CHAPTER 13

ELECTRONIC SCIENCE

Doctoral Theses

01. BANSAL (Monika)
Modeling and Simulation of Ferroelectric FETs with Advanced Channel Materials for Improved Reliability and Energy Efficient Applications.
Supervisor: Dr. Harsupreet Kaur
Th 25957

Abstract

For the past 5 decades, CMOS devices have been continuously miniaturized to meet the ever-growing needs of high speed computing with low power dissipation. The downscaling of devices has made integrated circuits (ICs) denser, smaller in size, and portable. However, in the current era of CMOS technology where 10 nm and 7 nm technologies are in the talks, it has become very difficult to further miniaturize devices and pace up with the Moore's law. The reasons behind the lacking pace of miniaturization are the consequences of downscaling also known as short channel effects. Among these effects, the major road blocks are threshold voltage roll-off, drain induced barrier lowering (DIBL), poor current drivability, and large leakage currents. These issues have been dealt with the innovation of advanced device designs such as channel engineering, gate dielectric engineering etc. Various nonconventional device structures such as Silicon-On-Insulator (SOI), Double Gate (DG), Tri-Gate (TG), FinFET etc. have improved the device performance in nanometer regime. However, these above mentioned alternatives in sub-10 nm regime cannot achieve low static power dissipation along with high performance. In order to reduce power dissipation, a unique phenomenon of Negative Capacitance (NC) effect exhibited by ferroelectric materials has been gaining popularity which reduces the subthreshold swing value below 60 mV/dec. The NC effect of ferroelectric materials helps in increasing the total gate capacitance more than both semiconductor and insulator capacitances. Due to this, the surface potential increases more than gate voltage in a small range leading to voltage amplification which reduces the subthreshold swing values below its lower limit of 60 mV/dec. There are various known ferroelectric materials which exhibit negative capacitance effect such as Strontium Bismuth Tantalate (SBT), Lead Zirconium Titanate (PZT), doped Hafnium Oxide (HfO2) etc. All these materials possess different ferroelectric properties such as coercive field, remanent polarization, Curie temperature etc. However, perovskite ferroelectrics such as SBT and PZT have very high dielectric constant which restricts the scaling of layer thickness to 50-70 nm due to which these materials are not suitable for ultra scaled devices. Whereas doped HfO2 materials have comparatively very low dielectric constant due to which these materials can be scaled down upto 3-5 nm of layer thickness and hence, are compatible with current CMOS technology. Further, the introduction of advanced high mobility channel materials has been proposed in last few years to improve the carrier mobility and current drivability in FETs. Among various semiconductor materials, Germanium (Ge) possesses highest hole mobility which makes Ge suitable for high performance p-channel MOSFETs. In addition, Germanium devices are easy to fabricate with the existing Silicon technology process flow since Ge resembles Silicon in structure as they both are

group IV elements. Other than Ge, Silicon-Germanium (SiGe) and Germanium-Tin (GeSn) semiconductor materials have higher carrier mobilities than Si and thus, can replace Si in future CMOS technologies. In addition to the high mobilities, these channel materials also have lower bandgap than Silicon which is required to scale the supply voltages while maintaining high performance of circuits.

Contents

02. CHAUDHARY (Prashant)
Design and Development of Microwave linearly/ Circularly Polarized Antennas With Metasurface for Mimo Application.
Supervisors: Dr. Kamlesh Patel and Dr. Ashwani Kumar
Th 25962

Abstract

Multiple-input and multiple-output (MIMO) technology is the foundation of high-speed communication technology, especially for 5G and many new upcoming technologies. Although a considerable amount of work has been published in the literature, multiple antenna systems provide much better data speed and link quality. Significant papers are published on planar low profile MIMO antenna with a wideband linear polarization. They are mostly limited to planar designs that can't cover all the whole angular space, even though the main challenge is in planar MIMO antenna to get a wideband circular polarization. Therefore, the purpose of the work in this thesis is to design wideband circularly polarized monopole antennas and then the development of MIMO antennas with pattern and polarization diversity. For this purpose, both linearly polarized and circularly polarized monopole antennas are designed, and these monopoles have been systematically used to design several new MIMO antennas with both pattern and polarization diversity. Further, the pattern and polarization diversity concept is used in 3D prism-shaped and cubic-shaped antennas. 3D antennas are designed to get 360o angular coverage in the space with polarization diversity. The metasurface is also adopted in the design to improve circular polarization and gain of the antennas. A unique concentric scalable metasurface polarizer is presented in transmission mode, and a sandwich metasurface is designed in reflection mode to convert linear to circular polarization. Finally, the metasurface is used to enhance the gain of the circularly polarized antenna.

