COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE
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Title: Temperature Dependence of The Conductivity of Gallium Arsenide (GaAs) Compound Semiconductor

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The undersigned here by certify that they have read and recommend to the department of physics for acceptance a project entitled **Temperature Dependence of The Conductivity of Gallium Arsenide (GaAs) Compound Semiconductor** by Aliyyi Adem in partial fulllment of the requirements for the degree of Bachelor of Science in Physics.

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List of Symbols and Abbreviations

$GaAs$	Gallium arsenide
CBM	Conduction Band Minimum
VBM	Valance Band Maximum
E_T	Localized Trap Energy
$g_c(E)$	The density of quantum states in conduction band
$g_V(E)$	The density of quantum states in valence
$E_g^{(0)}$	Band gap energy at absolute zero on the Kelvin
$E_g^{(T)}$	Band gap energy at any temperature
M_0	Rest mass of the electron (kg)
m_n^*, m_p^*	Electron and hole Effective mass (kg)
T	Temperature(K)
e	Charge of electron ($1.6 \times 10^{-19} C$)
h	Plancks constant ($1,054 \times 10^{-34} Js$)
K_B	Boltzmann constant ($1.38 \times 10^{-23} Jk^{-1}$)
E_g	Energy band gap (eV)
N_c, N_v	Electron and hole density of accessible state (cm^{-3})
E_i	Intrinsic Fermi energy (eV)
c	Speed of light vacuum (m/s)
E_F	Fermi energy (eV)
E_a, E_d	Energy of acceptor and donor (eV)
E_c, E_v	Energy of conduction band and valance band(eV)
n_0, p_0	Thermal equilibrium concentration of electron and hole (cm^{-3})

Abstract

This study introduces the electrical and optical properties of (GaAs)compound semiconductor. And also,the temperature dependence of conductivity of (GaAs) compound semiconductor. This have been studied through determination of the factor of temperature with mobility, carrier concentration, density of state and bulk conductivity. As temperature increases the conductivity of (GaAs) increases. GaAs also has a higher band gap so that the intrinsic carrier concentration would be low. a higher mobility can lead to an increase in conductivity. this Data was obtained and analyzed with aid of excel and origin softwares.

Chapter 1

Introduction

1.1 Background

The beginning of semiconductor research is marked by Faradays 1833 report on negative temperature coefficient of resistance of Silver sulfide. This is the first observation of any semiconductor property. In his 1833 paper, Experimental Researches in Electricity Faraday disclosed this observation. This observation was in distinction from the usual properties of metals and electrolytes in whose case resistance increases with temperature[1].

The next significant contributor to semiconductor field is the French experimental physicist Edmond Becquerel. In 1839, he reported the observation of photovoltage in the silver chloride coated Platinum electrodes. In his experiment, a AgCl coated Platinum electrode was immersed in an aqueous Nitric acid electrolyte solution. Illumination of the electrode generated photo-voltage that altered the electromagnetic field produced by the cell; in fact, it produced a reductive (cathodic) photocurrent at the AgCl coated electrode. This was the first reported photovoltaic device. Photovoltage was generated at the Ag/AgCl metal semiconductor contact, Ag at the junction was formed by the absorbed silver clusters in the AgCl electronic states [2].

The next important decade in the semiconductor research is the decade of 1870. During this period Selenium was discovered as a semiconductor, rectification at semiconductor interface came into scientists notice. In 1873, Willoughby Smith arrived at the discovery of photoconductivity of Selenium. He was initially working with submarine cables. He set in to experiments with Selenium for its high resistance, which appeared suitable for his submarine telegraphy. Various experimenters measured the resistance of Selenium bars, but the resistance as measured by them under different conditions did not agree at all. Then Smith discovered that the resistance actually depends on the intensity of incident light. When the Selenium bars were put inside a box with the sliding cover closed, the resistance was the highest. When glasses of various colours were placed in the way of light, the resistance varied according to the amount of light passing through the glass. But, when the cover was removed, the conductivity increased. He also found that the effect was not due to temperature variation [3].

