INFLUENCE OF CONCENTRATION IN INP_XAS_{1-X} OPTICAL PROPERTY OF TERNARY SEMICONDUCTOR ALLOY

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ABSTRACT

An essential issue in developing semiconductor devices for Opto electric is to design materials with appropriate band gaps plus the proper positioning of dopant levels relative to the bands. Ternary Semiconductor alloys provide a natural means of tuning the magnitude of the Optical properties for wide application of Semiconductor devices. The need to provide materials for applications in the long-wavelength range for infrared detectors has led to the development of III-V Ternary alloys of InP_xAs_{1-x}Ternary Semiconductor. InP_xAs_{1-x} III-V Ternary semiconductor is very important as an x of a constituent in the semiconductor is going to have significant changes in calculating Physical Property like Band Energy Gap. These Ternary Compounds can be derived from binary compounds InP and InAs by replacing one half of the atoms in one sub lattice by lower valence atoms, the other half by higher valence atoms and maintaining average number of valence electrons per atom. The subscript X refers to the alloy content or concentration of the material, which describes proportion of the material added and replaced by alloy material. This paper represents the InP_xAs_{1-x} III-V Ternary Semiconductor Optical constant values. Our results agree well with the available data in the literature.

***Keywords**:* Arsenic, Alloys, Band Energy Gaps, Band Gap Engineering, Binary Semiconductors, Composition, Optical constants, Doping, Optical properties, Indium, Phosphorus, Ternary Semiconductor alloys.

INTRODUCTION

In the present work, the solid solutions belonging to InP_xAs_{1-x} III-V Ternary Semiconductor Optical properties and application have been investigated. Doping of P component in a Binary semiconductor like InAs and changing the composition of do pant has actually resulted in modifying optical properties with enhancing Optical applications.

Thus effect of do pant tunes all optical properties and finds extensive applications in Semiconductor LASERS. The present investigation relates with variation of composition for

InP_xAs_{1-x} III-V Ternary Semiconductor. The fair agreement between calculated and reported values of Optical properties of InP and InAs Binary semiconductors give further extension of applications for Ternary semiconductors.

The present work opens new line of approach to Optical studies in InP_xAs_{1-x} III-V Ternary Semiconductor. Recently much attention is paid to the study of Ternary Semiconductor materials and their Alloys for Application in design of Heterostructures.

The important of all physical properties of these compounds are currently moving in to focus. Application of these Ternary Semiconductor materials in Optical devices has high experimental level of investigation.

More attention is paid to the study of these compounds including Indium, Arsenic of III Group and Phosphorus from V Group. InP_xAs_{1-x} is most Important Ternary Semiconductor material with Arbitrary alloy between InP and InAs with P Composition ranging between $0<x<1$. Changing P composition can vary Optical constants of these materials. The study of subject of these InP_xAs_{1-x} Ternary Materials has revoked much interest for increasing Applications.

The property of Ternary Semiconductors that makes them most useful for constructing electronic devices is that introducing impurities into their Crystal lattice may easily modify their conductivity. The process of adding controlled impurities to a Ternary semiconductor is known as doping.

The amount of impurity, or dopant, added to an semiconductor varies its level of conductivity. The materials chosen as suitable do pants depend on the atomic properties of both the dopant and the material to be doped. In general varying Concentration that produce the desired controlled changes are classified as either electron acceptors or donors.

Semiconductor alloys are made of elements from group III and group V on the periodic table such as InAs that is commonly used to interact with light in typical optical devices. InP_xAs_{1-x} ternary phosphates are potentially useful for opto electronic device applications.

InP_xAs_{1-x} is a wide band-gap alloy that is often employed in red light emitting diodes (LEDs) [1, 2]. InP_xAs_{1-x} is useful material for long-wavelength surface emitting lasers [3]. Although some experimental and theoretical investigations have been reported on the band-structure parameters for III-V crystalline phases with zinc-blend structure [4, 5] many fundamental properties of these materials remain to be determined precisely.

