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HEMT with fluorine implanted below the AlGaN/GaN interface for normally-off operation

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Abstract: AlGaN/GaN HEMTs are promising candidates for high frequency applications with high power and low noise. While switching applications demand normally-off operation, conventional HEMTs are normally-on. To achieve normally-off HEMTs, several structures have been proposed. One of the major normally-off HEMTs uses fluorine implantation in the AlGaN layer. We suggest in this work the implantation of fluorine ions under the AlGaN/GaN interface only below the gate electrode rather than implanting in the AlGaN layer. Simulation results show that the proposed method is capable of achieving normally-off operation and is more effective when it comes to the fluorine concentration required to obtain a desired threshold voltage

Index Terms— Gallium Nitride (GaN), High Electron Mobility Transistor (HEMT), Normally-off, TCAD Simulation, Wide bandgap devices.

I. INTRODUCTION

GaN HEMTs seems to be a very promising candidate for future power applications. Thanks to the GaN properties and the HEMT's topology, AlGaN/GaN HEMTs are now potential candidates for high frequency applications with high power and low noise. While power switching applications strongly demand normally-off operation, conventional HEMTs are normally-on. Several normally-off structures have been proposed such as recessed gate structure [1], fluorine ion treatment [2] and Gate Injection transistor (GIT) [3]. In the normally-off HEMT reported in [2], fluorine ions are implanted in the barrier layer. When this approach is used, small amount of fluorine ions penetrate into the channel, presenting themselves as impurities that lead to mobility degradation. In this paper, we propose the idea of implanting ions in the GaN layer, under the AlGaN/GaN interface, below the gate electrode.

II. SIMULATION RESULTS

To do this study, ATLAS, a physically-based TCAD simulation tool from Silvaco will be used. Physical models used in the simulation include Shockley-Read Hall recombination, Fermi-Dirac statistics and field-dependent mobility.

A. Fluorine implantation in the AlGaN layer.

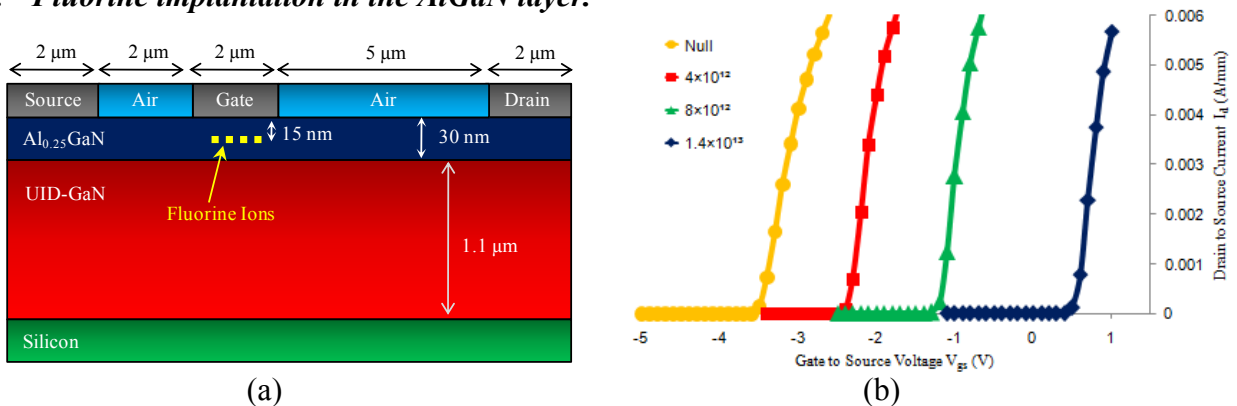


Fig. 1 : (a) Schematic cross-section of the simulated HEMT with fluorine implanted in the AlGaN layer and (b) its corresponding transfer characteristics at various fluorine concentration

Figure 1-b shows the transfer characteristics of the conventional normally-on HEMT (“Null”) and HEMT with fluorine implanted in AlGaN (figure 1-a) at various concentrations. It is clear that, at a certain fluorine concentration ($1.4 \times 10^{13} \text{ cm}^{-2}$), this technique is capable of shifting the threshold voltage to 0.5 V, making the HEMT normally-off.

B. Fluorine implantation in the GaN layer.

Figure 2-b shows the transfer characteristics of the conventional normally-on HEMT and HEMT with fluorine implanted in the GaN layer (Figure 2-a) at different concentrations. As the fluorine concentration increases, the threshold voltage increases to positive values, confirming that our technique is capable of achieving normally-off HEMT.

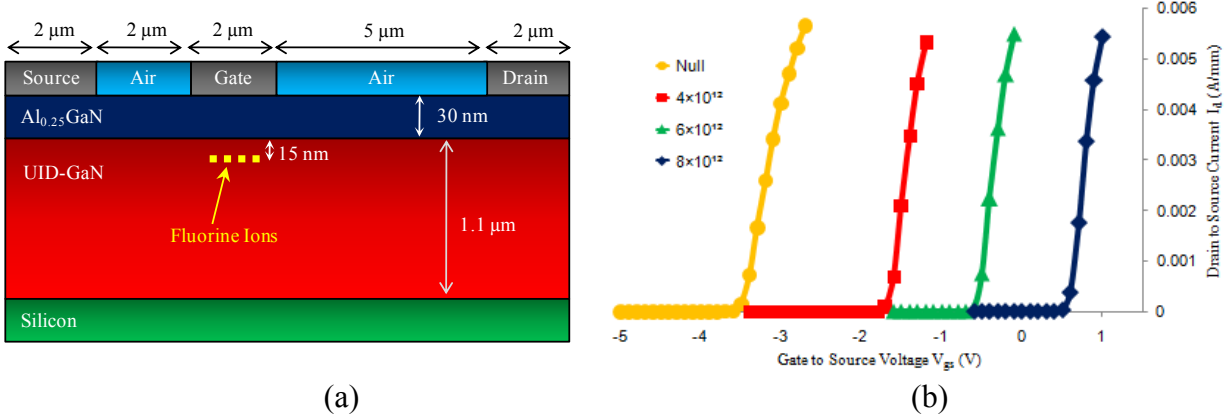


Figure 1 : (a) Schematic cross-section of the simulated HEMT with fluorine implanted in the GaN layer and (b) its corresponding transfer characteristics at various fluorine concentration

It is worth pointing out that although the same threshold voltage of 0.5 V was achieved in both cases after implantation, the fluorine concentration, required to achieve this threshold voltage, is equal to $8 \times 10^{12} \text{ cm}^{-2}$ when the implantation is performed in the GaN layer and equals to $1.4 \times 10^{13} \text{ cm}^{-2}$ when the implantation is done in the AlGaN layer. This makes our proposed technique more efficient since, for the same threshold voltage, higher fluorine concentration is required when implantation is done in AlGaN rather than in GaN.

III. CONCLUSION

In this work, for the sake of obtaining normally-off HEMT, we suggest the implantation of fluorine ions in the GaN layer, under the AlGaN/GaN interface only below the gate electrode, rather than the implantation in the AlGaN layer as previously proposed in other papers. Using TCAD simulation, we have shown that this approach is capable of shifting the threshold voltage to positive values. In addition to that, this technique is more effective when it comes to the concentration required to achieve normally-off operation. Moreover, with this technique, scattering of channel electrons with fluorine ions will vanish, since fluorine is implanted below the channel layer.

ACKNOWLEDGMENT

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