For different semiconductor devices, one needs materials with different parameters, like energy band-gap. Physical properties are very different among different semiconductors due to distinct characteristics of energy band-gaps and impurities. These impurities play a major role in determining the electrical and optical properties of semiconductors. Almost all of todays technology involves the use of semiconductors, with the most significant aspect being the integrated circuit (IC) [4].

GaAs is a III-V compound semiconductor composed of the element gallium (Ga) from column III and the element arsenic (As) from column V of the periodic table of the elements. GaAs was first created by Goldschmidt and reported in 1929, but the first reported electronic properties of III-V compounds as semiconductors did not appear until 1952. The GaAs crystal is composed of two sub lattices, each face centered cubic (fcc) and offset with respect to each other by half the diagonal of the fcc cube. Gallium arsenide devices are not sensitive to heat because of their wide band gap. Also, these devices typically have less noise than silicon devices, especially at high operating frequencies. This crystal configuration is known as cubic sphalerite or zinc blende. so Gallium arsenide crystallizes in zinc-blende structure. It has a high electron mobility and a small dielectric constant; GaAs is extensively utilized in high temperature resistance, ultrahigh frequency, low-power devices and circuits. Based on mobilities, GaAs would be the material to choose for higher conductivity but GaAs also has a higher band gap so that the intrinsic carrier concentration would be low [5].

1.2 Statement of the problem

The purpose of this project paper was about the temperature dependence of the conductivity of Gallium Arsenide (GaAs) Compound semiconductor. This research work will be expected to answer the following question at the end of the research project work. Hence, the following questions were answered: the relationships between mobility and conductivity of semiconductor, how the conductivity of Gallium Arsenide (GaAs) semiconductor material is depending on the temperature and how Temperature of Gallium Arsenide (GaAs) semiconductor is vary with density of state?

1.3 Objectives of the study

1.3.1 General Objective

The main objective of this project is temperature dependence of the conductivity of Gallium Arsenide (GaAs) Compound semiconductor.

1.3.2 Specific objective

The specific objectives of this study was:-

- To determine the Variation of effective densities of electrons and holes of Gallium Arsenide (GaAs) compound semiconductor with temperature.
- To analyze how conductivity of Gallium Arsenide (GaAs) compound semiconductor depends on carrier concentration and mobility.
- To describe the effect of temperature on bulk conductivity of Gallium Arsenide (GaAs) compound semiconductor.
- To verify the conductivity of Gallium Arsenide (GaAs) compound semiconductor at different temperature.

1.4 Significance of the study

This particular study was more about the conductivity of semiconductors and explain especially the Gallium Arsenide compound semiconductor materials. This project further investigate the role of temperature dependence of conductivity in (GaAs) semiconductors. The aim of this work is to develop better understanding of temperature dependence of energy band gap of Gallium Arsenide compound semiconductor and how the mobility and conductivity are related with temperature. It is serves as a reference for researcher doing on the same topic in the future. Another significance of this paper is for student who takes this course to get information for their preparation of exam and improving their knowledge. This project is also expected to propose some inspirations for overcoming current defects or limitations and give a brief outlook for the future work.

1.5 Scope of the study

Our studies have been focused to analyze the temperature dependence of conductivity of Gallium Arsenide. We consider temperature as a dependent variable terms and other variable was independent variable. In this project there is different variable that affect the conductivity of Gallium Arsenide semiconductor conductivity.

1.6 Limitation of the study

The limitation of this project are:

- There is no enough book.
- Lack of internet accessibility.
- Lack of time.
- Lack of budget.
- shortage of electric power.

Chapter 2

Literature Reviews

2.1 Energy band gap in Semiconductors

The energy band gap is a major factor in determining the electrical conductivity of a solid. Energy band gap is a gap of energy in solids where no electron states can exist. Energy band gap, also called an energy gap or band gap. The band gap generally refers to the energy difference (in electron volts) between the top of the valence band and the bottom of the conduction band in insulators and semiconductors. The closest point between the top of the valance band curve and the bottom of the conduction band is called the materials Energy Gap. For insulating materials, this gap can be greater than ten electron volts. However, for semiconductor electronic devices operating a reasonable voltage, the gap has to be a few electron volts [6].

