Addressing Oxidation and Diffusion Challenges in shallow p-GaN Contacts via Mg/SiNx Bilayer Annealing

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Introduction

Achieving low-resistance ohmic contacts to p-type GaN remains a persistent challenge due to the high ionization energy of Mg acceptors and the tendency of Mg layers to oxidize and diffuse uncontrollably [1]. Conventional strategies employing ~50 nm Mg layers often suffer from roughened surfaces and degraded device reliability [2][3]. In this study, we propose an ultrathin Mg/SiNx bilayer annealing method that effectively balances surface protection with controlled Mg diffusion, paving the way for shallow, smooth, and reliable p-GaN ohmic contacts. This advance complements recent progress in two-dimensional Mg intercalation (MiGs) structures, highlighting a broader materials design principle: precise control of Mg incorporation at the nanoscale enables simultaneous improvement in carrier activation and contact properties. The proposed Mg/SiNx bilayer scheme is highly promising for integration into LEDs, HBTs, and p-channel GaN transistors, and ongoing efforts include in-situ TEM analysis of diffusion mechanism

Experimental Procedures

A ~5 nm Mg film was deposited on epitaxial p-GaN, immediately capped with a ~45 nm SiNx layer in vacuum. Rapid thermal annealing (RTA) was performed under N_2 ambient. For comparison, reference samples with thicker (~50 nm) Mg layers and the blank sample were also fabricated. Electrical properties were evaluated by circular transmission line measurement (CTLM), while Mg diffusion depth and uniformity were analyzed using secondary ion mass spectrometry (SIMS) and transmission electron microscope (TEM). Atomic force microscopy (AFM) was used to assess surface morphology.

Results and Discussion

The Mg/SiNx bilayer structure significantly suppressed surface roughening relative to the thick Mg films. AFM revealed smoother morphology, while SIMS indicated a shallower and more uniform Mg profile. Importantly, contact resistance was reduced to levels comparable to, or lower than, those obtained with conventional thicker Mg deposition. The SiNx capping layer effectively prevented oxidation of Mg during annealing, while simultaneously acting as a diffusion barrier to control Mg penetration depth. These results suggest that the bilayer strategy enables reliable shallow ohmic contacts suitable for scaled-down GaN device architectures. Future investigations will include transmission electron microscopy (TEM) analysis of diffusion behavior and exploration of alternative capping layers such as Al_2O_3 and AlN.

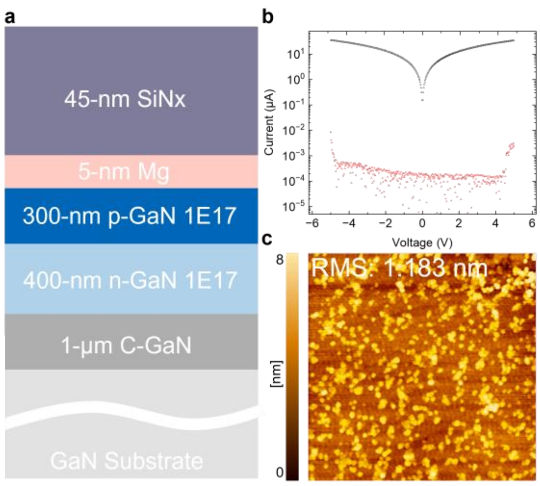

Figure 1 (a) Schematic of the p-GaN/AlGaN/GaN epi-wafer. (b) Typical current–voltage characteristics with and without the annealed thin Mg layer. (c) Atomic force microscope images of the sample surface after Mg annealing.

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References

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