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Article

An Analysis on Semiconductor Material, Classification, uses and its Heating Properties

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A B S T R A C T

Semiconductor substantial are the constructing tablet of entire electronic and computer industry. This broadside make available an all-purpose conversation of semiconductor quantifiable, their history, and organization and temperature effect in semiconductor. This article also offers the application of semiconductor material in diverse sector of recent electronics and communication.

Keywords: Semiconductor, History of Semiconductor, Temperature Effect in Semiconductor, Application of Semiconductors

Introduction

As we distinguish nearby are a convinced material that are neither conductor nor insulator. A constituent which has crystalline construction and comprise few electrons at room temperature is called semiconductor. It perform like insulator at room temperature. Its restivity lie amid conductor and insulator. For instance silicion, germanium, carbon etc.

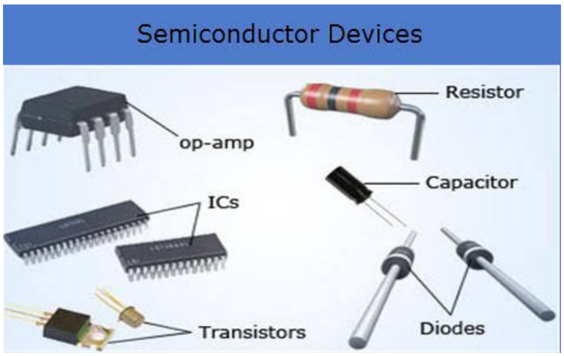

Figure 1.Semiconductor Device

As we say semiconductor are the basic building block of modern electronic including, transistor, solar cell, led and digital and analog integrated circuit.

The modern understanding of the properties of semiconductor in quantam physics to explain the movement of electrons and holes inside a crystal structure and also in lattice as we increase electrical conductivity of semiconductor material increase with increase in temperature.

Current conduction in semiconductor occur through the movement of electrons and holes collectively know as charge carriers. Adding any impurity in semiconductor material knows as doping i.e. the charge carrier also increased.

When doped semiconductor mainly consist of holes then it is known as p-type and when doped semiconductor mainly consist of electron then it is known as n- type semiconductor A single semiconductor crystal can have many p- and n-type regions; the p–n junctions between these regions are responsible for the useful electronic behavior. Due to the development of quantam physics is turn allowed the development of transistor in 1948. A large number of element and compound of semiconductor found in group 14 of periodic table and commercial we use galiuim, silicion. They are mostly use because they have 4 valence electron in the outermost shell so they have ability to gain or lose the electron at the same time.

Figure 2.Silicon crystals are the most common semiconducting materials used in microelectronics and photovoltaics

Now-a-days semiconductor solid are castoff in each sector of recent expertise. In this article we analysis the classification of semiconductor, initial times gone by of semiconductor, temperature outcome of semiconductor.

History of Semiconductor

The times past of the thoughtful of semiconductors begins with research on the electrical properties of materials. The belongings of negative temperature coefficient of resistance, rectification, and light-sensitivity were perceived starting in the initial 19th period.

In 1833, Michael Faraday stated that the resistance of samplings of silver sulfide diminutions when they are heated. In 1839, A. E. Becquerel reported remark of a voltage among a solid and a liquid electrolyte when struck by light, the photovoltaic effect. Then in between 19th century there are many researches done a unified details of the occurrences required a theory of solid state physical which greatly developed in first half of 20th century.

In 1878 Edwin Herbert Hall established the deflection of flowing charge transporters by an applied magnetic field, the Hall Effect. The recognition of the electron by J.J. Thomson in 1897 encouraged philosophies of electron-based transmission in solids. Karl Baedeker, by sensing a Hall Effect with the contrary sign to that in metals, hypothesized that copper iodide had positive charge carriers. Outstanding to this perception another time many examines take place. By 1931, the band system of conduction had been recognized by Alan Herries Wilson and the idea of band gaps had been industrialized. Once more there determination so much revolution take place like light sensitive possessions, working of solar cell, power rectifier etc.

At Bell Labs, William Shockley and Holden underway revising solid-state amplifiers in 1938. The first p–n junction in silicon was experiential by Russell Ohl about 1941, when a specimen was originate to be light-sensitive, with a shrill boundary amid p-type contamination at one end and n-type at the other. A slice cut after the example at the p–n boundary manufacturing a voltage when vulnerable to light. In France, all over the war, Herbert Matare's had observed amplification amid adjoining point acquaintances on a germanium base. Subsequently the war, Matare's group announced their "Transistron" amplifier solitary at the moment after Bell Labs professed the "transistor".

