such calculated *C-V* curves correspond to low frequency *C-V* curves.

3. Results and discussion

We used for our simulations different concentrations of deep levels and we found out, that in order the changes in the *C-V* curves should be visible, the traps concentration should be in the 10^{16} cm^{-3} order of magnitude. The change of the *C-V* curve with increasing concentration of deep levels of donor type in AlGaN buffer layer is shown in Fig. 1 only small decrease of the capacitance is observed for the traps concentration in the 10^{16} cm^{-3} order of magnitude. Marked capacitance shift to the left and the capacitance decrease for lower reverse and forward voltages were observed for deep levels concentration $1x10^{17}$ cm^{-3}.

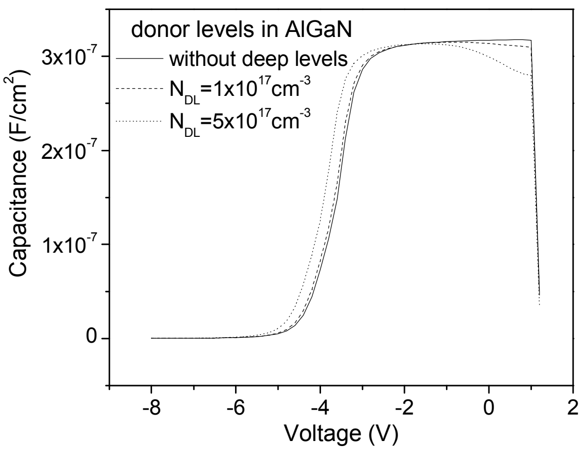

Fig.1: *Influence of the deep donor levels in AlGaN on the C-V curves.*

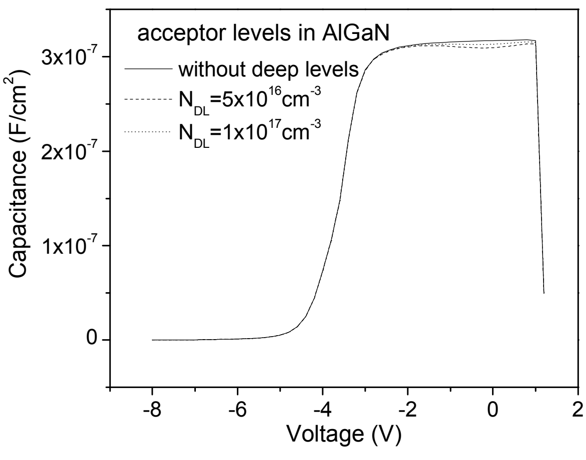

Fig. 2. *Influence of the deep acceptor levels in AlGaN on the C-V curves.*

The curves were simulated for GaN doping concentration $1x10^{16}$ cm^{-3}. For acceptor type deep levels in the AlGaN layer, the simulation shows formation of a valley in the voltage region in which there is approximately constant capacitance for the structures without deep levels (Fig. 2). The depth of the valley is larger for higher traps concentration. Acceptor type traps are occupied in the voltage region where the valley is formed and the consequence is the shift of the charge centroid, which results in lower measured capacitance.

In GaN layer the presence of the donor type deep levels is visible already at lower concentration (Fig. 3). They cause capacitance lowering as is the case for deep levels in AlGaN layer, but we observed also a change of the slope of the capacitance decrease. The capacitance decrease connected with starting of the GaN depletion is not so steep for higher traps concentration since donor type traps under the conduction band minimum located near the AlGaN/GaN interface are populated. For higher GaN doping concentration there are two different slopes of the capacitance decrease. The same effect was observed for the GaN doping concentration dependent *C-V* curves without the deep levels [7].

The influence of acceptor type deep levels in GaN is similar to the one caused in AlGaN. Fig. 4 shows again the capacitance valley but now it is more visible already at lower traps concentration. We did not observe any shift of the *C-V* curves for this type of traps. From our simulation it cannot be simply stated that the deep levels situated in GaN layer influence more the capacitance in reverse bias and the deep levels in AlGaN layer in forward bias [8]. For example, the effect of deep acceptor levels in AlGaN layer is very similar to the effect of deep levels in GaN layer, only the sensitivity of the *C-V* curves for the deep levels presence in GaN is higher than in AlGaN barrier layer.

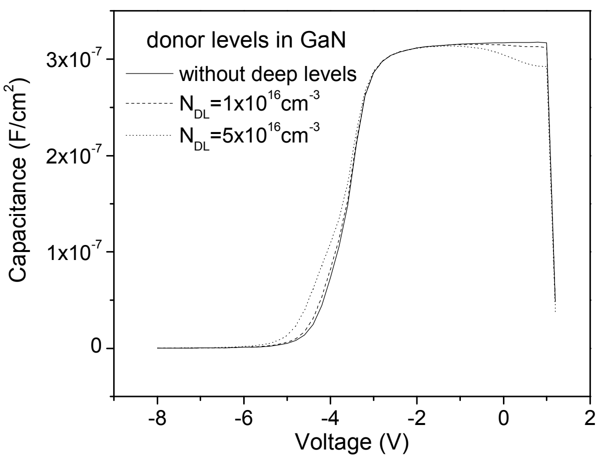

Fig. 3: *Influence of the deep donor levels in in GaN on the C-V curves.*

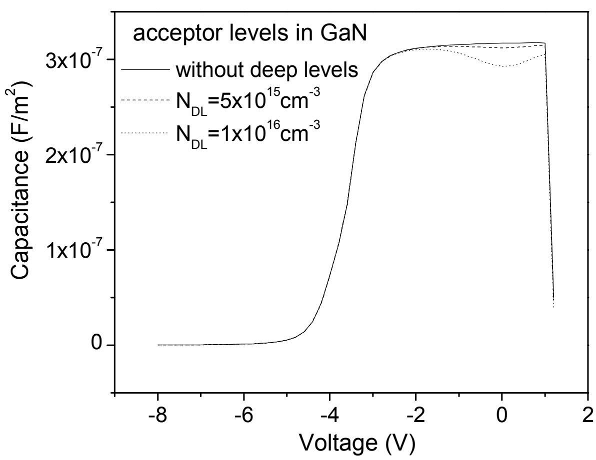

Fig. 4. *Influence of the deep acceptor levels GaN on the C-V curves.*

4. Conclusion

We have shown that the presence of deep levels causes diminishing of the capacitance in the voltage region where there is a capacitance plateau for the state without the deep levels. The donor type deep levels in GaN influence the tilting of the capacitance and for donor type levels in AlGaN the shift of the *C-V* curve toward more negative voltages was observed. Finally, we have shown that the deep levels presence in the AlGaN/GaN heterostructures could be at certain conditions – relatively high deep levels concentration and low frequency measuring signal – detected by standard *C-V* measurement.

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