CHAPTER 15

ELECTRONIC SCIENCE

Doctoral Theses

157. AMANDEEP KAUR
Fabrication and Characterization of Carbon Nanotubes and Polymer Based Vapor Sensor.
Supervisors : Prof. Mridula Gupta and Prof. P. K. Bhatanagar
Th 22510

Abstract

Carbon nanotubes based vapor sensors have been widely investigated because of their nanosize morphology and high surface to volume ratio which provides large surface area for vapor adsorption. But pristine CNTs have tendency to stay in bundle form which limit its dispersion in organic solvents. This problem can be solved by functionalization of CNTs. We have developed a composite sensor using functionalized MWCNT and PMMA. Important parameters which affect the sensor performance are doping content of MWCNTs in the composite, degree of mixing of the nanotubes in the polymer matrix and surface chemistry of the nanotubes. Firstly, we have worked on doping content of CNTs in the polymer matrix. We have used ethanol as a test vapor as it is highly toxic in nature. Maximum change in resistance was obtained for sample in which doping content of CNTs in the PMMA was just above the percolation threshold concentration. Next two parameters i.e. the degree of mixing of nanotubes and its surface chemistry have been achieved by functionalization of nanotubes. Conventional functionalization techniques damage the physical and mechanical properties of the nanotubes, converting most of their sp^2 bonds into sp^3 bonded carbon atoms resulting in reduction of the available adsorption sites for vapors on the nanotube surface. We have employed nanotubes which are functionalized by mild chemical treatment viz direct cyclo addition to π electrons of the CNT which that does not hamper the physical structure of the nanotubes. Sensor based on this nanotube was found to exhibit excellent performance. To study the selectivity of this composite sensor, we have exposed our sensor to ten volatile organic compounds. Their response, response time and recovery time were recorded. The sensor was observed to be highly selective for methanol vapor owing to its smallest molecular size and highest electronegativity.

Contents

158. ANITA KUMARI

Characterization of graphene for device applications.

Supervisors : Prof. E. K. Sharma and Prof. P. K. Bhatnagar

Th 22513

Abstract

Graphene is a potential material which because of its unique properties finds application in electronic and optoelectronic devices. Therefore the aim of present thesis is to study the electronic transport properties of graphene. For this purpose single layer graphene (SLG) on SiO_2/Si substrate was patterned so as to serve as Hall bar for measuring the conductivity and Hall mobility. It can be noted that SLG are not suitable for device fabrication. Hence in the present work chemical vapor deposition (CVD) grown large area graphene has been chosen. From electrical measurements the effect of one dimensional grain boundary of polycrystalline samples on the mobility and conductivity of charge carriers has been investigated. It has been found that the one dimensional grain boundary deteriorates the mobility of carriers in graphene samples. Besides graphene's own unique properties, the polymer based composites infused with graphene have high mobility, stiffness, stability as compared to that of pristine material. Therefore, graphene based composite films in photovoltaic devices have been explored. In order to address the low efficiency issues reported, the sample has been thermally annealed. The power conversion efficiency (PCE), open-circuit voltage, short-circuit current density and fill factor have been calculated through electrical measurements. It has been found that by incorporation of graphene there is an improvement in all above parameters of the solar cell. Being a planar 2D structure, graphene is a promising material for sensing, thereby improving the sensitivity of graphene based alcohol sensor as compared to pristine functionalized-multiwalled carbon nanotubes (f-MWCNT) based sensors. In order to accomplish this, an ethanol sensor has been fabricated with a composite of graphene and f-MWCNTs. These graphene based sensors has high sensitivity, high selectivity and fast response/recovery time. Raman spectroscopy was used to find the number of graphene layers and defects in the sample.

Contents

159. JAIN (Priyal)

Surface Plasmon Resonance in Tin Sulfide Thin Films : Application in Solar Cells.

