Characterization of Ion Implanted AlGaN/GaN Epilayers for Planar Isolation of High Electron Mobility Transistors

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One of the most important steps during the processing of AlGaN/GaN HEMT structures is electrical isolation of adjacent transistors, which must be reliable i.e. both highly resistive and thermally stable. Commonly used dry-etching process may cause a significant gate leakage current between electrode and MESA sidewall. Alternatively, ion implantation can be used for creation of high-resistivity isolation region, which overcomes problems with the occurrence of leakage current. Moreover, planar implantation-isolation simplifies fabrication process and increases the yield and uniformity of devices.

The aim of this work was to develop ion-implantation process for planar isolation of AlGaN/GaN HEMTs. Our approach is based on the formation of high concentration of vacancies in AlGaN/GaN epilayers using aluminum or carbon ion implantation. Using the simulation in SRIM software we determined parameters of implantation required to create uniform vacancy concentration >$4x10^{20}$ cm^{-3} to a depth of ~0.7 µm. Such concentration level of vacancies arising from irradiation damage was suggested to ensure a sufficiently high resistivity of isolation regions [1]. Energies and doses for Al^+ ions were 300keV - $1x10^{13}$ ion/cm^2, 800keV – $1.5x10^{13}$ ion/cm^2 and 250keV - $4x10^{13}$ ion/cm^2, 520keV – $5x10^{13}$ ion/cm^2 for C^+. For thermal-stability studies we performed annealing in N_2 atmosphere at 400, 600 and 800 °C. To study effects of defect buildup we carried out implantation with higher Al^+ ion doses up to $2.5x10^{15}$ ion/cm^2. Characterization included X-ray diffraction and Rutherford backscattering spectrometry, photoluminescence and Raman spectroscopy. Electrical parameters were evaluated from temperature dependent I-V characteristics of TLM structures.

The electrical characterization shows that the carrier transport in the isolation region occurs via hopping mechanism. Resistivity of as-implanted samples was ~$1x10^{11}$ Ω/sq and reached maximum of $1x10^{14}$ Ω/sq after annealing at 400 °C, then decreased to $1x10^{8}$ Ω/sq after 800°C. XRD studies showed appearance of damage-related peak close to 0004 GaN reflex in the as-implanted samples, originating from the implanted layer with larger lattice parameter than that for GaN matrix. In Raman spectra of as-implanted sample bands associated with vacancies in GaN epilayers were observed, which vanished after thermal annealing. Near-band emission in photoluminescence spectra was not observed in any of the implanted samples proving that the lattice was not completely recovered even after thermal annealing. Defect buildup in samples implanted with high ion doses was confirmed in XRD patterns, RBS and Raman spectra. Resistivity of those samples was decreasing with increasing ion doses to a level of 10^8 Ω/sq for a dose of $2.5x10^{15}$ ion/cm^2.

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