The band gap of a semiconductor, given by the energetic difference between its valence band maximum and conduction band minimum, has important implications for both the semiconductors light absorption properties and the maximum photo voltage that can be expected from a corresponding device. In order to absorb a photon, an electron generally must be excited from the valence band of the semiconductor to the conduction band. Thus, a photon must possess energy greater than or equal to that of the semiconductor band gap in order to be absorbed and create an excited electron-hole pairs. The processes excitation of free carriers must obey the law of energy and momentum conservations. This, in particular, leads to the fact that the minimum quantum energy sufficient to excite electron from the valence band to the conduction band is equal to the band gap of the semiconductor. The energy bands may be occupied or unoccupied. The highest occupied band is called the valence band at energy E_V, and contains the valence electrons. The lowest unoccupied band is called the conducting band that lies at the energy level E_c. The energy bands can be empty, partly full or completely full and determines the properties of the solid. The band gap energy, E_g is the energy deference between the conduction and the valence band [7].

$$E_g = E_c - E_v. \tag{2.1}$$

The thermal excitation of electrons from the valence band to the conduction band creates free carriers in both bands. A large band gap will make it more difficult for a carrier to be thermally excited, hence the concentration of thermal carriers is lower in higher band gap materials.The first empirical relation for the band gap shift with temperature developed by Varshini was given by :

$$E_g(T) = E_{g_0} - \frac{\alpha T^2}{\beta + T} \tag{2.2}$$

Where α and β are constants choosen to obtain the best fit to experimental data and E_{g_o} is the limiting value of the band gap at zero Kelvin. It was found that $E_{g_0} = 1.519$ ev α=$5.41x10^{-4}ev/k$ and $\beta = 204K$ for gallium arsenide [8].

2.2 Intrinsic and Extrinsic Semiconductors

The semiconductors may be divided into two categories; the pure un doped semiconductor, which is usually referred to as the intrinsic semiconductor, and the doped semiconductor, which is also called the extrinsic semiconductor. The total thermal equilibrium density of electrons in a semiconductor is given by [9]

:

$$n_0 = N_c exp \frac{-(E_c - E_F)}{(k_B T)} \tag{2.3}$$

Where,

$$N_c = 2\frac{(2\pi m_n^* k_B T)^{\frac{3}{2}}}{h^3} \tag{2.4}$$

is the effective density of the conduction band states, m_n^* is effective mass of electrons in the conduction band and h is the known Plancks constant. The hole thermal equilibrium density in the valence band is also given by:

$$p_0 = N_v exp\frac{-(E_F - E_v)}{(k_B T)} \tag{2.5}$$

Where,

$$N_v = 2\frac{(2\pi m_p^* k_B T)^{\frac{3}{2}}}{h^3} \tag{2.6}$$

And m_p^* is effective mass of holes in the valence band. The values of m_p^* and m_n^* for GaAs is given by [10]:

$$m_p^* = 0.48 m_p \qquad and \qquad m_n^* = 0.063 m_n, \tag{2.7}$$

Where, m_n is the rest mass of electron which is equal to 9.11× 10^{-31} kg.