Supervisor : Dr. P. Arun

Th 22514

Abstract

Over the past few years, a lot of research work has been done in the field of "Plasmonics" for overcoming the problem of low absorption in thin film solar cells. Literature shows that photovoltaic devices including silicon, organic and Dye sensitized solar cells have benefited by incorporating metal nano-particles in the absorber layers. However, this plasmonic enhancement approach has not gained much popularity in inorganic thin film materials. This motivated us to choose an inorganic semiconducting material (SnS) to study the plasmonic effects of metal nano-

particle in its thin film solar cells. We fabricated plasmonic based SnS solar cells and investigate the influence of scattering efficiency of Ag nano-particles on the energy conversion process. Solar cells were fabricated with a range of thickesses of SnS:Ag active layers and SnS active layers respectively. The cells having corresponding thickness of the two mentioned materials were compared. The plasmonic devices were observed to be 67% more efficient as compared to the pristine SnS solar cells. This enhanced efficiency can be attributed to the 38% increase in the photo-generated current which is due to an increased optical path lengths of the incident light. These results make it evident that the plasmonic approach can be used to benefit the performance of SnS thin film solar cells.

Contents

1. Introduction 2. Fabrication and characterization techniques. 3. Tin sulfide (SnS) 4. LSPR in SnS:Ag thin films 5. Plasmonic solar cell 6. Conclusion and future scope. Appendix and bibliography.

160. PARVEEN

Three-Port RF Characterizations and Noise Modeling for Separate Gate Double Heterostructure InAlAs/InGaAs/InAlAs DG-HEMT for Millimeter Wave and Mixer Applications.

Supervisor : Dr. Jyotika Jogi

Th 22511

Abstract

Motivated by the superior performance of double heterostructure nano-scale double-gate high electron mobility transistor (DG-HEMT), the present research is aimed at three-port RF characterization and noise modeling of separate-gate double heterostructure InAlAs/InGaAs/InAlAs DG-HEMT for millimeter wave and mixer applications. Till now, the two gates in DG-HEMT have been employed in tied-gate geometry where the voltages applied at the two gates was same. However, the presence of double-gates can prove advantageous in terms of its utilization in mixer applications. The impact of application of separate bias at the two gates offers better gate control over the device performance. In the present analysis an analytical model is developed to study the dynamic behavior of double heterostructure double-gate HEMT, in which the obtained analytical results establish improved performance of separate-gate $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As/In_{0.52}Al_{0.48}As$ DG-HEMT as compared to tied-gate in terms of its higher current density, transconductance etc. To determine the microwave performance of DG-HEMT, a three-port small signal equivalent circuit is obtained for the separate gate DG-HEMT and S-parameters have been extracted in terms of Y-parameters. Further, to determine the noise performance of separate-gate DG-HEMT, various noise performance parameters such as minimum noise figure and minimum noise temperature are obtained in terms of drain noise coefficient, gate noise coefficient, and correlation coefficient between drain and gate noise sources. Finally an analytical model of DG-HEMT is also developed for mixer application in which two signals i.e., the LO and RF, are applied at one of the gates along with a constant dc offset applied to the second gate, which renders better charge control, higher transconductance and better noise immunity. The obtained analytical results are compared with the available experimental and Monte Carlo simulation results and are also compared with the ATLAS device simulation results that are found to be in good agreement.

Contents

161. PRASAD (Neetu)
Electronic and Optical Characterization of Graphene and its Applications.
Supervisors : Prof. P. K. Bhatnagar and Prof. E. K. Sharma
Th 22512