Today, the production and the use of InAs with technological devices with added P become more important gradually, increase more and more. Experimental studies on such type of produced semiconductor alloys are carried out intensively. This study was carried out to shed light on the future studies of scientists who experimentally prepare and test these alloys in laboratories to help them in determining the change in amounts of additives in Semiconductor alloys are made of elements from group III and group V on the periodic table such as InAs that is commonly used to interact with light in typical optical devices.

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In this study, electronic and optical properties of InP_xAs_{1-x} alloys (for x= 0, 0.25, 0.50, 0.75 and 1) were calculated as a function of P composition. Obtained results were found in good agreement compared with experimental and theoretical data in literature. We have considered InP_xAs_{1-x} ternary alloys as having cubic symmetry in our calculation for all the five systems to maintain Consistency and simplicity. We expect that for x = 0.5 the alloy is a layered structure and should be non-cubic. We have taken four layers and hence a cubic unit cell for x = 0.25, 0.50, 0.75 we have replaced one, two and three As atoms, respectively, by In to get the desired concentration of theoretical and experimental data [5, 12-14]. The band profiles and band gap values are in good agreement with the earlier theoretical works. The band gaps are smaller than the experimental values. The layout of this paper is given as followings:

OBJECTIVE

The main Objective of this paper is to calculate InP_xAs_{1-x} III-V Ternary Semiconductor Optical constants which determines Ternary semiconductor alloy applications in Semiconductor LASERS.

RESULTS AND DISCUSSION

The following relation calculates Optical constants of refractive index, Optical polarizability, Absorption coefficient of Arsenide Semiconductor alloys are evaluated by using Principle of additivity and quadratic expressions. The principle of additivity is used to study Physical properties even at very small compositions.

The values required for these estimations are calculated from the following formulae and presented in below table.

Method 1

$n_{12}=n_1*x+n_2*(1-x) + 1/1000*SQRT (n_1*n_2)*x*(1-x)$
$n_{12}=n_1*x+n_2*(1-x) +1/1000* SQRT (n_1*n_2*x*(1-x))$
$n_{12}=n_1*x+n_2*(1-x) – 1/1000*SQRT (n_1*n_2)*x*(1-x)$
$n_{12}=n_1*x+n_2*(1-x) – 1/1000*SQRT (n_1*n_2*x*(1-x))$

