CHAPTER 13

ELECTRONIC SCIENCE

Doctoral Theses

01. CHETNA
Role Of Graphene Oxide In Growth Of Zinc Oxide Nanorods and its Application in Gas Sensing .
Supervisors : Prof. Avinashi Kapoor and Dr. Amit Jain
Th25507

Abstract
(Not Verified)

Nanostructured materials are being comprehensively studied by the research community to invent proficient devices with matchless properties. Graphene oxide is an inimitable material with large surface area, bearing heavily oxygenated functional groups, and can be chemically functionalized easily. Zinc Oxide, on the other hand, possesses high mechanical, thermal and chemical stability at room temperature. Quasi-one-dimensional structure and large surface to volume ratio of ZnO nanorods made them of particular interest amongst a variety of nanostructures of ZnO. The aim of this research work is to realize a simple and novel pathway to synthesize the Graphene oxide - Zinc oxide hybrid material and to explore its application in gas sensing. Thin films of graphene oxide solution have been deposited over ITO coated glass substrate and Zinc Oxide nanorods were grown over these graphene oxide coated ITO substrate and pristine ITO substrates using electrochemical deposition method. An improved density with reduced feature size was obtained for ZnO nanorods grown on GO substrate. It has been established that the presence of GO does not alter the crystal structure of these nanorods. Furthermore, a significant reduction in stress, as well as lattice strains, was pragmatic in the GO substrate sample. Thus GO can be a potential substrate material for the growth of ZnO nanorods. The effect of Graphene oxide in the growth of Zinc oxide nanorods was further investigated by employing a novel approach. Interdigital electrodes (IDE) of Aluminium were fabricated over the glass substrates and then GO solution was coated over them. Later, the electrochemical deposition method was utilized to grow ZnO nanorods over these GO coated IDEs. Further, this synthesized structure was explored for sensing of highly volatile hydrogen gas at room temperature.

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02. SHANI KUMAR
Fabrication of Graphene Oxide Membranes for Their Potential Use in Water Purification Applications.
Supervisor : Dr. Amit Garg
Th25509

Abstract
(Verified)

Globally, more than 800 million people are struggling to access clean drinking water due to the increasing population. Demand for highly efficient, cost-effective, and environmentally friendly water treatment technologies is increasing. All water treatments predominantly involve the removal of solids (especially by filtration and sedimentation), bacteria, algae, and inorganic compounds. There are various traditional and modern methods used to perform wastewater treatment. Recent and upcoming technology used in modern methods involves the use of graphene oxide (GO) material which exhibits hydrophilicity property, possess well-defined nanosized pores, contains high antifouling property, and shows chemical and mechanical stabilities. All these properties make graphene oxide a strong contender in the water purification industry. Thus, in the present study GO has been synthesized, characterized, and studied the use of GO membranes in water purification. In this study, three different GO membranes were prepared using Hummer's method by tailoring the temperature in the last stage of its synthesis process, three different temperatures (50, 70, and 95 °C) were used. These different membranes having different interlayer spacing have been synthesized and their antifouling properties were measured. Since sonication is known to influence the microstructure of GO sheets, the GO membranes were sonicated for different periods. This study could help in detecting the optimum sonication time required to get a compact GO membrane's structure, which is one of the most important factors of water purification. Lastly, the mildly reduced graphene oxide (MRGO) membranes were synthesized and observed that they have better stability, less swelling, and enhanced water filtering ability when compared with highly reduced graphene oxide membranes. Thus, the present study has discussed the development and application of GO membranes in water treatment. This study indicates that the use of GO membranes on a large scale could help shortly to meet the increasing demand for clean water.

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03. SHARMA (Sugandha)
Investigation of Group II Oxide Thin Films for Optoelectronic Applications.
Supervisor : Prof. Avinashi Kapoor
Th 25510

Abstract
(Verified)

ZnO with a direct, wide bandgap of 3.37 eV can be alloyed with CdO to form CdZnO (CZO) and generate bandgaps ranging from 2.37 to 3.37 eV. This makes it possible

to extend the photonic absorption/emission of ZnO in the UV region to the optically important blue-green region. In this dissertation, we have endeavoured to understand the growth dynamics of the ternary semiconductor CZO, and explore its viability in various optoelectronic functionalities. Exploratory studies conducted on CdO and ZnO thin films using sol-gel method revealed a bandgap of 2.4 – 2.6 eV, excellent transmittance in the yellow-green region and large electron concentrations for CdO, making it suitable for TCO applications. PL measurements revealed the NBE peak of ZnO at 3.4 eV. For CZO films with varying cadmium content in the precursor solution, bandgap lowering down till 2.6 eV was achieved for film with 40% Cd and annealed at 300 ˚C. But the high Cd content was found to introduce phase instability/segregation in the material. However, single-phase films with low resistivity (~10-3 Ω-cm) and high carrier mobilities were obtained for CZO films deposited using PLD technique. ZnO and CZO films were epitaxially grown on (0002) sapphire, (111), and (100) silicon substrates and lattice mismatch in each case as a consequence of Cd incorporation was estimated. MS junctions of ZnO and CZO with non-alloyed In and Al contacts were fabricated and I-V measurements were performed under dark and light conditions. The photodetecting potential of MS junctions was estimated in MSM and schottky diode configurations. The heterojunctions (HJ) of CZO with two p-type materials – Si (100) wafer and PLD-grown NiO layer, were studied. Figures of merit associated with each of the HJs were estimated using Cheung's and Norde's models and the future application of these HJs in realizing efficient photodiodes was discussed.