Contents

and reflection mode) Conclusion and future scope of work. Bibliography and Reprint of publication.

03. DUBEY (Avashesh)

Modeling and Simulation of Radiation Induced Effects in Field Effect Transistors.

Supervisors: Prof. Mridula Gupta and Dr. Manoj Saxena

Th 25955

Abstract

In the last few decades, the commercial semiconductor industry based on MOSFET has been heavily influenced by the development of military and space electronics as the demand for highly scaled and lower power consumption devices is increased. Various new MOS based architectures have been proposed to overcome the scaling limits and the power dissipation problems. However, reliability is the primary concern when these devices are to be used in the high energy radiation environment. The exposure of ionizing radiation such as gamma rays, X-rays, heavy ions, and cosmic rays can cause hazardous effects in nano-scale devices. These effects can be total ionizing dose effects, single event transient effects, crystal defects, and other reliability issues. This imposes the need for the CMOS device that should be radiation hardened. The dissertation aims to investigate the effects of radiation on the devices such as Junctionless Double Gate MOSFET, Junction-less Accumulation Mode MOSFET, Floating Gate Junctionless Double Gate MOSFET, and Tunnel FET. The entire work on radiation effects has divided into two categories: radiation sensitive and radiation-hardened. Both have different applications in space and nuclear laboratory, radiation-sensitive device can be used as radiation dosimeters, and the radiation-hardened device can be used in applications where the reliability of the device is the main concern. The thesis starts with the proposal of an analytical model to investigate the applicability of junctionless double-gate MOSFET as a radiation dosimeter and progresses with the introduction of floating gate double gate MOSFET in order to operate the device as a radiation dosimeter without having a gate supply voltage. The various radiation dependent parameters have been explored.

Contents

04. KOHLI (Himani)

Design and Analysis of Electronic Healing Devices for Biomedical Applications.

Supervisors: Dr. Sanjeev Kumar Sharma, Sc 'G' and Prof. Sangeeta Srivastava

Th 25961

Abstract

In the past few decades, the applications of non-pharmacological healing interventions have expanded dramatically in medicine. Non-pharmacological interventions work in tandem with conventional drug therapy. Due to their non-invasive nature and minimal discomfort to the person under treatment, they have gained popularity as an effective healing modality. Bioelectromagnetics is an interdisciplinary branch that deals with the effects of non-ionizing radiation on biological systems and has also been found useful in healing interventions. It is widely spread across multiple application domains, ranging from research to pain

management, post-surgery recuperation to wound healing, covering various aspects of enhanced cell proliferation, reduction of pain, edema, swelling and bacterial infection control. Pulsed Electromagnetic Field Therapy (PEMFT) and Low Level Light Therapy (LLLT) are two such non-invasive and safe techniques that can be directly applied to the site of injury or to reduce pain and inflammation. These are state of the art healing techniques that do not have any known side effects. Although, several studies claim positive results from these techniques, in-depth studies must be conducted to establish optimal repeatability. Several commercial instruments are available in the market. As, they are pre-programmed and do not allow researchers to change the dose parameters required for this non-pharmacological healing therapy. This has necessitated the emergent need to design and develop electronic healing devices with programmable features based on PEMFT and LLLT so that one can explore their biological implications. This research work aims to design and analyze electronic healing devices that people at large or even the armed forces can use to reduce pain, inflammation, tissue damage and wound healing. To achieve the aforementioned goal, microcontrollers have been integrated with electromagnetic energy generating tools such as the Helmholtz Coil and Light Emitting Diode (LED). The biological implications and therapeutic effects of both the modalities have been researched, and conclusive results establishing the efficacy of the two therapies have been reported adhering to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for time-varying field exposure. In particular, we have designed the PEMFT system as an ELF-PEMF system using a microcontroller-based control system capable of generating various waveforms such as sine, square, saw-tooth and triangular. The system allows the modification of the frequency from 5 Hz to 100 Hz with a timer implementation lasting up to 24 hours. The initial parameters required for dose optimization have been extensively tested and further processed by the designed power modulator unit. The modulator offers the flexibility of modulating the signal's power so that magnetic fields of different strengths can be generated. Finally, the core of the PEMFT is the exposure system consisting of the Helmholtz Coil, which produces the magnetic field. To carry out biological experiments, it is imperative to have a uniform magnetic field for exposure of small animals and future human trials. Hence, the physical coil system has been realized using the parameters obtained after numerous theoretical simulations that would ensure a uniform magnetic field within the constraints of the ICNIRP guidelines.

