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Nano Science is the Study of the Fundamental Principles of Molecules and Structures

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ABSTRACT:

Recently the physics of electrons and holes under confined system has acquired enormous importance. The origin of the name 'Confined System' lies in the fact that in the substance, electron and hole motions are restricted in one, two or three dimensions unlike bulk structures. Nano Science is the study of the fundamental principles of molecules and structures with at least one dimension roughly between 1 and 100 nanometers and Nano technology encompasses how we harness the knowledge of nano science to create material products, devices and instruments that fundamentally change the way of modern life. National Science Foundation document edited by Mike Roco and issued in 2001 gives a concise definition of nanoscience and nanotechnology as, *"One nanometer is a magical point on the dimensional scale. Nanostructures are at the confluence of the smallest of human made device and the largest molecules of living things. Nanoscale science and engineering here refer to the fundamental understanding and resulting technological advances arising from the exploitation of new physical, chemical and biologicalproperties of systems that are intermediate in size, between isolated atoms and molecules and bulk materials, where the transitional properties between the two limitscan be controlled.*

KEYWORD: Nano Science, Electronic, Optoelectronic and Nonlinear Optical Properties

INTRODUCTION:

Modern research has made it possible to design and fabricate semiconductor nano particles, especially those belonging to II-VI, III-V and IV-V group of the periodic table. These semiconductors exhibit considerable quantum size effects leading to size dependent electronic, optoelectronic and nonlinear optical properties[1-7,13]. The fact that the band gap of any of these materials varies with size, gives a great potential for optoelectronic and optical applications. The dramatic change, as one goes from bulk to nanometer size[24,25], is principally due to redistribution of the electronic states and changes in the corresponding wave function[22,23]. Nano particles, in the study of non-linear optics, is found to be the promising field of research recent days. In non linear optics, the interaction processes between the exciting light waves and the nano material are no longer linear but involves higher orders[5,7]. Due to optical properties, nanostructures have been proved to be the potential candidate for many non-linear optical applications[9-17] e.g second harmonic generation.

CLASSIFICATION OF NANO-PARTICLES:

Depending upon the confinement of charge carriers, nano particles are classified into three categories. These are:

I. Quantum Well

If the thickness of a structure becomes comparable to de Broglie's wavelength of electron at Fermi energy of electron and the electronic motion is confined along thethickness only, the structure is called **quantum well[2].**

Quantum well is a two dimensional (2D) structure where the electrons arefree to move in two dimensions but confined along third dimension, results in the formation of quantum states for motion of electrons in the confined direction.

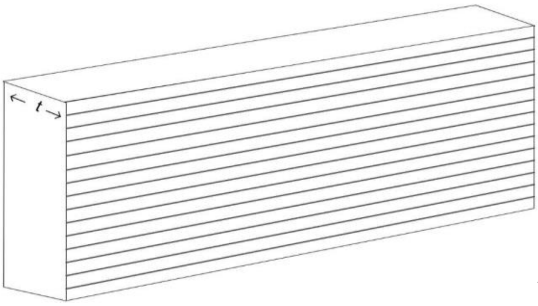
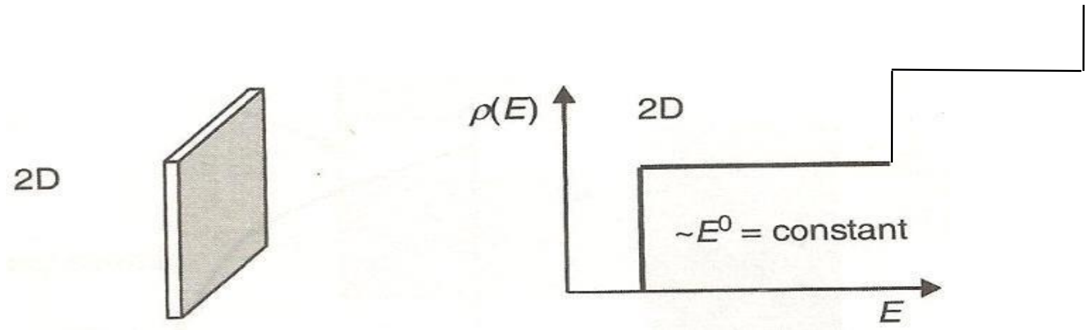


