STUDIES ON OPTOELECTRONIC PROPERTIES OF SEMICONDUCTOR DEVICES FOR INFRARED

By

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CERTIFICATE

This is to certify that the thesis presented by Mr. S.B.Kaushik is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under our guidance and supervision and that the results contained in it have not been submitted in part or full to any other University or Institute for award of any degree/diploma.

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A B S T R A C T

The emergence of practical and widely useful infrared systems has been made possible by advances in infrared sensing components. Because photon detectors approaching theoretical behaviour are becoming available, thermal imaging, surveillance and other military, space, medical and commercial systems are achieving performance levels that open up new and broader opportunities. The possibility of improved system behaviour has in turn supported and encouraged the development of practical infrared detectors. This study includes optoelectronic properties of various devices for useful wavelengths of 1.06 μm, 1.30 μm, 1.63 μm and 12.0 μm for which new sources and detectors are both under development and where overall system performance is being optimised.

This thesis consists of six chapters, which describe studies of optoelectronic properties of p-n junction photodiode, planer barrier diode, metal semiconductor field effect transistor and metal insulator semiconductor field effect transistor for infrared wavelengths. The first chapter gives the historical background of the development of the field of photodetection, a review of the various types of photodetectors and the importance of the area of work. Chapters from two to five describe the research work done and summary of these chapters is as follows :

CHAPTER II

Silicon photodiodes are finding varied roles in ever increasing industrial and military applications. Theoretical aspects of a p-n junction photodiode and experimental work carried on the fabrication of silicon photodiode is described in this chapter.

1. The physical theory of a photodiode, its principle of operation as a detector and influence of load resistance on its performance have been presented. Various parameters like spectral response, spectral detectivity and response time used for characterising detectors have been explained.

2. The design aspect of various parameters has been discussed with a view to obtain a good detector.

3. Standardisation of parameters for various experimental processes viz wafer cleaning, n^+ diffusion, photolithography for mesadiode etching, aluminium metallisation for p^+ back surface ohmic contact and front electrode, pattern delineation, anti-reflection coating, passivation, dicing, wire and die bonding and packaging etc have been described.

4. Experimental set up for characterisation of diffused layers viz determination of junction depth, average resistivity and surface carrier concentration are discussed.

5. Test procedures and laboratory experimental set up to evaluate spectral responsivity, spectral detectivity, minority carrier lifetime and response time of photodiodes are described.

CHAPTER III

Planar doped barrier (PDB) diode is a novel, high speed and very high sensitivity majority carrier photodetector. This chapter describes the work done on PDB diodes of some III-V ternary compounds as infrared detectors. The salient features of the work are as below :

1. The physical principles leading to the development of planar doped barrier diodes are described. Theoretical background for operation of a PDB diode is presented and it has been shown that sensitivity of such a photodetector increases with decreasing power.

2. Theoretical expression for the spectral detectivity of a PDB photodiode have been developed and utilised to calculate spectral detectivity of some III-V ternary compound PDB photodetectors. Two nomographs have been developed for determining the resistance area product and spectral specific detectivity.

3. The calculated spectral specific detectivity of a GaInAs PDB photodetector has been compared with that of an abrupt p^{+}-n homojunction photodiode and the relative merits of the former structure are discussed.

CHAPTER IV

GaInAs and GaInAsP devices are being extensively studied and used as photodetectors for fibre optical communication for the near infrared wavelengths. This chapter describes the optical effects in MESFETs of GaInAs and GaInAsP. The followi are the salient features of the contents :

1. The theoretical background and the physical principles for the operation of a MESFET are described.

2. Based on simple physical concepts, theoretical expression for photogenerated excess minority carriers is developed for the MESFET with a transparent Schottky gate. Also, an expression is derived for photovoltage developed at the gate by the photo-generated excess minority carriers

3. Drain current versus drain voltage characteristics for both GaInAs and GaInAsP MESFETs have been calculated for various intensities of radiation. Drain Saturation Voltage under illuminations for pinch off conditions are evaluated. Gain and optical gain for varying values of gate voltages have been presented graphically.

4. The theoretical model has been further modified by taking into account the effect of surface states density at the metal semiconductor interface. Drain current under illumination and optical gain are calculated by using this modified model and these values are compared with experimen values for GaAs MESFET.

CHAPTER V

The development of monolithic infrared sensitive integ rated circuits to perform advanced signal processing is an important area of present research on (HgCd)Te devices. MISFET is a degice suitable for integration with photodiode and has potential use for signal processing. This chapter describes optical effects in (HgCd)Te n- channel MISFET and the salient aspects of the work are :

1. The theoretical background and the principle of operation for a MISFET is described. Available information on metal-insulator-semiconductor interface of (HgCd)Te is presented.

2. Theoretical expression for photogenerated current in an n-channel MISFET has been developed by considering two different processes of excitation, namely electron-hole pair excitation across the bandgap in the depletion layer of the field induced junction and excitation of carriers to the conduction band from surface states lying near the middle of the bandgap. Photogenerated current at $77^{o}K$ when the semitransparent gate of an $Hg_{1-x}Cd_{x}Te$ ($x = 0.205$) n-channel MISFET is illuminated with IR radiation of varying intensities has been evaluated. Theoretical calculations also show that photogenerated current of the device for the parameters considered for this study are primarily due to excitation of carriers to the conduction band from surface states lying within the band gap.

3. A comparison between dark drain current and photogenerated drain current as a function of gate voltage is also given. It is seen from this comparision that there exists a range of gate voltages for which maximum advantage of illumination can be derived.

CHAPTER VI is a concluding chapter which gives an overview of the current research trends in this fascinating field

LIST OF PUBLICATIONS

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