2.2.1 Intrinsic Semiconductors

Semiconductors are considered to be as intrinsic semiconductors if its thermally generated carrier density represented by n_i is much larger than the background doping or residual impurity densities. At room temperature (T=0K), an intrinsic semiconductor behaves like an insulator because the conduction band states are totally empty and the valence band states are completely filled. However, as the temperature increases, some of the electrons in the valence band states are excited into the conduction band states by thermal energy, leaving behind an equal number of holes in the valence band. Suppose that $\Re$ is the concentration of electron-hole pairs thermally generated in the respective bands and $\Re_R$ is the concentration of electron hole annihilated after the generation, the free carrier concentrations in the conduction and valence bands adjust for the intrinsic semiconductor to be:

$$n_0 = \Re - \Re_R = n_i = p_0. \tag{2.8}$$

Since the non-degenerate relations are obviously valid for an intrinsic semiconductor, the intrinsic carrier concentrations are given as follows:

$$n_i = N_c exp\frac{-(E_c - E_i)}{(k_B T)} = N_v exp\frac{-(E_i - E_v)}{(k_B T)} \tag{2.9}$$

where, E_F is the Fermi level, E_i intrinsic energy level and K_B Boltzmann constant which is equal to 1.38× 10^{-23} JK^{-1}. The intrinsic Fermi energy derived from effective density of electron and holes as follows:

$$E_i = \frac{(E_c - E_v)}{2} + \frac{K_B T}{2} \ln \frac{N_v}{N_c} \tag{2.10}$$

$$E_i = \frac{(E_v + E_c)}{2} + \frac{3K_B T}{4} \ln \frac{m_p^*}{m_n^*} \tag{2.11}$$

which indicates that if $m_p^* = m_n^*$ or T=0 the Fermi level in an intrinsic . semiconductor is positioned at mid-gap. In real cases m_p^* different from m_n^* , resulting in small deviation of the fermi level from mid-gap. The equilibrium density of electrons and holes in a non-degenerate semiconductor is constant at a given temperature. The product of the electrons and holes density, in a non-degenerate semiconductor at equilibrium, is always equal to the square of the intrinsic carrier density[11].

$$n_i^2 = p_0 n_0 \tag{2.12}$$

The intrinsic carrier density (which is specific to a given semiconductor) is related to the effective density of conduction and valence band, i.e.

$$n_i = \sqrt{N_c N_v} exp \frac{(E_v - E_c)}{(2K_B T)} \tag{2.13}$$

This relationship, referred to as the law of mass action, which allows (at thermal equilibrium) to determine the electron density if the hole density is known or vice versa. It should be noted that this equation signifies that, the electron-hole pairs may be continuously generated and recombined; the product of the concentration (averaged in time) stays constant. This equation also indicates that, for a non-degenerate material in equilibrium, the $p_0 n_0$ product depends on the effective conduction and valence band densities of states, the energy band gap of a semiconductor, and the temperature. It is independent of the Fermi level position and of the individual electrons and holes densities. In other words, the $p_0 n_0$ product is constant at a given temperature regardless of doping[12].

2.2.2 Extrinsic Semiconductors

The availability of charge carriers in the valence and conduction bands greatly affected by the presence of impurities (i.e., foreign atoms incorporated into the crystal structure of a semiconductor). In semiconductors, some impurities are deliberately introduced to produce materials and devices with desired properties. The process of putting impurities into the lattice is doping. The contribution of free carriers by dopants requires them being ionized (i.e., the dopants have donated or accepted an electron). The ionization of the dopants depends on the thermal energy and the position of the impurity level in the energy gap of a semiconductor. In an extrinsic semiconductor, electrons are majority carriers and holes are minority carriers in n-type semiconductor. In p-type material, electrons are minority carriers and holes are majority carriers [13].

As shown in the Figure (2.1) below, at low temperature, the donor impurity levels are filled. But with increasing T, the electron in the donor levels are excited into the conduction band and similarly the holes in the acceptor levels are excited into the valence band. With a small temperature, these donors or acceptors can be thermally excited into the band. Therefore, the donor impurities donate free electrons to the conduction band, whereas the acceptor impurities give free holes to the valence band. However, at very low temperature, these carriers are bound back to their respective nuclei so that they can no longer carry electricity, a phenomenon known as carrier freeze out [14].