Classification of Semiconductor

Semiconductors may be categorized as:

- Intrinsic semiconductor
- Extrinsic semiconductor

Intrinsic Semiconductor

In informal words an intrinsic semiconductor is unique which completed up and about of an exact pure semiconductor material. In methodological terminology it can government that an intrinsic semiconductor is unique anywhere not at all. Of holes is equivalent to no. of electron in the conduction band.

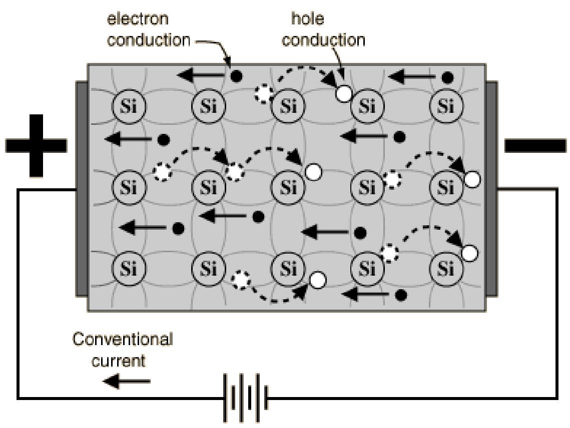

Figure 3.Intrinsic Semiconductor

At this time forbidden energy gap is smallest and energy is obtainable at room temperature in adequate for electron to change from valence band to the conduction band.

Fermi level mention to that level of energy anywhere the probability of conclusion an electron is half and this probability is amount in scale. Fermi level of semiconductor lie amid one way or another in valence and conduction band.

If the potential difference is useful transversely intrinsic semiconductor, electron will change in the way of positive terminal whereas holes will drift to negative terminal. If the temperature of semiconductor intensification the no. of holes–electron pair propagations and current finished semiconductor intensification.

Extrinsic Semiconductor

In extrinsic semiconductor we enhance unimportant total of impurities that is known as dopant and doping agent. The materials selected for doping are intentionally chosen in such a manner that either they have 5 electrons in their valence band, or they have just 3 electrons in their valence band. Hence such dopants are acknowledged as pentavalent or trivalent dopants separately. The type of dopant also gives rise to two kinds of extrinsic semiconductors namely P-type and N-type semiconductors.

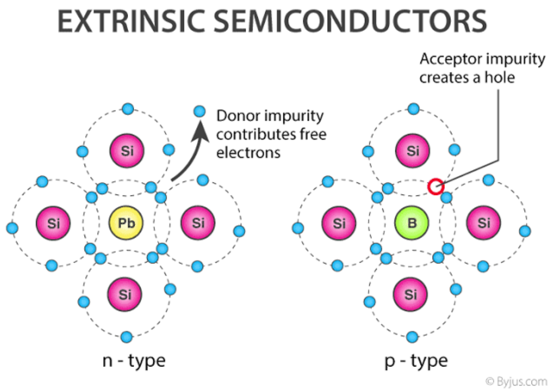

Figure 4.Extrinsic Semiconductor

A Pentavalent dopant such as Antimony are recognized as donor impurities meanwhile they donate an extra electron in the crystal structure which is not compulsory for covalent bonding determinations and is willingly obtainable to be removed to the conduction band. This electron prepares not give rise to a equivalent hole in the valence band since it is already excess, consequently upon doping with like a material, the base material like as Germanium contains more electrons than holes, hence the nomenclature N-type intrinsic semiconductors. On the supplementary indicator when a trivalent dopant such as Boron is added to Germanium additional or extra holes formed due to exactly reverse process as we discoursed in n-type semiconductor. this dopant which is also known as acceptor creates a P-type semiconductor. Hence electrons are the majority carriers in N-type while holes are minority carriers.

Alternative alteration is that while the Fermi level of intrinsic semiconductors is wherever equidistant amongst the valence band and the conduction band, it modifications

Figure 5.Germanium

upwards in case of N-type while it meanings downward in case of P-type.

