Effect of AlN Spacer Layer on AlGaN/GaN HEMTs

Niraj Man Shrestha[1], Yuen Yee Wang[1], Yiming Li[2,*], and E.Y. Chang[1,*]
[1]Compound Semiconductor Device Laboratory, Department of Material Science and Engineering
[2]Parallel and Scientific Computing Laboratory, Department of Electrical and Computer Engineering
National Chiao Tung University, 1001 University Road, Hsinchu 300, Taiwan
* ymli@faculty.nctu.edu.tw (Y. Li); edc@mail.nctu.edu.tw (E.Y. Chang)

Abstract - Two-dimensional electron gas (2DEG) formed at AlGaN/GaN interface is a critical part to tune the characteristic of AlGaN/GaN HEMT devices. AlN spacer layer is used between AlGaN and GaN layer to improve 2DEG density, mobility, and drain current. Our device simulation indicates the mobility and current will attain their maximum at the 0.5-nm- and 1.2-nm-thick AlN layers, respectively. For the spacer of device which is thicker than 1.2 nm, the ohmic resistance is increased. Recess ohmic electrodes help to significantly reduce the ohmic resistance.

I. Introduction

AlGaN/GaN high electron mobility transistors (HEMTs) have been the subject of many recent investigations because of their potential to use in high-temperature, high-power devices. One of the most unusual features of these HEMT is that very high 2DEG densities (10^{13} cm^{-2}) can be found in even nominally or undoped heterostructures [1-3]. However, the existence of scattering mechanism plays important role to limit the mobility of 2DEG of conventional AlGaN/GaN HEMT. An additional thin AlN spacer between AlGaN and GaN improves the mobility at low temperatures, where the thickness of AlN is an important parameter for the mobility in AlN/GaN heterostructures [4-6]. In this study, the electron transport for different AlN spacer thickness is simulated. In addition, Ohmic electrode is recessed in order to reduce the ohmic resistance.

II. Simulation and Result Discussion

Fig. 1 shows the schematic of explored device; the device characteristic is simulated by solving a set of quantum mechanically corrected transport equations. Mobility and carrier concentrations are calculated for both the conventional HEMT and the explored new HEMT which is with the AlN spacer layer between the layers AlGaN and GaN. Fig. 2 shows that carrier improved electron concentration on inserting AlN spacer layer, which is mainly due to the increase in the quantum well depth, as shown in Fig. 3. Not shown here, the carrier mobility is also increased significantly. Due to the increase in quantum well depth, the scattering is lowered. Alloy scattering is lowered because binary compound such as AlN has less alloy scattering in comparison to ternary compound [7]. As a result, the mobility is also increased; and, the current is thus increased. We further explore the effect of AlN spacer layer thickness on the device characteristic. Figs. 4(a) and 4(b) show that both the quantum well depth and electron concentration are increased with respect to the thickness of AlN layer. However, the electron mobility increases first, where the maximum appears at the 0.5-nm-thick of AlN layer, it then reduces on further increasing AlN layer, as shown in Fig. 5. This is owing to the Coulomb scattering between 2DEG carriers when very thick spacer layer is used. Fig. 6 shows the simulated drain current at the zero gate voltage. This shows that drain current is maximum when AlN is 1.2 nm thick. Fig. 7 shows that contact resistance is increased for the thick AlN layer. To overcome this effect recess ohmic electrodes are used as shown in Fig. 8.

III. Conclusions

The findings of the different thickness of AlN spacer layer conclude that electron concentration increases with the increases of AlN thickness. The device's mobility reaches the maximum at 0.5-nm-thick AlN layer and the drain current's maximum at 1.2nm thick spacer. The recess ohmic electrodes has been adopted to reduce the resistance.

Acknowledgement

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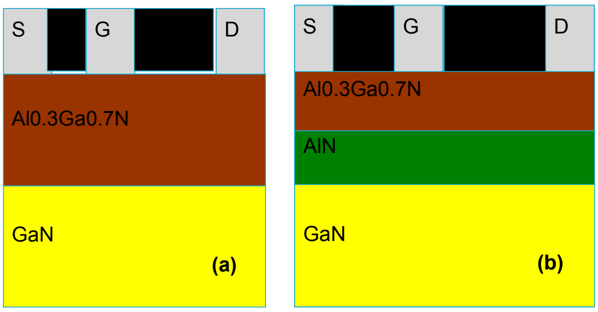


Fig. 1. The simulated structure of HEMTs, where the plots (a) and (b) are without and with the AlN spacer layer.

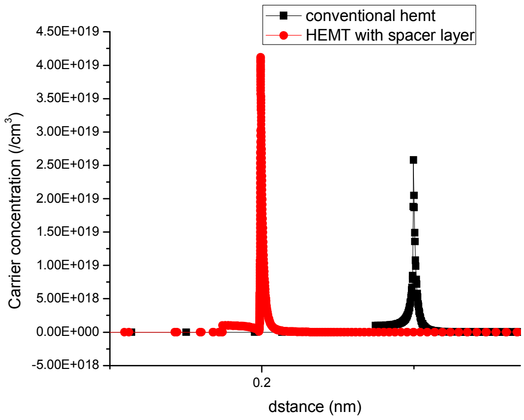


Fig. 2. The electron concentration for the device with and without AlN spacer layers.

