

Optimization of Annealing and Subsequent Processes for Improved Ohmic Contact Resistance in AlGa_{0.3}N/GaN HEMTs

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Abstract—This study investigates the optimization of annealing temperatures and subsequent fabrication steps to improve the ohmic contact resistance of Ti/Al/Ni/Au electrodes on AlGa_{0.3}N/GaN high-electron-mobility transistors (HEMTs). Ohmic contacts underwent rapid thermal annealing (RTA) at 880°C, 910°C, or 940°C for 30s. After device isolation process, further processing steps including 60-nm silicon nitride (SiN_x) deposition, via etching, and metallization were conducted. Remarkably, these subsequent processes reduced the contact resistance by up to 40%, with an optimal final value of 0.44 Ω·mm achieved at the annealing temperature of 880°C. Additionally, a significant decrease in sheet resistance (~30%) was observed after SiN_x passivation. This result underscores the critical role of integrated subsequent processes rather than isolated ohmic contact formation process in reducing final contact resistance in AlGa_{0.3}N/GaN-based HEMTs.

Keywords—AlGa_{0.3}N/GaN HEMTs, ohmic contact, contact resistance, annealing, SiN_x passivation.

I. INTRODUCTION

AlGa_{0.3}N/GaN high-electron-mobility transistors (HEMTs) are promising devices for high-power and high-frequency applications due to their superior electrical characteristics, such as high breakdown voltage and electron mobility. [1] Achieving low ohmic contact resistance is particularly critical for device performance and reliability. [2] Conventional studies have largely focused on isolated optimization of the ohmic contact formation process. [3–5] However, in practical device fabrication, subsequent manufacturing processes inevitably influence the final device characteristics. Thus, examining the combined effect of annealing and subsequent fabrication steps is essential for obtaining optimized ohmic contacts.

In this work, we explore the systematic optimization of both annealing temperatures and subsequent fabrication steps, including SiN_x passivation, via etching, and first metal interconnection processes. Unlike previous studies focused

solely on initial ohmic contact formation, our approach systematically incorporates subsequent manufacturing steps, providing a comprehensive perspective crucial for practical device optimization.

II. DEVICE FABRICATION AND METHODOLOGY

AlGa_{0.3}N/GaN epitaxial structures used in this study were grown by metal-organic chemical vapor deposition (MOCVD) on silicon carbide (SiC) substrates. The epitaxial layers consists of a 2 nm GaN cap layer, a 10 nm Al_{0.3}Ga_{0.7}N barrier layer, a 1 nm AlN insertion layer, and a 250 nm GaN channel layer. [7] Sheet resistance was measured to be approximately 328.1 Ω/□ using a Lehighton system.

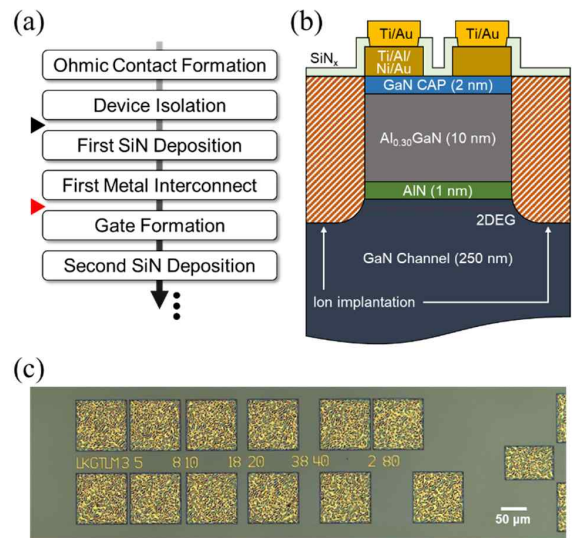


Fig. 1. (a) Fabrication process flow and (b) schematic cross-section of the AlGa_{0.3}N/GaN HEMT device structure used in this study. (c) Optical microscopy image of the fabricated Transmission Line Method (TLM) patterns.

