سامية محمد مصطفى

شبكة المعلومات الجامعية

بسم الله الرحمن الرحيم

سامية محمد مصطفى

شبكة المعلومات الجامعية

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

شبكة المعلومات الجامعية

سامية محمد مصطفى

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات

يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار

سامية محمد مصطفى

شبكة المعلومات الجامعية

بعض الوثائق الأصلية تالفة

سامية محمد مصطفى

شبكة المعلومات الجامعية

بالرسالة صفحات لم ترد بالأصل

Electrical Properties of Indium Phosphide Single Crystal Devices

Thesis

Submitted to the Faculty of Science
Alexandria University
for
The Degree of Doctor of Philosophy of Science in Physics

By

Eman Mohamed Ahmed El-Shafey

B. Sc. in Physics (1986)
M. Sc. in Physics (1992)

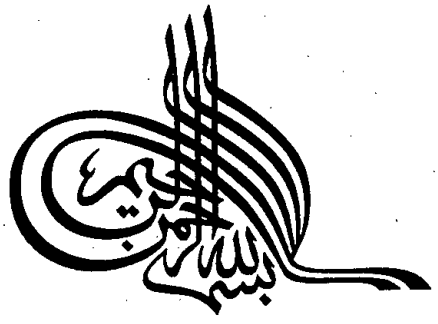
Supervised By

Prof. Dr. A. A. Bishara
Head of Physics Department
Prof. of Nuclear Physics
Faculty of Science
Alexandria University

Prof. Dr. T. G. Abdel-Malik
Head of Physics Department
Prof. of Solid State Physics
Faculty of Science
Menia University

Prof. Dr. A. E. El-Samahy
Prof. of Solid State Physics
Faculty of Science
Alexandria University

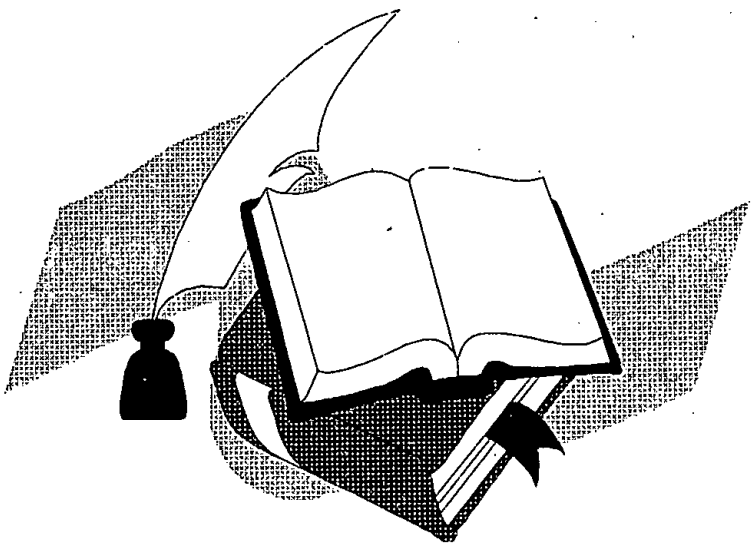
1998



(وقل رب زدنی علماً)

صدق الله العظیم

TO MY FAMILY



CONTENTS

ABSTRACT

CHAPTER I INTRODUCTION

1.1 An Introduction to III-V Semiconductors. 1

1.2 The Scope of The Present Investigation. 2

1.3 The Format of The Thesis . 4

CHAPTER II INDIUM PHOSPHIDE CRYSTALS AND RELATED COMPOUNDS

2.1 Transition Metal Impurities in III-V Compounds 5

2.2 Interststitial and Substitional Zn in InP Compounds. 9

2.3 Defect States in InP Crystals 13

2.4 Review of Electrical Measurements on InP Crystals. 20

CHAPTER III THEORETICAL CONSIDERATIONS

3.1 The Metal Semiconductor Contact 22

3.2 Ohmic and Space-Charge-Limited Conduction 26

3.2.1 Thermal Activated Ohmic and Space -Charge-Limited Conduction

I The Extrinsic Case 32

II The Nonextrinsic Case 34

3.3 Exponential Distribution of Traps 35

3.4 Current-Transport Mechanisms (Thermonionic-Emission Theory) 35

3.5 Reverse Characteristics 41

3.6 Schottky Barrier Capacitance 44

3.7 Alternating Current Conductivity 46

CHAPTER IV DESCRIPTION OF EXPERIMENTAL TECHNIQUES

4.1 Liquid Encapsulation Czochralski(LEC) 51

4.2 Thermal Annealing 51

4.3 Rapid Thermal Annealing (RTA) 53

4.4 Face to Face Annealing 56

4.5 Sample preparation 56

4.6 The Sample Holder and Heater 57

4.7 Current-Voltage Measurements 59

I Interference from external fields 59

II Leakage Current 60

III The Effect of Microphone 60

4.8 Capacitance-Voltage measurements 61

4.9 Alternating Current Measurements 61

ELECTRICAL Transport PROPERTIES IN InP:Zn CRYSTALS

5.1 Current-Voltage Characteristics 62

5.2 Temperature-Dependence of Ohmic and Space-Charge-Limited Conduction 66

Temperature Dependence of the Schottky Barrier Capacitance in Al/InP:Zn/Au Samples 71

