ABSTRACT of the Ph. D. thesis

"Realization, Characterization and Analysis of Epitaxial AlGaN/GaN Two-Dimensional Electron Gas Based Non-Volatile Memory Device Heterostructures"

submitted by

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In this thesis, a comprehensive research has been made on realization, characterization and analysis of epitaxial AlGaN/GaN two-dimensional electron gas (2DEG) based heterostructures for non-volatile memory (NVM) applications. For this purpose, AlGaN/GaN heterostructures are grown on both sapphire (0001) and Si(111) substrate by Cluster Tool Plasma Assisted Molecular Beam Epitaxy (CTPAMBE) with optimized growth conditions. Next, as passivation layer on these $Al_{0.3}Ga_{0.7}N$/GaN heterostructures, silicon nitride (Si_3N_4) is used as active charge-storage insulator for nonvolatile memory devices. A simple metal-insulator-semiconductor (MIS) structure comprising of Si_3N_4 on p-Si substrate is first investigated for initial NVM applications. For this Si_3N_4/p-Si structure, a memory window of 4.6 volt is found with an interface trap density of 6.4×10^{11} cm^{-2} eV^{-1}. Also, charge retention property after applying 5 volt charging voltage for 1 ms, was monitored at measuring voltage 3 volt. This shows increasing capacitance value upto 60 seconds that was sustained for the next 12 hours. On the other hand, the two dimensional electron gas density (2DEG) at the heterointerface is directly involved in Read/Write/Erase operation of the corresponding memory device. Therefore, the enhancement of 2DEG density in view of strain induced piezoelectric charge measurement at $Al_{0.3}Ga_{0.7}N$/GaN hetero interface after Si_3N_4 passivation has been investigated from non-destructive High Resolution X-ray Diffraction (HRXRD) analysis, depletion depth and capacitance-voltage (C-V) profile measurement. All these analytical and experimental studies confirm a significant enhancement of 2DEGs (9% and 8.5%) after 40 nm passivation on $Al_{0.3}Ga_{0.7}N$/GaN heterostructure (on sapphire (001) and Si(111) respectively). The enlarged hysteresis loop of $Si_3N_4/Al_{0.3}Ga_{0.7}N$/GaN heterostructure reveals a large memory window with trap charge density in the order of $10^{12}cm^{-2}$. Finally, the charge retention property of $Si_3N_4/Al_{0.3}Ga_{0.7}N$/GaN structure is investigated for six hours without any charge reduction which signify the reliability of these NVM device heterostructures.