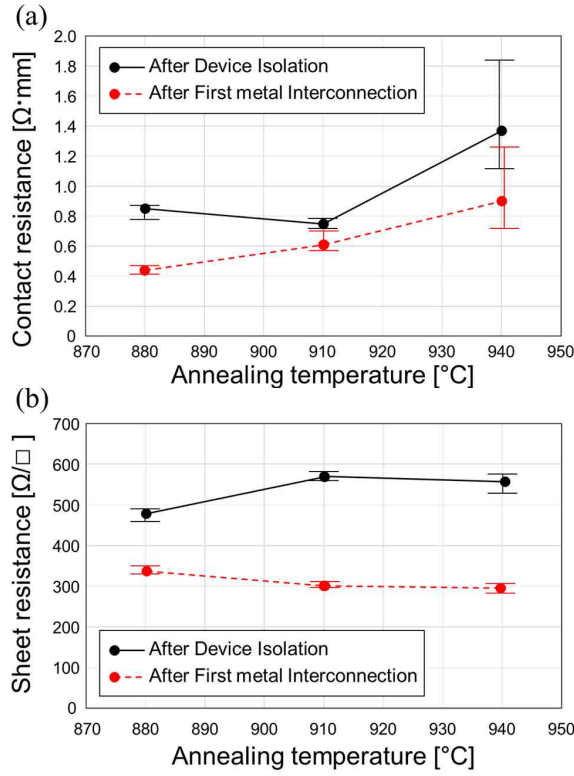


Fig. 2. Measured (a) contact resistance and (b) sheet resistance of the AlGaIn/GaN HEMT samples as a function of annealing temperatures (880°C, 910°C, and 940°C), immediately after device isolation and after completion of subsequent processes (first SiN_x deposition, via etching, and first metal interconnection). Error bars indicate the variation measured across the wafer.

Device fabrication followed the process flow illustrated in Fig. 1(a). First, ohmic contact electrodes consisting of Ti/Al/Ni/Au layers (30/100/30/100 nm, respectively) were deposited. Subsequently, two-step rapid thermal annealing (RTA) was performed: initially at 550°C for 10s, followed by secondary annealing at temperatures of 880°C, 910°C, and 940°C for 30s each, under nitrogen ambient. After the annealing process, device isolation was accomplished through phosphorus (P) ion implantation. Then, a 60-nm-thick SiN_x dielectric layer was deposited by plasma-enhanced chemical vapor deposition (PECVD). Following SiN_x film deposition, via etching through SiN_x was conducted to expose the ohmic metal. Finally, the first metal interconnection was deposited by electron-beam (e-beam) evaporation, as shown in Fig 1(b).

The contact resistance and sheet resistance were measured using the transmission line method (TLM). The shown in Fig. 1(c), TLM patterns were fabricated along with the AlGaIn/GaN HEMTs device, allowing accurate and repeatable resistance measurements.

III. RESULTS AND DISCUSSIONS

Fig. 2 shows the contact resistance and sheet resistance measured at different annealing temperatures, before and after subsequent processes.

Initially, the lowest ohmic contact resistance of $0.74 \Omega \cdot \text{mm}$ was achieved at the annealing temperature of 910°C. However, after completing subsequent processes, significant further improvement in contact resistance was observed. Notably, the 880°C annealing condition exhibited the greatest improvement, reaching the lowest final resistance value of $0.44 \Omega \cdot \text{mm}$, representing approximately a 40% reduction from its initial state.

Additionally, it was observed that the deposition of the SiN_x passivation layer played a key role in reducing the sheet resistance. Initially, the sheet resistance ranged from approximately 480–560 $\Omega/\square$ across the different annealing conditions. After subsequent processing including SiN_x deposition, the sheet resistance decreased to around 300–330 $\Omega/\square$. The optimized SiN_x passivation layer could increase the 2DEG density through induced film stress. [6] Conclusively, the measured sheet resistance was decreased after the subsequent processes, highlighting the beneficial role of optimized SiN_x passivation.

IV. CONCLUSION

In this study, we demonstrated that both annealing temperature and subsequent fabrication steps must be jointly optimized to minimize ohmic contact resistance in AlGaIn/GaN HEMTs. A systematic approach combining Ti/Al/Ni/Au ohmic contacts annealed at 880°C followed by SiN_x passivation, via etching, and metallization yielded the lowest final contact resistance of $0.44 \Omega \cdot \text{mm}$. This study highlights the necessity of considering subsequent processes beyond initial contact formation to exploit the performance potential of GaN-based electronic devices.

Future work will investigate long-term device reliability and further optimization of individual subsequent process conditions to comprehensively improve overall device performance and stability.

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