5.4 Discussion of Results 73

CHAPTER VI ALTERNATING CURRENT MEASUREMENTS

6.1 Variation of AC Conductivity with Frequency and Temperature for Al/InP:Zn/Al Samples 78

6.2 Variation of Capacitance and Loss Tangent with Frequency and Temperature for Al/InP:Zn/Al Devices 79

6.3 Variation of Capacitance with Temperature and Frequency for Al/InP:Zn/Au Devices 81

6.4 Variation of Parallel Equivalent Conductance with Frequency and Temperature 83

6.5 Variation of Quality Factor Q with Frequency and Temperature 85

6.6 Discussion of Results 88

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and deepest gratitude to ***Prof. Dr. A. A. Bishara*** for his kind supervision, stimulating discussions and assistance throughout this work.

I wish to express my gratitude and deepest thanks to ***Prof. Dr. T. G. Abdel-Malik,*** who suggested this point, for supervision and assistance throughout the various stages of progress of this work.

I would like to express my sincere appreciation and deepest thanks to ***Prof. Dr. A. E. El-Samahy*** for guidance, assistance throughout this work and help in the final stage of this thesis.

I wish to express my gratitude to ***Prof. Dr. Salah. D. M. Darwish*** Department of physics, Minia University for supplying and performing the speciments used throughout this work. My thanks are also due to the staff members of physics Department, Faculty of Scince, Alexandria University and Minia University

ABSTRACT

ABSTRACT

The electrical properties of zinc-doped indium phosphide single crystals which have been pulled from the melt by the liquid encapsulation Czochralski technique have been studied using aluminum and gold electrode combinations. Samples with aluminum electrodes showed ohmic conduction in the lower voltage range and two separate regions of space-charge-limited (SCL) conductivity at higher voltage levels controlled by a discrete trapping level and by an exponential distribution of traps above the valence band edge, respectively. Measurements of current density-temperature characteristics in the SCLC regions yielded voltage variable slopes on plots of the logarithm of current density as a function of the inverse temperature in accordance with the theory for exponential distribution of traps. On the other hand, constant slope was obtained for a single dominant level which immediately yielded its depth above the valence band edge. A number of parameters were evaluated on the basis of the theory of space-charge-limited conduction and the following values were obtained : excess acceptor concentration ($N_a - N_d$) = 1.7×10^{18} m^{-3}, discrete trap level E_t = 0.20 eV above the valence band edge with a state density $N_{t(s)} = 2.2 \times 10^{20}$ m^{-3}, hole mobility $\mu = 7 \times 10^{-3}$ $m^{-2}V^{-1}s^{-1}$, room temperature hole

concentration $P=5.1x10^{15}$ m^{-3}, concentration of traps per unit energy range at the valence band edge $P_o=1.7x10^{38}$ $J^{-1}m^{-3}$, temperature parameter T_t of trapping distribution 750 K and total trapping concentration $N_{t(e)} = 2.2x10^{20}$ m^{-3}. Samples having one electrode of each metal showed different behaviour. At low voltages $V \leq 60$ mV, under forward bias (aluminum electrode positive), Schottky diode behaviour was observed. At applied voltage greater than 60 mV, the forward characteristics showed a similar overall trend to that of Al/InP:Zn/Al samples i.e ohmic conduction followed by two separate regions of space-charge-limited conductivity controlled respectively by a single dominant level and by an exponential trap distribution. Under reverse bias (aluminum electrode negative), the conduction processes could be interpreted in terms of both the Pool-Frenkel (field-assisted thermal detrapping of carriers) and Schottky effects (field lowering of the interfacial at the injected electrode interface). Barrier height and width were determined as a function of applied voltage. The results showed that with the increase of voltage, the barrier width increased appreciably but the barrier height retained almost the same value. The Schottky barrier capacitance of Al/InP:Zn/Au samples was measured as a function of voltage at several temperatures. The barrier heights measured by capacitance method and those determined from conductivity measurements were in good agreement.