Abstract

In the present thesis, initially optical properties of graphene were experimentally studied. Raman spectroscopic and UV-Vis absorption properties of CVD grown few layer graphene (FLG) were explored and were compared with that of single layer graphene (SLG) and AB-stacked FLG. Secondly, CVD grown SLG was experimentally tested to be used as interconnect in VLSI circuits and it was observed that it exhibits one order higher current carrying capacity than that of copper. Here current induced annealing method was employed to remove the resist residuals left on the surface of graphene after multiple lithographic processes. Additionally, a back gated graphene field effect transistor (GFET) was fabricated using CVD grown SLG and was characterized to study the interfacial effects for device reliability. Output drain and transfer characteristics of the fabricated device showed that thermal annealing improved the conductivity of the graphene channel but the interfacial defects remained unaffected. To study the interfacial effect further, a metal oxide semiconductor (MOS) device was fabricated with SLG inserted in between the metal and oxide layer and its capacitance-voltage (C-V) characteristics were studied. It was found that graphene does not alter the work function of the metal gate (Cr/Au). Being impermeable to metal particles, graphene restricts them to diffuse through to the SiO_2 without altering its work function Therefore, graphene can be used as interfacial layer in MOS devices. Further, graphene nanosheets were blended with MEH-PPV polymer and it was observed that graphene incorporation enhances the photoluminescence (PL) emission by ~6 times. Light emitting diode (LED) was fabricated using this composite that resulted in 6 times enhancement of the device luminance with an addition advantage of reduced turn-on voltage. This was attributed to the increased charge carrier mobility of the emissive layer as well as improved electron injection from cathode.

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162. SANJEEV KUMAR

Development and Modification of Semiconducting Oxide Based Nanostructure and Nanocomposite by Ion Irradiation for Photovoltaic Applications.

Supervisor : Prof. Avinashi Kapoor and Dr. Fouran Singh

Th 22346

Contents

1. Introduction 2. Experimental and characterization technique 3. Synthesis and characterization of semiconducting oxide (ZnO, CdO) nanostructure 4. Ion irradiation induced modification of nanostructured CdO films 5. Ion irradiation Induced Modification in surface, interface and transport properties of ZnO films 6. Development of Zno Based Nanocomposites for photovoltaic application 7. Summary and future scope. Research publications.

163. YOGESH PRATAP

Modeling, Simulation and Characterization of Gate-All-Around Junctionaless Transistor-Reliability and Digital Applications.

Supervisors : Prof. Mridula Gupta and Prof. R. S. Gupta

Th 22515

Abstract

Continuous market demand motivates device engineers to make Integrated Circuits (ICs) which are area efficient and low power dissipated with reduced fabrication complexity. Integrated circuit industry has shown a lot of technological progress since past few decades. The Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a central component of IC. Scaling is the major factor behind it. It has attracted many possibilities of novel structures. But scaling poses many challenges as it enters into the nanometer regime. In short channel device, the fabrication complexity also increases as it becomes difficult to form a steep source/drain to channel junctions. To survive future design, fundamental device level changes become mandatory. Recently Junctionless Nanowire Transistor (JNT) has been introduced as the substitute of the junction based transistor. It is uniformly heavily doped throughout the source, channel and drain regions and thus there is no formation of junctions. ITRS mentions reliability as one of the "Design Technology Challenges". In this dissertation, implications of hot carrier/stress/process/radiation damage induced localised charges on performance of JNT at device and circuit level are studied. Some new techniques are required in order to reduce these reliability issues. In this direction, JNT with vacuum dielectric is proposed as a suitable replacement for SiO_2/Al_2O_3dielectric to have immunity against hot carriers. The origin of hot-carrier phenomenon is the large longitudinal electric field near the drain end. The greatest control over hot-carrier effects is exerted by minimizing this longitudinal electric field. Electric field at the drain end is found to be much lower in case of vacuum dielectric. For the digital performance, junctionless twin gate transistor has been proposed which has two independent gates. This provides two threshold voltages on a single silicon channel. The full functionality of "NAND" gate circuit is achieved by using only one twin gate transistor.

Contents

1. Introduction 2. Impact of various device design engineering in inversion mode cylindrical gate-all-around mosfet 3. Localised charge dependent ananytical model for junctionless nanowire transistor (JNT) for high temperature applications 4. Effect of

localized charges on analog/RF and linearity performance of junctionless nan wire transistor (JNT) 5. III-V compound semiconductor based JNT with material engineered and asymmetric vacuum gate dielectric for enhance electrostatic control and hot carrier reliability 6. Junctionaless nanowire twin gate trnasistor (JNTGT) for digital circuit applications 7. Summary and scope for future work.