Additivity

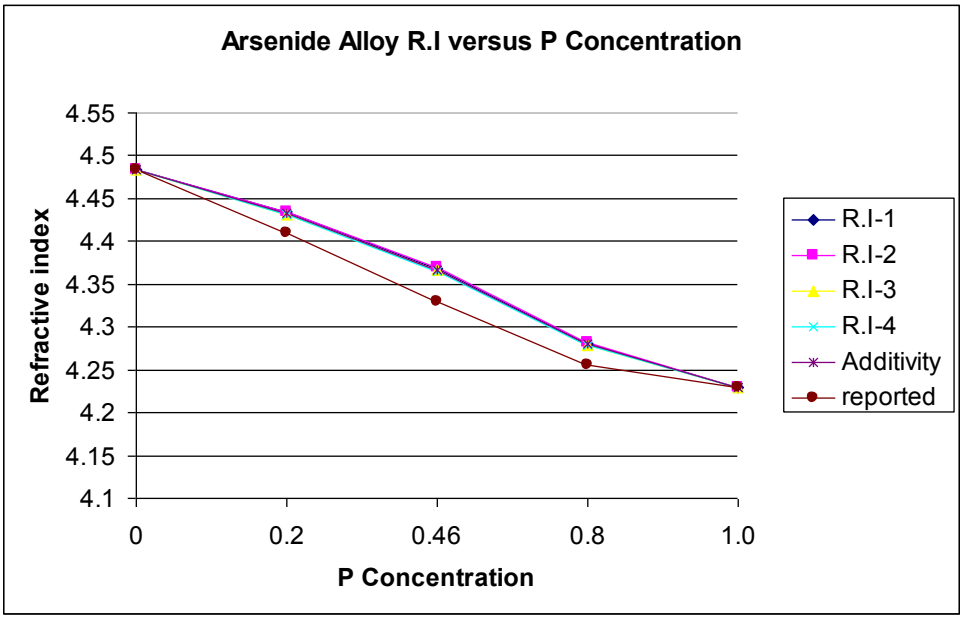
$n_{12}=n_1*x+n_2*(1-x)$

Where A_{12} denotes Refractive index (n_{12}), Optical Polarizability (α_{m12}), Absorption coefficient (α_{12}). A_1 and A_2 denotes Refractive index (n), Optical Polarizability (α_m), Absorption coefficient (α), of two binary compounds forming ternary compound.

X	1-X	R.I Method1	R.I Method2	R.I Method3	R.I Method4	Additivity	Reported
0.00	1.00	4.484	4.484	4.484	4.484	4.484	4.484[17]
0.20	0.80	4.434	4.435	4.432	4.431	4.433	4.409[17]
0.46	0.54	4.368	4.369	4.366	4.365	4.367	4.329[17]
0.80	0.20	4.281	4.282	4.279	4.278	4.280	4.255[17]
1.00	0.00	4.229	4.229	4.229	4.229	4.229	4.229[17]

Graphical Representation

A Graph is drawn by taking P Concentration on x axis and corresponding Refractive index on y axis



The applications of III-V Arsenide Ternary Semiconductor Alloys of $InP_{1-x}As_x$ as Electronic, Optical and Optoelectronic devices are determined by elementary material properties of Refractive index, Optical Polarizability, Absorption coefficient, Energy gap and Mobility. Photonic crystals, wave guides and solar cells require knowledge of refractive index and Energy gap of all above Arsenide Group alloys. The Energy gap of Semiconductor alloys determines Threshold for absorption of photons in semiconductors. Refractive index is measure of transparency of Semiconductor alloys to incident radiation. Refractive index and Energy gap of Ternary Semiconductor alloys has significant impact on Band structure. High absorption coefficient Semiconductor alloys can be used for fabricating in thin film hetero junction photovoltaic (PV) devices.

bonds have the same structure as in Silicon or Germanium. In fact, the missing electron of the group III is provided by the column V element and these bonds have a low ionicity. Most of III-V Ternary semiconductor alloys $InP_{1-x}As_x$, $In_xGa_{1-x}As$, $Al_xGa_{1-x}As$, $Al_xIn_{1-x}As$ and $GaAs_{1-x}P_x$ have direct band gap. The minimum photon energy that is needed to excite an electron into the conduction band is associated with the band gap of a material. When

electron-hole pairs undergo recombination, photons are generated with energies that correspond to the magnitude of the band gap. A phonon is required in the process of absorption or emission in the case of an indirect band gap. There must be a direct band gap in applications of optical devices. The evaluation of refractive indices of semiconductor is of considerable importance for different applications, where the refractive index of the material is the key parameter for the device design**.**

The Refractive index of Group III-V Arsenide Ternary Semiconductor alloys $InP_{1-x}As_x$ and $In_xGa_{1-x}As$, $Al_xGa_{1-x}As$ and $GaAs_{1-x}P_x$ reduces significantly by adding a small amount of Arsenic to InP, Indium to GaAs, Al to GaAs and P to GaAs. The Refractive index of these alloys are expected to vary from 4.433(InP) to 3.157 (InAs) in $InP_{1-x}As_x$ and 4.484 (GaAs) to 4.229 (InAs) by increasing As and In Concentrations. These ternary alloys are used for manufacturing infrared detectors, gas sensors. This occurs due to the large disparity in the electro negativity and the atomic size between P and As in $InP_{1-x}As_x$ and between In and Ga in $In_xGa_{1-x}As$. The Arsenic atom, Indium atom, Aluminium atom and Phosphorus atoms induces several perturbations in the host crystal.