Contents

05. MANJU RANI

Investigation of Optical and Electrical Properties of Silicon Based Plasmonic Solar Cells Using FDTD Method.

Supervisor: Dr. Udaibir Singh

Th 25770

Abstract

Plasmonics has become increasingly interesting area of enhancing light absorption in solar cells recently. When nanoparticles of a metal have size much smaller than the wavelength of incident radiation, the electrons in conduction band interact

strongly with the electromagnetic field. The scope of plasmonics has been expanding continuously since its contrivance. Sub-wavelength confinement, large scattering cross-section and strong enhancement of electromagnetic field in the direct proximity of nanostructures are the key features of plasmonics that enable its appositeness to different fields of science and technology. Examples of several applications areas of plasmonics include photonics, biomedical imaging and sensing, molecular spectroscopy, and photocatalysis. Present work exp;oits the above said features of plasmonics in the field of photovoltaics. Thin film solar cell technology has been proven to be a cost-effective and easy-to-install methodology over traditional crystalline silicon solar cells. But due to their low effviency,thin film solar cells could gain limited commercial popularity. Increasing the optical thickness of thin photovoltaic absorbers can revolutionize high-efficiency photovoltaic device designs. An efficient approach to achieve this is through the resonant scattering and concentration of light in arrays of metal nanoparticles, or by coupling light into surface plasmon polaritons and photonic modes that propagate in the plane of the semiconductor layer. As the incident radiation couples effectively with the natural frequency of the electrons in conduction band, the surface plasmon resonance are generated in metals. When the nanoparticles are deposited over the absorber layer of thin-film solar cells, they act as local flux domains. In this condition, they have the ability to scatter the incident radiation in this manner so that it may be trapped in the absorber layer below. The Properties and applications of these nanoparticles depens on various parameters such as size, shape, inter-particle distance and surrounding material. By making use of this technology, extremely thin photovoltaic absorber layers (thickness of the order of tens to hundreds of nanometres) eventually become able to absorb the full solar spectrum and lead to significant rise in efficiency.

Contents

1. Introduction 2. Theory of scattering & absorption by metal nanoparticles and modelling techniques 3. Deposition of silver nanospheres on ITO/c-Si structure for photovoltaic application 4. Optimization of dielectric spacer layer thickness in ag nanosphere/ITO/c-Si for photovoltaic application 5. Broadband light trapping in a-Si:H based plasmonic solar cells using Au Core- Al2O3 shell composite nanospheres. 6. Conclusion and future scope of work. Reprint of published research articles.

06. PRAVEEN PAL
Modeling, Simulation and Characterization of AlGaN/GaN HEMT Based Biosensors.
Supervisor: Dr. Sneha Kabra
Th 25956

Abstract

In the last few decades, the commercial semiconductor industry based on MOSFET has been heavily influenced by the development of biosensors for medical and food industry applications. As the demand for high sensitivity, low response time and reusable sensors is increasing, various architectures based on Silicon-MOSFETs, FinFETs and GAA-JLT has been proposed to overcome the low sensitivity and selectivity problems. However, reliability is the primary concern when these devices are to be used in the high-energy radiation or in high temperature environment. The exposure of device to alkaline solutions such as sodium hydroxide, potassium hydroxide and magnesium hydroxide can etch silicon surface in silicon based nano-scale devices. This imposes the need for the suitable AlGaN/GaN HEMT device that can overcome this problem. In order to increase the sensitivity, it is important to (i)