Figure (2.1) also shows that, when donor impurities are added, at zero temperature, these states are near the top of the band gap, and are filled. Thus, the Fermi energy is moved up to the top of the band gap. On the other hand, when acceptors are added, the acceptor states near the bottom of the band gap are empty. Thus, the Fermi energy is moved down to the bottom of the band gap. The presence of impurities in a material can have dramatic effect on its optical properties. There are two main optical effects of impurities. The first effect is that the impurities add charge carriers to the materials. This obviously can have some important effects on the interaction with light. The second important effect is the introduction of new energy levels within the gap. Whereas before the introduction of impurities, the lowest energy transition that can be made is the full energy of the gap, now one can have optical transitions between impurity states, or from the bands to the impurity states [15].

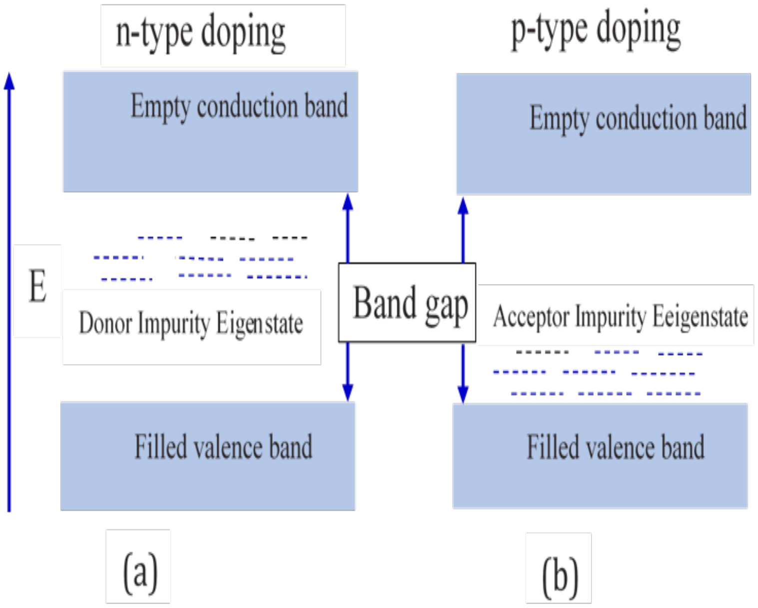

Figure 2.1: Doped semiconductors with (a) donor(b) acceptor impurities.

The most important and unique feature of a semiconductor material lies in the fact that its electrical conductivity can be readily changed by many orders of magnitude by simply doping the semiconductor with shallow-donor or shallow-acceptor impurities. By incorporating the doping impurities into a semiconductor, the electrons or holes density will increase with increasing shallow-donor or shallow-acceptor impurity concentrations. Adding donor or acceptor impurity atoms into semiconductor will change the distribution of electrons and holes in the material, and as a result, the Fermi energy will change.

$$n_0 = n_i exp\frac{-(E_i - E_F)}{(K_B T)} and \;\; p_0 = n_i exp\frac{-(E_F - E_i)}{(K_B T)} \tag{2.14}$$

2.2.3 Conductivity of Semiconductor

Conductivity in a semiconductor is due to movement of electrons in the CB and holes in the VB in an applied electric field. The formation of electron and holes and their recombination is a dynamic process. This depends on the temperature of the sample (for an intrinsic semiconductor) so that there is an equilibrium concentration at a given temperature. Conductivity in a semiconductor depends on two factors;

1. Concentration of electrons and holes. Denoted as n and p and is temperature dependent.
2. Ability of the electron and holes to travel in the lattice without scattering.