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04. MEHTA (Hema)
Modeling and Simulation of Ferroelectric MOSFETs for Ultra Law Power Applications.
Supervisor : Dr. Harsupreet Kaur
Th 25511

Abstract
(Verified)

In order to address various short channel issues, advancements have been made in semiconductor industry and various novel device concepts have been proposed which exhibit better short channel immunity. Junctionless (JL) transistors have been researched which have same doping type in source, channel and drain. Various studies have reported ferroelectric (FE) material based transistors or Negative Capacitance FETs (NCFETs). However, most of the studies have restricted analysis to conventional perovskites such as Strontium Bismuth Tantalate (SBT), Lead Zirconium Titanate (PZT) etc. which are difficult to integrate. However, ferroelectricity in doped Hafnium oxide has enabled integration of FE gate insulator into devices of nanometer range due to its low dielectric constant (~ 30) and high coercive field (~ 1-2 MV/cm). Therefore, in this thesis, the objective is to study the impact of ferroelectric insulator on both Junctionless and inversion mode devices. A novel device design Double Gate Ferroelectric Junctionless (DGFJL) transistor has been studied and significant improvement in device characteristics has been demonstrated. A temperature dependent model of DGFJL transistor has been

developed to examine its suitability for high temperature applications. In addition, long channel Cylindrical Surrounding Gate Ferroelectric Junctionless transistor has been proposed and an analytical model has been developed. Impact of FE gate insulator on short channel Double Gate Gaussian Doping Negative Capacitance Junctionless (DGGDNCJL) transistor has been studied. One of the other alternatives that have been proposed is DGNCJLT with high-k spacer which incorporates spacers of equal lengths on both sides of gate. The impact of incorporating FE layer along with channel engineering design has been studied and Planar Graded Channel Negative Capacitance SOI FET has been proposed. In addition, a novel device design Dual Material Double Gate Ferroelectric FET (DMGFeFET) has been proposed which incorporates advantages of both metal gate workfunction engineering and FE layer.

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1. Introduction 2. Modeling and simulation study of lung channel double gate ferroelectric juncionless transistor 3. Modeling and simulation of junctionless surrounding gate ferroelectric transistor 4. Performance study of short channel double gate gasussian doped negative junctionless transistor 5. Performance assessment of double gate junctionless negative capacitance transistor with high *k* spacer 6. Impact of channel engineering and negative capacitance on short channel inversion mode devices 7. Subthreshold analytical model for dual material double gate ferroelectric field effect transistor (DMGFeFET) 8. Conclusion and future scope of work. Bibliography and publications.

05. NIKHIL
Design and Analysis of Coupled Mode Photonic Devices.
Supervisors : Dr. Geetika Jain Saxena and Prof. Enakshi Khular Sharma
Th 25508

Abstract
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In Optical waveguides are the backbone of all photonic devices and circuits. The modal analysis of various waveguide geometries is presented for the understanding of their propagation characteristics. When the propagating fields of two closely spaced waveguides interact through their evanescent tails, a periodic transfer of power can be obtained between the waveguides. Such a configuration is referred to as a directional coupler and its variants can be used in the design of more complicated devices such as switches, modulators, filters and polarizers. The devices designed in this thesis are also extensively based on evanescently coupled waveguides. First, we propose the design of coaxial fiber, an evanescently coupled dual concentric core fiber, to achieve constant group velocity dispersion for its use in pulse repetition rate multiplication of a periodic sequence of optical pulses by temporal Talbot effect. Next, we utilize different design strategies based on evanescent coupling to design compact optical switches based on optical phase change materials like Ge2Sb2Te5 (GST), Ge2Sb2Se4Te (GSST), GeTe, etc. In particular, we design an ON-OFF switch based on GST, a 1×2 switch based on GeTe and a 2×2 switch based on GSST. Another important application of photonics is in the area of sensing. The use of slot waveguides for integrated photonic sensing applications results in a better sensitivity due to strong confinement of the optical field within a slot between the two high index rails resulting in a high interaction of the propagating field with the analyte to be sensed. For integrated photonic devices and circuits, the strip waveguides are commonly used. We design a compact and broadband strip waveguide to slot waveguide mode converter based on adiabatic

mode evolution coupled with a fast quasi-adiabatic approach for optimizing the taper profiles to obtain the required adiabatic mode evolution within the small lengths.

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