understand electrical characteristics of AlGaN/GaN HEMT to improve its performance as a sensor (ii) develop analytical compact models to include effects of ions/charges and dielectric constant of biomolecules, and (iii) explore double channel and dual channel device architectures with recessed gate and step graded Aluminum composition in barrier layer.Since the trap charges are always present at the surface of AlGaN barrier layer, these surface trap charges lead to change in the device parameters such as threshold voltage, drain current, subthreshold slope, transconductance, and cut-off frequency when exposed to biomolecules. Therefore, in this dissertation, different architectures of AlGaN/GaN HEMT have been studied for electrical detection of neutral and charged biomolecules. An analytical model for the detection of neutral biomolecule has been proposed. The model accurately predicts the behavior of AlGaN/GaN MOSHEMT for biosensing applications. Another analytical model for the determining acidicity or alkalinity of a solution by determining its pH using MOSHEMT sensor has also been developed. To develop pH sensor, a nano gate cavity has been used to fill the electrolyte solution. The gate electrode is not immersed in the electrolyte solution; therefore, even when the device is used for long time, threshold voltage sensitivity of the device remains stable. In case of cavity based design, the surface area available for biomolecule im-mobilization is less due to which it exhibits low sensitivity. To overcome this problem, an open gate AlGaN/GaN HEMT based biosensor has also been successfully designed for detection of biomolecules. Open gate AlGaN/GaN structure has large surface area for biomolecule im-mobilization, which enhances the sensitivity of the device. Impact of physical parameters on sensitivity has also been studied to predict optimum device design. It has been seen that the drain current sensitivity decreases with increase in Al composition and barrier layer thickness. Since, the samples that are used for detection of diseases consist of different concentration levels of particular biomarker, thus it is important to design a sensor which can detect different concentration levels of biomarker in any sample. It is difficult to detect small level of concentration without functionalizing conventional AlGaN/GaN HEMT because the AlGaN barrier surface is not sensitive to concentration which is very small and not able to generate as much ions (positive/negative) as compared to the 2DEG charge carrier concentration. Therefore, in this work, in order to find uric acid concentration (3.6-8.3 mg/dL) present in human serum, the AlGaN/GaN HEMT device has been functionalized with ZnO-tetrapods so that small concentration can be easily detected with high sensitivity. The proposed sensor also offers less threshold hysteresis and low response time of 1.9mV and 260µs respectively. Sensitivity analysis of ScAlN/GaN HEMT based biosensor has also been carried out to detect the presence of neutral biomolecules. ScAlN barrier layer has four times high piezoelectric coefficient as compared to AlGaN barrier layer which makes ScAlN/GaN HEMT more suitable for biosensor applications. Other than sensing metrics, which have been evaluated on single channel AlGaN/GaN HEMT, DC and RF performance of double channel AlGaN/GaN HEMT (DCHEMT) and double channel MOSHEMT (DCMOSHEMT) with undoped barrier layer has also been analysed. The linearity and intermodulation distortion analysis has been optimized using various figures of merit including high order transconductance, VIP3 and IMD3. The undoped barrier layer provides the advantage of increased drain current, broader peak of transconductance and high threshold voltage, which is suitable for small signal and high power applications. Further, the DC and RF characteristics of Common Drain Dual Channel HEMT have been studied. The performance has been compared for different recess gate depth with the step graded Al composition in AlGaN barrier layer of CDDC HEMT. The proposed work can be used to design enhancement mode CDDC HEMT without compromising recess depth. In case of graded CDDC HEMT, lesser drain current is obtained as compared to non graded device. Threshold voltage of both the devices decreases with increase in recess depth whereas due to graded barrier layer, the 2DEG layer starts to deplete early as compared to non-graded barrier layer. The increasing transconductance with increasing recess depth signifies good gate controllability on Two Dimensional Electron Gas (2DEG) channel.

Contents

07. SHEHREEN ASLAM

Growth and Characterization of one Dimensional Magnetic Nanowires for High Frequency Tunable Microwave Monolithic Devices.