Electrons and holes are said to drift in the lattice. This is because they undergo multiple scatterings with the atoms. For semiconductors concentration of electrons and holes are small so that electron-electron scattering can be ignored. Define a quantity called mobility, denoted by the symbol μ. Mobility refers to the ability of the carriers to move in the lattice. Mobility is related to the effective mass of the carrier (m_n^* or m_p^*) and the time between two scattering events (τ_e or τ_h). The relation is

$$\mu_e = \frac{e\tau_e}{m_e^*} \tag{2.15}$$

$$\mu_h = \frac{e\tau_h}{m_h^*} \tag{2.16}$$

The effective mass term takes into account the effect of the lattice arrangement on the movement of the carriers. Using the carrier concentration and the concept of mobility it is possible to write a general equation for conductivity σ given by:

$$\sigma(T) = n(T)e\mu_e(T) + p(T)e\mu_h(T) \tag{2.17}$$

higher the carrier concentration (n or p) higher the mobility. Also, higher the mobility, higher the conductivity. Since mobility is related to the time between 2 scattering events, by equation 2, more the time between 2 scattering events greater is the conductivity [16].

the electron concentration is the comparable in magnitude to the atomic density and explains why semiconductors have a poor conductivity compared to metals. The conductivity is given by:

$$\delta_i = n_i e(\mu_e + \mu_h) \tag{2.18}$$

$$\delta_i = \sqrt{N_c N_v} exp \frac{-E_g}{K_B T} e(\mu_e + \mu_h) \tag{2.19}$$

Chapter 3

Methodology

3.1 Research work area and period

This research project work would be conducted in Wolkite University which was found in Gurage zone at Chaha woreda and the time will take to perform this study is from March 2019 to June 2019.

3.2 Source of Data/Source Information

The information for this study had been gathered in different ways. The source of information is only secondary source of data. The sources of information are published articles, Internet, text books.

3.3 Project design

To write this senior project, we used previous written source and gather information from internet. This project is describe in general terms the methods to be employed to achieve the objectives of the research, data, sources, collection and method of arriving at the conclusions.

3.4 Method

The primary task in this work is to select Gallium Arsenide compound semiconductor sample in which conductivity as a function of temperature is studied. The next task is to collect important data concerned with density state of hole and electron, carrier concentration, conductivity and all parameters of this semiconductor. Then, the statistics of the accumulation of free carriers in the conduction band and valence band are formulated. Upon the determination of the mobility, carrier concentration, density of state and conductivity for electron and hole concentration, one can describe the competition between conductivity as a function of temperature for a given compound semiconductor. This can be done by using excel and origin softwares.

Chapter 4

Results and Discussions

In this topic the effective densities of electrons and holes with temperature, variation of carrier concentrations with temperature and variation of bulk conductivity with temperature of gallium arsenide compound semiconductor is described in detail.

4.1 Variation of effective densities of electrons and holes with temperature

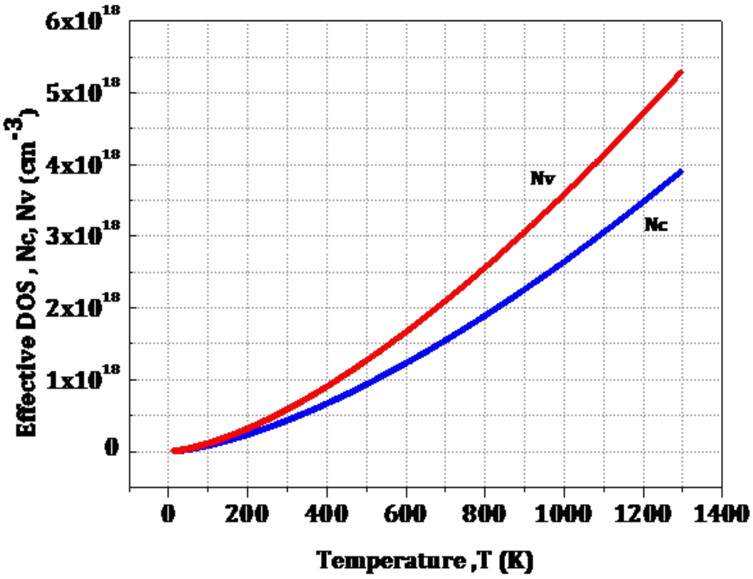

Figure 4.1: Variation of effective densities of electrons and holes with temperature

The density of state of holes and electrons are related with temperature as shown in equation (2.4) and (2.6) above respectively and both of them are depend on effective mass of electron and holes. Density of states of hole in valence band have greater than density of state of electron in conduction band. From the above graph since the effective mass of hole is greater than the effective mass of electron the effective densities of hole in valence band N_v is greater than the effective densities of electron in conduction band N_c As we can see from the above figure (4.1), both the density of states of electrons and holes are increases as the temperature increases [17].

