CHAPTER 24

ELECTRONIC SCIENCE

Doctoral Theses

01. ANUPAMA ANAND
Numerical Modeling, Characterization, and Design Optimization of GaN and AlGaN Channel HEMTs for RF and Power Applications.
Supervisors: Prof. Mridula Gupta and Prof. Manoj Saxena, DR. Meena Mishra
Th28698

Abstract

This thesis explores performance optimization strategies for AlGaN/GaN HEMTs in high-frequency, high-power applications, emphasizing gain, linearity, noise, and breakdown voltage. A combination of circuit-level modeling, TCAD simulation, and material/architectural innovations is employed. Small-signal equivalent circuit modeling (16- and 22-element) demonstrates higher accuracy with 22-element models, validated by TCAD simulations calibrated with experimental S-parameters. Barrier thickness and Al mole fraction studies reveal that thinner barriers enhance transconductance and gain, while thicker barriers boost 2-DEG density and current, with trade-offs analyzed for microwave noise performance. Comparative analysis shows AlGaN channel HEMTs offer superior linearity and reduced parasitics, while a thin graded AlGaN buffer improves breakdown voltage without degrading other properties. Field plate engineering on 150 nm gate HEMTs identifies ABSCFP as the most effective for improved breakdown and RF performance together. Overall, the work presents a unified framework linking material properties, geometry, and modeling to optimize GaN HEMTs for low-noise, high-linearity, and high-voltage RF applications, offering guidelines for next-generation communication and power electronics.

Contents

02. PRASHANT KUMAR
Transition Metal Alloy Based Thin Film and Their Application in Spintronics Devices.
Supervisors: Prof. Manoj Kumar Khanna and Prof. Bijoy K. Kuanr
Th28287

Abstract

This thesis is divided into three parts. First part discusses the thickness-dependent structural, morphologic, and magnetic properties of $Co_{20}Fe_{80}$ thin films fabricated by Pulsed Laser Deposition (PLD). The results are a comprehensive insight into the important impact of film thickness on the crystalline structure, surface morphology, and magnetic characteristics. In the second part the effects of growth temperature on magnetization dynamics of sputtered Co40Fe40B20 thin films deposited on a different substrate as well as thickness variation on SiO2 and application in microwave devices, were studied. Through systematic experimentation, we have demonstrated that growth temperature and thickness-driven modifications crucially affect the structural and magnetic properties of Co40Fe40B20 films that are essential for their application in spintronic and microwave technologies. This part also investigates thoroughly the effect of growth temperature on structural, morphological, and magnetic properties of sputtered nickel (Ni) thin films. In the last part three different films such as Single layer CoFeB thin film of 20 nm, bilayer CoFeB(20nm)/Ta(04nm) and tri-layed structure of CoFeB(20) /Ta(04) /Ni(20) film using a sputtering technique at 250℃ on Si/SiO2 substrate were fabricated. A controlled oxidation process was used to thermally oxidize top Ni layer in order to form Ni to NiO of tri layered thin film. The oxidation process was performed at four different temperatures i.e. 250, 350, 400, 450℃ in presence of oxygen gas. The transition of Ni to NiO was observed by XRD and Raman spectroscopy. The static and dynamic magnetization properties were analyzed by VSM and FMR respectively. The dynamic magnetic response indicates an enhancement in the damping parameter which can be seen as a result of the spin moment across the ferromagnetic/ nonmagnetic interface. The observed result indicates that the magnetic properties of heterostructure change as Ni is converted into NiO. The interface quality and FMR induced spin pumping can be characterized by measuring effective spin mixing conductance (g_eff^(↑↓)).

Contents

1. Introduction 2. Thin Film Fabrication and Characterization Technique. 3. Thickness dependent structural, morphological, and magnetic properties of PLD grown CoFe thin film. 4. Influence of growth temperature on the magnetization dynamics of sputtered CoFeB thin films on various substrates and their microwave device functionality 5. Effect of Ferromagnetic Layer Thickness on the Static and Dynamic Magnetic Properties of Sputter grown CoFeB thin Film. 6. Effect of Growth Temperature on the Structural, Morphological and Magnetic Properties of Sputtered Ni -thin Film 7. Impact of Gradual Ni to NiO Oxidation on Magnetization Dynamics in Sputtered CoFeB/Ta/Ni Heterostructures. 8. Conclusion and Future Perspective.

03. SEHRA (Khushwant)
Design and Evaluation of Advanced GaN HEMT Architectures for High-Power, High-Frequency, and Radiation-Hardened Applications.
Supervisor: Prof. Manoj Saxena
Th 28288

Abstract

This thesis investigates advanced GaN HEMT architectures to enhance performance and reliability in high power, high frequency, and radiation hardened applications. The research begins with a comprehensive analysis of conventional GaN HEMT designs, identifying critical bottlenecks such as suboptimal electrostatic control and carrier confinement. This limits device performance under high bias and electric field conditions. To address these challenges, the study introduces innovative modifications including the implementation of a Π – Gate architecture and back barrier techniques. These modifications mitigate issues such as drain induced barrier lowering (DIBL) and parasitic leakage, thereby improving RF performance and overall device robustness.

Extensive simulations were carried out to evaluate the modified architectures under varied operating conditions, including exposure to heavy ion strikes and γ – ray irradiation using a 60Co source. Results indicate that the field modifications due to Π– shaped Gate, significantly reduce performance degradation and enhance the reliability of GaN HEMTs, particularly in harsh space radiation environments. The thesis further explores the implications of these findings for next generation mmWave and space electronics, demonstrating that the optimized GaN HEMT designs offer substantial advantages over conventional device architectures. The outcomes not only contribute to a deeper understanding of high-performance wide bandgap semiconductors but also pave the way for future advancements in Defence and Space applications. Overall, this work systematically investigates the challenges mentioned above and explores the efficacy of Gate engineering techniques to mitigate several reliability issues for aforementioned applications.

Contents