Semiconductor Material

Semiconductor physical can easily regulate, can be conduct electric current and act as both insulator and semiconductor. The conductivity of the semiconductor is commonly sensitive to disease, brilliance, magnetic field and lowest amount of impurities. Outstanding to the sensitivity and conductivity kind the semiconductor unique of the furthermost significant factual for electronic use.

Temperature Effect in Semiconductor

Effects on temperature like current density, threshold voltage, leakage current.

Energy band Gap

Temperature affect the possessions of electronic system in no. of significant procedures. The greatest essential assets in energy band gap Eg which pretentious by temperature.

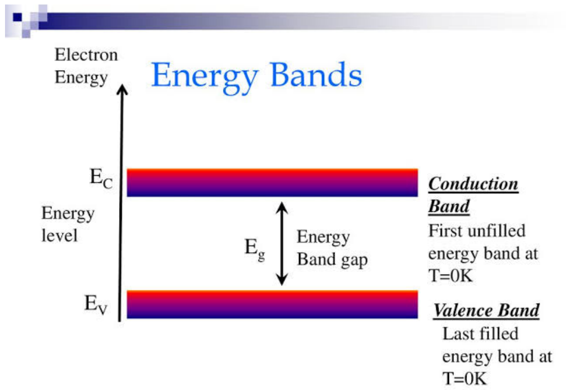

Figure 6.Energy Band

$Eg(t)=Eg(0)-\alpha Et^2/T+\beta E$ (1)

Eg(0) stands is the band-gap energy at absolute zero on the kelvin scale in the specified physical.

αE and βE is material specific constant.

Semiconductor Conductivity

Conductivity of semiconductor is given by:

$\sigma = q\ (\mu n\ n + \mu P\ p)$ (2)

where, µn and µP refer to the mobility of the electrons and holes n and p refer to the density of electrons and holes, respectively.

conductivity depends on both carrier concentration and mobility, so there are a variety of possible temperature needs for conductivity.

One largely stimulating case occurs at high temperatures (above 400k or higher) when carrier attentiveness is intrinsic and mobility is controlled by lattice scattering.

$\sigma\ \alpha\ Exp\ \{-Eg/2KT$ (3)

In this case conductivity depend only on semiconductor bandgap and temperature.

Carrier Density

Carrier densities affect electrical and thermal conductivity, and are a function of the effective density of states in the appropriate band. Fermi energy level in the material and the temperature.

$n = N_{ce}\text{-}E_C\text{-}E_f/KT$ (4)

$p = N_{ce}\text{-}E_C\text{-}E_v/KT$ (5)

where, n is the electron density,

p is the hole density,

NC is the density of states in the conduction band,

NV is the density of states in the valence band,

EC is the conduction band energy level,

EV is the valence band energy level,

FE is the Fermi energy level,

k = 1.38.10-23 J/K is the Boltzmann constant,

T is temperature

Mobility

The carrier mobility, µ (cm2 /V.s), describes the drift velocity of a particle in an applied electric field. Under small to moderate electric fields, µ= vd/ξ where vd is the drift velocity, and ξ is the electric field.

MOSFET mobility has very complex temperature dependence. Each of these scattering parameters is related to the temperature of the material, T and the effective transverse electric field in the channel, ξeff, which is approximated.

$\xi eff= nQ_{inv}+Q_c/\ \varepsilon Si =V_{gs}+V6T_{OX}$ (6)

where η is a constant (η ≈ 0.4 in PMOS devices and η ≈ 0.5 in NMOS devices), Qinv is the inversion layer charge density, Qb is the substrate depletion charge density, and εSi = 11.7 is the relative permittivity of Silicon. This approximation is not very convenient for circuit analysis, so ξeff is also approximated in terms of the gatesource voltage Vgs, the threshold voltage VT, and gate oxide thickness Tox.

Carrier Diffusion

Diffusion is the movement of a element from higher concentration to a region of low concentration. Carrier diffusion coefficients Dn and Dp (for electrons and holes, correspondingly) are connected to mobility by the Einstein relationship

$D/\mu =k/Tq$ (7)

Here, q is the charge on an electron, and kT/q is an important value known as the thermal voltage. Dn and Dp in room temperature silicon.

Current Density

The temperature dependence of the carrier concentrations, mobility and diffusion coefficients affect the temperature behavior of the carrier current densities, with the carrier densities.