4.2 Variation of carrier concentrations with temperature

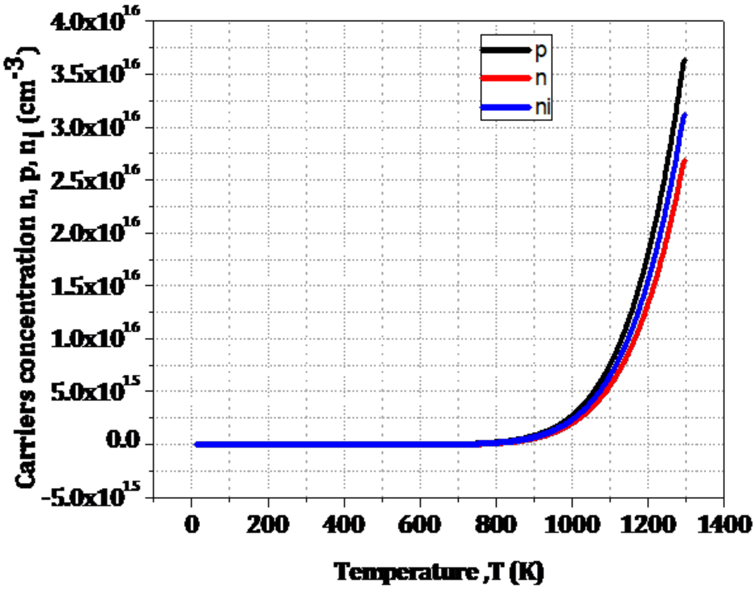

Figure 4.2: Variation of carrier concentrations with temperature

In this section, temperature dependences of carrier concentration for gallium arsenide are described. The concentration of electron, concentration of hole and intrinsic concentration are described using equation (2.3), (2.5) and (2.9) above respectively. For an electron-hole pair to be created in an intrinsic semiconductor, a bond must be broken in the lattice, and this requires energy. An electron in the valence band must gain enough energy to jump to the conduction band and leave a hole behind. n_i represents the intrinsic carrier concentration, or we can see it as the number of bonds broken in an intrinsic semiconductor. As the temperature is increased, the number of broken bonds (carriers) increases because there is more thermal energy available so more and more electrons gain enough energy to break free. Each electron that makes it to the conduction band leaves behind a hole in the valence band and there is an increase in both the electron and hole concentration. As the temperature is decreased, electrons do not receive enough energy to break a bond and remain in the valence band. If electrons are in the conduction band they will quickly lose energy and fall back to the valence band, annihilating a hole. The region from the right up to $0(K)$ is called the freeze out region and the region from $0(K)$ to $1000(K)$ is extrinsic region. The region from $1000(K)$ to the right is intrinsic region. At room temperature the hole concentration is $1.64 \times 10^5 cm^3$ the electron concentration is $2.22 \times 10^5 cm^3$ and intrinsic concentration is $1.9 \times 10^5 cm^3$ for gallium arsenide. This variation is due to the effective mass m_n^* and m_p^* and since the effective mass is the measure of how well a particle moves in a crystal, this parameter may have a slight dependence on the interactions with ionic nuclei of the crystalline lattice. Therefore, as the temperature increases the carriers concentration increases. Upto a temperature of $800K$, carriers concentration remains constant and starts to increase above this temperature. Therefore, lowering the temperature causes a decrease in the intrinsic carrier concentration, while raising the temperature causes an increase in intrinsic carrier concentration. [18].