Supervisors: Dr. Manoj Kumar Khanna and Prof. Bijoy Kumar Kuanr

Th 25958

Abstract

The study of ferromagnetic nanowires and their behavior at microwave frequency is an fascinating area of research not only just fundamental research point of view but also for device application. The characteristic shape anisotropy and collective tunable behavior of nanowires prompt the intriguing properties to explored the design of high-frequency signal processing devices like phase shifters and tunable filters, etc. For microwave device the key elements still in use consists of ferrite substances; that make them bulky and reduces the efficiency of the system. The recent emergence of high-frequency devices has to be monolithic, smaller in size, cost effective due to the increasing demand for compactness of the device. Ferromagnetic nanowires-based high-frequency systems have great potential though have a long way to go for practical use. A thorough understanding of the physics behind this and the ways to exploit the nanostructured magnetic material is still to be explored to make practical devices. This dissertation is mainly devoted to the development and growth of magnetic nanostructures in one dimensional nanowire geometry. Template assisted growth of nanowires technique is used for the mass production of highly organized nanowires which possess induced shape anisotropy and showed prominent results in the applications for higher GHz-frequency device applications. After careful and through literature survey, FeCo was chosen as the base material for the thesis investigation because of its high saturation magnetization to boost the operating frequency of the microwave devices. Attempt was to make various one-dimensional nanowires structures like (i) compositional variation of FeCo (ii) gradient compositional variation in a single nanowires, (iii) multi-segmented nanowires and investigate their structural and magnetic studies. Finally, magnetic nanowires are employed to fabricate tunable microwave devices like bandstop filters and phase shifters in a broad frequency range. The work carried out in this thesis is divided mainly into three segments. The first part comprises the synthesis of template-assisted deposition of ferromagnetic nanowires such as series of nanowires with different composition, gradient nanowires, and multi-segmented nanowires using the electrodeposition technique. The detailed microstructural and magnetic characterizations are investigated. In part two we focused on using the Vector Network Analyzer (VNA) to investigate the high-frequency dynamic behavior of ferromagnetic nanostructure using ferromagnetic resonance (FMR) spectroscopy. This technique can detect the important dynamic parameters such as gyromagnetic ratio, Gilbert damping, saturation magnetization, and linewidth. The investigation of

linewidth in nanowires is a critical parameter for the design of a devices in the higher microwave range (15 GHz). The Narrow Linewidth is crucial for designing of tunable devices. Therefore, the different approach has chosen to reduce the linewidth for high frequency devices application. In part three our aim is to fabricate miniaturized tunable devices that can operate in a wide frequency range without altering the device functionalities. For designing, FeCoB was chosen due to its narrowest Gilbert damping and FMR linewidth. This leads to the design of an efficient filter and phase shifter in a wide frequency ranging from Ku to Ka band with a much narrower linewidth in comparison to pure FeCo nanowires. The FeCoB ferromagnetic nanowire-based tunable notch filter and phase shifter in the high-frequency range will be demonstrated in microstrip line geometries.

Contents

1. Introduction 2. Experimental and characterization techniques 3. Ferromagnetic resonance and magnetization dynamics in ferromagnetic nanowires 4. Study of microstructure to magnetic properties of concentration gradient Co-Fe nanowire arrays 5. Study of magnetization dynamics of $[Fe_{75}\ Co_{20}\ Cu_5/Cu(x)]^{30}$ multilayer nanowires 6. Microwave monolithic devices based on ferromagnetic nanowire arrays 7. Conclusion and perspectives. And Reprint of published.

8. SONI (Neha)
Face Recognition Using Neural Networks: Implementation and Comparative Analysis.
Supervisors: Dr. Amita Kapoor Prof. Enakshi Khular Sharma
Th 25959