$J_n=q\ \mu_n n_e+qD_n\nabla_n$......(8)

$J_p=q\ \mu_p p_e+qD_p\nabla_p$......(9)

where J_n and $J_p$electron and hole current densities, respectively

µn and µp corresponding to the electron and hole mobility

ne & np is the electric field

∇n &∇p is electron and hole concentration.

LEAKAGE SEMICONDUCTOR:

Sub threshold leakage current $I_{sub}$is exponentially dependent on temperature. When VGS = 0, I_{sub} may be represented by the Shockley diode model.

$I_O= Ate^{-1.12}/2.\varnothing\ T$

I_O=reverse saturation current

A= Isa constant

V_{ds}=drain source voltage

$\varnothing t=KT/Q$......(10)

$I_0$is responsible for exponential temperature dependence.

Application of Semiconductor

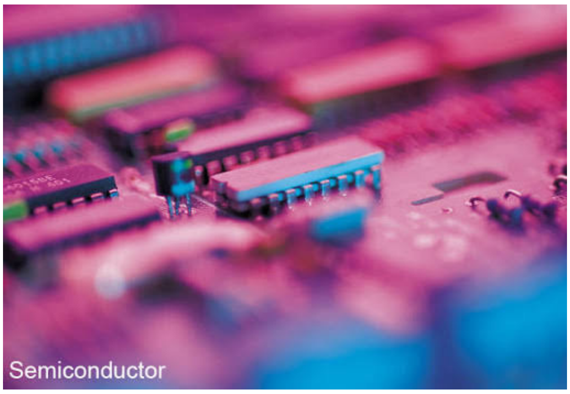

Figure 6.Semiconductor

- Electronic device
- Solar cell
- Telecommunication
- Transmitter and receiver
- Wireless communication
- Semiconductor in computer

Conclusion

In the times gone by of info there remained binary revolutions. The leading was that of Johan Gutenberg who made info obtainable to various, the other is the development of the transistor. Now the universal quantity of info doubles each year. Various belongings we are enchanting for granted (such as, e.g., computers, Internet and mobile phones) would not be conceivable deprived of silicon microelectronics. Electronic circuits are too current in cars, home appliances, machinery, etc. Optoelectronic devices are similarly imperative in ordinary life, e.g., fiber optic communications for data transfer, data storage (CD and DVD recorders), digital cameras, etc. Subsequently the commencement of semiconductor electronics, the numeral of transistors in an integrated circuit has remained cumulative exponentially with time. In instantaneous obtainable the summary of semiconductors, their initial times absent by and organization. The energy band gap, mobility, threshold voltage and saturation velocity are diminution with cumulative temperature. On the additional indicator the conductivity, carrier density, leakage current and connect resistant intensification with accumulative temperature. The submissions of semiconductors in rudimentary electronic devices, telecommunication and wireless systems and finally in solar scheme.

References

1. Filanovsky IM, Allam A. Mutual compensation of mobility and threshold voltage temperature effects 2001.
2. Agarwal A, Mukhopadhyay S, Raychowdhury A et al. Leakage power analysis 2006.
3. Yacobi BG. Semiconductor Materials: An Introduction to Basic Principles.
4. Łukasiak L, Jakubowski A. History of Semiconductors. *Journal of Telecommunication and Information Technology* 2010.
5. Morris PR. A History of the World Semiconductor Industry 1990.
6. H Davy 1840 Historical Sketch of Electrical Discoveries. Collected Works of Sir Humphry Davy v01 111, ed J Davy, (London: Smith)
7. Koenigsberger J. Metallische Leitung Handbuch d Elektr. und d. Magnetismus Bd I11 ed L Graetz (Leipzig: Barth) 1923; 597-724.
8. Baedeker K. Eigentumliche Form elektrischen (351 Baedeker K 1912 *Kunstliche metallische Leiter Phys* 1908; 2(13): 1080-2.
9. Wagner C, Schottky W. Theorie der und fliissigen Korpern Z. Phys. 35 652-69 geordneten Mischphasen Z. Phys. Chem. 1931; 11: 163- 210.
10. 1451 von Baumbach H H and Wagner C 1933 Die elektrische Leitfahigkeit von Zinkoxyd und Cadmiumoxyd 2. Phys. Chem. B 22 199-211.