4.3 Effects of temperature on bulk conductivity

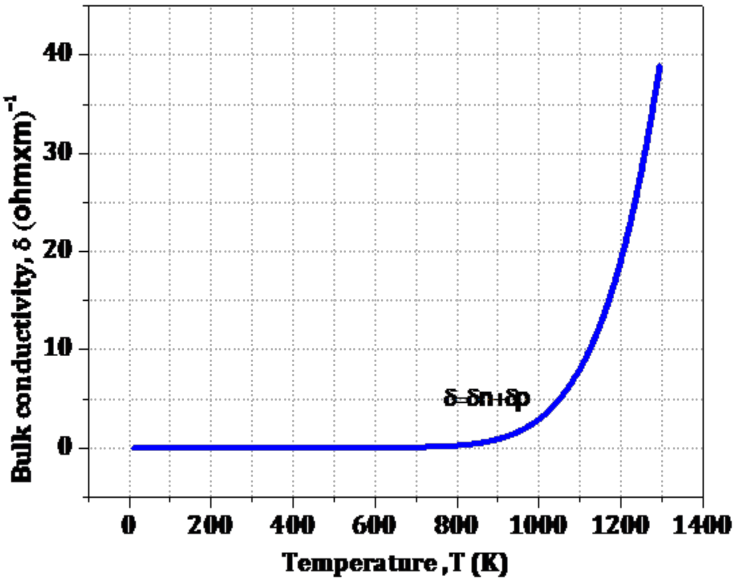

Figure 4.3: Temperature dependence of bulk conductivity of Gallium Arsenide (GaAs) compound semiconductor

Figure (4.3) above depicts the variation of conductivity of both electron and holes with temperature for Gallium Arsenide (GaAs) compound semiconductor. This figure was drawn using relations given in equation (2.17) above. From the above result the bulk conductivity depended on both carrier concentration and mobility, so there have been a variety of possible temperature dependencies for conductivity. For instance, at fairly low temperatures (less than 650K),there were similar variation of temperature and conductivity. as conductivity would be seen to increase with temperature by equation (2.19) other possibilities, depending on the material, doping, and temperature will show different temperature dependence of conductivity. One particularly interesting case occurs at high temperatures (above 1000K or higher) when carrier concentration was intrinsic and mobility was dominated by in such cases, the conductivity can easily be varied with temperature by equation (2.19). In this case, conductivity depends only on the semiconductor band gap and the temperature. In this temperature range, measured conductivity data can be used to determine the semiconductor band gap energy, E_g. the holes contribute very little to the conductivity. It can be seen from this graph that if the doping level is significantly higher than the intrinsic electron/hole density, the majority carrier does most of the conducting in the material and that the conductivity is directly proportional to the doping level[19].

Chapter 5

Conclusion and Outlook

5.1 Conclusion

Generally, lowering the temperature of (GaAs) causes a decrease in the intrinsic carrier concentration, while raising the temperature causes an increase in intrinsic carrier concentration. This effect each electron exited to the conduction band leaves behind a hole in the valence band and due to this an increase in both the electron and hole concentration. And also both the density of states of electrons and holes are increases as the temperature increases. Based on mobilities, GaAs would be the material to choose for higher conductivity but GaAs also has a higher band gap so that the intrinsic carrier concentration would be high. Higher mobility can lead to an increase in conductivity the dominant term is the carrier concentration and consequently the band gap. Since the carrier concentration has an exponential dependence on Eg. Lowering Eg will have the greatest effect on conductivity.

5.2 Outlook

As seen in previous parts, the variables such as mobility, carrier concentration, Variation of effective densities, and bulk conductivity were factors most probable affects status of conductivity of (GaAs) compound semiconductor. Considering this in mind we make the following recommendations: According to the results of our data,as temperature of (GaAs) tends to increases we can get narrow energy band gap. Therefore the study will further investigate the role of temperature dependence of conductivity in (GaAs) semiconductors. This particularly study gives more about the band gap of semiconductor and explain especially the Gallium Arsenide compound semiconductor materials. They study will further investigate the role of conductivity and band gap in semiconductors. And also further study is focusing on the application of gallium arsenide compound semiconductor.

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