Abstract

Face recognition is the task of identifying a person using his/her face. We humans perform this task easily, repeatedly, and expeditiously in our everyday life. We have the capability to recognize the face of a family member, friend, neighbor or acquaintance even if we see the person after years. However, the same task is a challenging research problem when performed by algorithms and has received significant attention in the past four decades.A general problem statement for the face recognition task can be expressed as: Given a set of face images, and their labels, , we define a set where is the number of known individuals. The face recognition task is then, to determine the identity, of the unknown face image, using the stored set of face images. There are many factors (associated with the images) that make the machine recognition of faces a challenging task in the physical world viz. face expressions, age, scale, occlusions, scale, pose, noise, image quality etc. In literature, these variations have been reported to degrade the performance of most of the state-of-the-art face recognition algorithms. In ideal case, a face recognition algorithm trained on a particular set of face images of a person should be able to identify the person under all these variations in face images. Face recognition offers various advantages as a biometric technique over other biological traits such as fingerprints, face, iris, retina, palm, etc.- 1. Face is one of the most easily accessible biometric modalities. 2. Face recognition can be done passively without any explicit action or participation of the user since face images can be captured by the camera from a distance. Face recognition is completely non-intrusive and does not carry any risk to health from the transmission of germs. 3. Sufficient high-resolution face images can be obtained using inexpensive cameras. The above advantages of face recognition allow the technology to be used for a wide variety of applications. In our work, we have used face detection, landmark detection and feature extraction as the pre-processing steps for the identification of face images. Face detection is used in

all proposed methods. For the detection of faces, we have used the face detection algorithm proposed by Paul Viola and Michael Jones. The algorithm has motivated many recent advances in face detection and has made the task practically feasible for real-world applications. Figure 2 shows the successful detection of faces using the Viola-Jones algorithm. The algorithm is able to return the co-ordinates of all the sixteen faces in the image successfully. The robustness of the algorithm can be estimated from the detection of a shadow of one face in the mirror, which has also been detected. Different methods are used for landmark detection and feature extraction depending upon the proposed methodology of face recognition.

Contents

1. Introduction 2. Face recognition: an introduction 3. Conventional methods of face recognition 4. Face recognition using HNN 5. Novel BSSSO-Based- DCNN 6. Novel MV-CBO-DCNN. Conclusion and future research direction. Bibliography and Reprint of publications.

09. VISVKARMA (Ajay Kumar)
Experimental study of Metal Contacts on AIGaN/GaN HEMTs for Device DC & RF Characteristics Improvement and their Response Under Gamma Radiation.
Supervisors: Dr. Prof. Manoj Saxena and Dr. D.S. Rawal
Th 25960

Abstract

III-nitride semiconductor materials have been used for a long time in different aresa of electronic industries including high power and high frequency RF applications, solid state lighting, and various kinds of sensors. A majority of these devices were based on well-known semiconductor Gallium Arsenide (GaAa). The Potential of GaAs was limited because of its material properties like bang-gap which limits its operation for harsh environment conditions. Thus to fulfil the demands of RF technology wide band-gap III-V materials like AIGaN and InGaN are explored keenly and have been established as next generation of the existing GaAs technology due to their superior material properties. Gallium nitride has a wide and direct band –gap of 3.4 e V which makes it suitable material for opto-electronic devices that can be operated to high temperature tanges. A part from this, the bonding between Gallium and Nitrogen atom is very strong and hence the compound is stable in harsh invironment conditions including radiations and chemicals. GaN is also a polar material which enables it to from a two dimensional electron/hole gas doping to form this channel at the hetero-interface that too without any doping, whereas, GaAs requires doping to form this channel at the hetero-interface.This conducting channel is utilized to fabricate the popular high electron mobility transistor (HEMT) devices. Unlike field effect transistors (FETs) HEMTs also have three man contacts pronounced as source, drain and gate source and drain are ohmic in nature whereas gate is schottky metal contact. This work includes in-depth study of contacts on AIGaN/GaN hetero-structure which are the building block of GaN based HEMT devices more or less the static (DC) and dynamic (pulsed I-V and RF) performance of the device is govern by these two types of contacts

Contents

1. Inception to GaN and GaN HEMTs 2. AlGaN/GaN HEMT device fabrication 3. Understanding the AlGaN/GaN schottky contacts with the application of different metal contacts 4. Improvement in DC and pulse characteristics of AlGaN/GaN HEMT employing dual metal gate (DMG) architecture 5. MIS-HEMT combined with DMG

architecture making a hybrid structure for improvement in device performance parameters 6. Dopant based low resistance ohmic contact with Si/Au/Ti/Ni/Au to III-Nitride HEMT with sub 0.2 Ω-mm contact resistance 7. Impact of gamma radiations on schottky and ohmic parameters 8. Impact of gamma radiations on various device parameters 9. Conclusion and future Perspectives and Bio-data.