The Optical Polarizability of Group III-V Arsenide Ternary Semiconductor alloys $InP_{1-x}As_x$ and $In_xGa_{1-x}As$, $Al_xGa_{1-x}As$ and $GaAs_{1-x}P_x$ reduces significantly by adding a small amount of Arsenic to InP, Indium to GaAs, Al to GaAs and P to GaAs. The Optical Polarizability of these alloys are expected to vary from 102.7 $(Cms)^3$ (InP) to 90.340 $(Cms)^3$ (InAs) in $InP_{1-x}As_x$ and 87 $(Cms)^3$ (GaAs) to 75.66 $(Cms)^3$ (InAs) by increasing As and In Concentrations. These ternary alloys are used for manufacturing infrared detectors, gas sensors. This occurs due to the large disparity in the electro negativity and the atomic size between P and As in $InP_{1-x}As_x$ and between In and Ga in $In_xGa_{1-x}As$. The Arsenic atom, Indium atom, Aluminium atom and Phosphorus atoms induces several perturbations in the host crystal.

In III-Arsenide Ternary Semiconductor alloys of $InP_{1-x}As_x$, $In_xGa_{1-x}As$, $Al_xGa_{1-x}As$, $Al_xIn_{1-x}As$ and $GaAs_{1-x}P_x$ replacing existing atom with high Atomic number results in Decreasing of Energy gap due to increase of charge carriers with increase of mobility and by replacing existing atoms of low atomic number result in Increase of Energy gap due to decrease of charge carriers transmitting from valence band to conduction band with decrease of mobility.

The Absorption coefficient of Group III-V Arsenide Ternary Semiconductor alloys $InP_{1-x}As_x$ and $In_xGa_{1-x}As$, $Al_xGa_{1-x}As$ and $GaAs_{1-x}P_x$ reduces significantly by adding a small amount of Arsenic to InP, Indium to GaAs, Al to GaAs and P to GaAs. The Absorption coefficient of these alloys are expected to vary from 7.132 $(Cms)^{-1}$ (InP) to 3.012 $(Cms)^{-1}$ (InAs) in $InP_{1-x}As_x$ and 2.298 $(Cms)^{-1}$ (GaAs) to 0.967 $(Cms)^{-1}$ (InAs) by increasing As and In Concentrations. These ternary alloys are used for manufacturing infrared detectors, gas sensors. This occurs due to the large disparity in the electro negativity and the atomic size between P and As in $InP_{1-x}As_x$ and between In and Ga in $In_xGa_{1-x}As$. The Arsenic atom, Indium atom, Aluminium atom and Phosphorus atoms induces several perturbations in the host crystal.

1. Current data set of values of InP_xAs_{1-x} III-V Ternary Semiconductors and Band Energy Gap values include the most recently developed methods and basis sets are continuing. The data is also being mined to reveal problems with existing theories and used to indicate where additional research needs to be done in future.

2. The technological importance of the ternary semiconductor alloy systems investigated makes an understanding of the phenomena of alloy broadening necessary, as it may be important in affecting semiconductor device performance.

CONCLUSION

1. This paper needs to be addressed theoretically so that a fundamental understanding of the physics involved in such phenomenon can be obtained in spite of the importance of ternary alloys for device applications.
2. Limited theoretical work on Band Energy Gap of InP_xAs_{1-x} III-V Ternary Semiconductors with in the Composition range of ($0<x<1$).
3. Our results regarding the x values of III-V Ternary Semiconductors are found to be in reasonable agreement with the experimental data
4. This phenomenon is used in Semiconductor applications. The band structures of the alloys show similar features to that of bulk InAs and InP.
5. The above calculated 4 methods explain about transparency of Semiconductors to incident radiation indicating Optical property of Arsenide ternary alloy

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