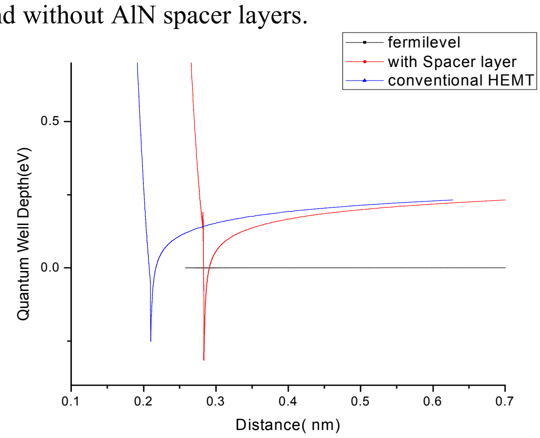
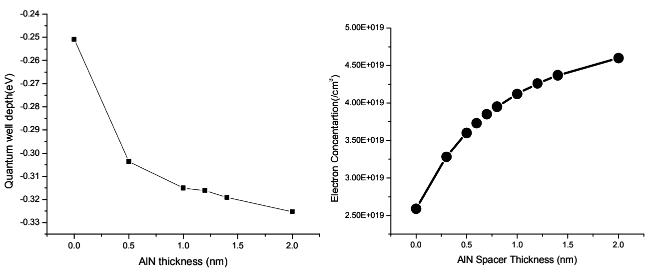


Fig. 3. The calculated quantum well depth for the device with and without AlN spacer layers.



(a) (b)

Fig. 4. (a) The quantum well depth and (b) the electron concentration with the AlN thickness.

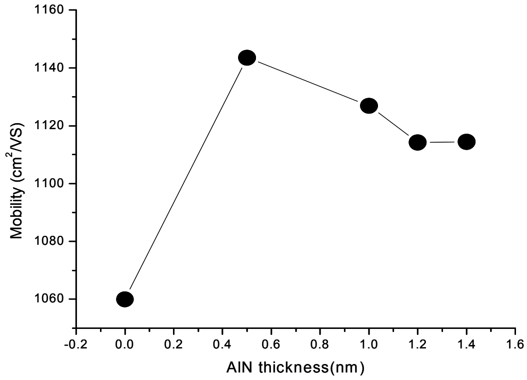


Fig. 5. The mobility versus the AlN thickness.

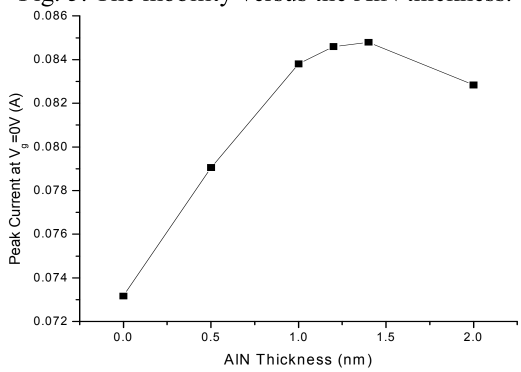


Fig. 6. The simulated current for the device with different AlN thicknesses.

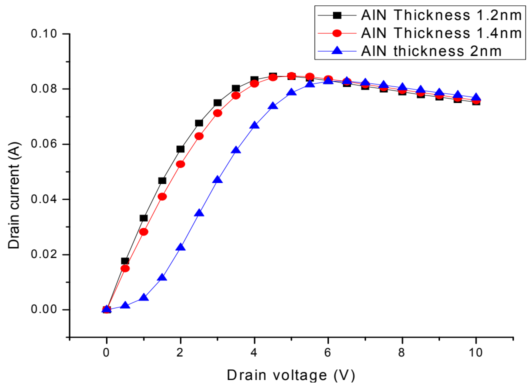


Fig. 7. The drain current versus the drain voltage, where three different AlN thicknesses are simulated.

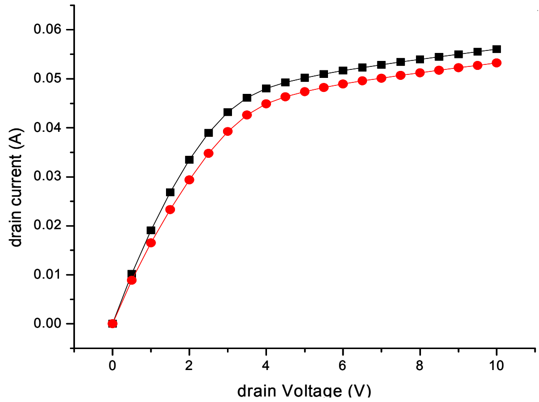


Fig. 8. The I-V for the device with the recess (black line) and without the recess ohmic (red line) electrodes, where the AlN spacer layer is at 1.2 nm.