Figure : 1.1 Confinement along 't'

The density of states (DOS) for two dimensional (2D) structure is expressed as:

$$\rho(E)_{2D} = \frac{m^*}{\pi \hbar^2} \sum_i H(E - E_i)$$

Where H (E- E_i) is the Heaviside function[2]/ unit step function[4]. It takes the value of zero when E < E_i, and 1 when E ≥ E_i, E_i is the *i*th energy level within the 2D quantum well.



(a) Degrees of freedom (b) Density of states

Figure: 1.2 (a) Electron trapped in 2D plane: Quantum well. (b) The DOS variation of quantum well as a function of energy. DOS(2D) shows a step function behaviour.

Ultra thin film layers (each ~ few nm thick) grown on a substrate, shows quantum confinement along the low dimensional z -axis and periodicity exists in x-y plane. We assume infinite confining potential (v=∞ at the barrier)

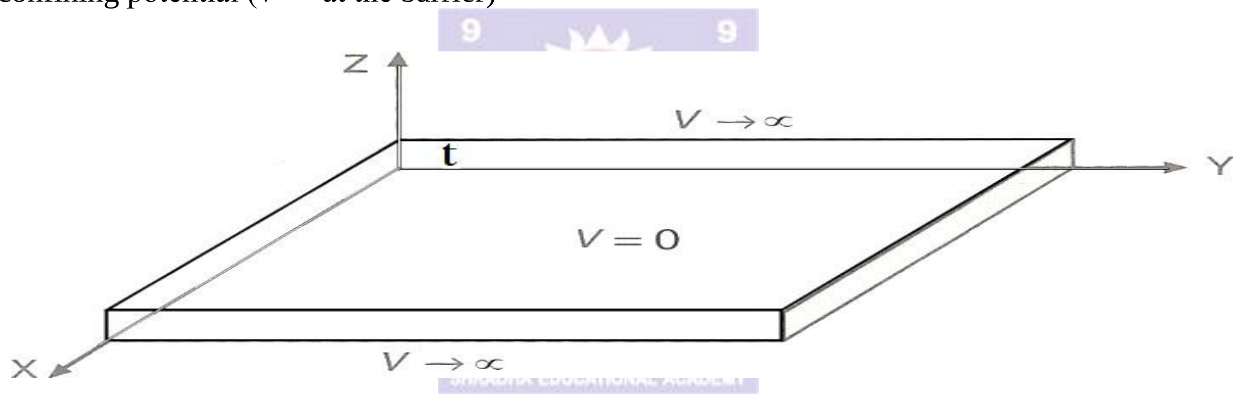


Figure:1.3 Two dimensional space. Carriers can move along X and Y directions freelybut confined along Z-direction by a small thickness t

In the above figure (Figure 1.3) carriers are confined in one dimension say along Z-direction to a very small thickness 't'. This is the case of quantum well wherecarriers are allowed to move along two dimensions namely X and Y. In this case, the resultant quantised energy levels are found by solving one dimensional (1D) form of the time independent Schrödinger equation[2] viz.,

$$-\left(\frac{\hbar^2}{2m}\right)\frac{d2y}{dx2}\psi(z) + V(z)\psi(z) = E\psi(z)$$

The expression for wave function and energy will be respectively,

$$\psi_n(x,y,z) = \left(\frac{2}{t}\right)^{1/2} \sin\left(\frac{n_z \pi z}{t}\right) e^{ik_x x} e^{ik_y y}$$

And the allowed energy states of the confined electron in a quantum well is

$$E_n = \underbrace{\left\{\left[\frac{h^2}{8mt^2}\right] n_z^2\right\}}_{\text{confinement along z-axis}} + \underbrace{\frac{\hbar^2 k_x^2}{2m} \frac{\hbar^2 k_y^2}{2m}}_{\text{free carrier movement along x-}}$$

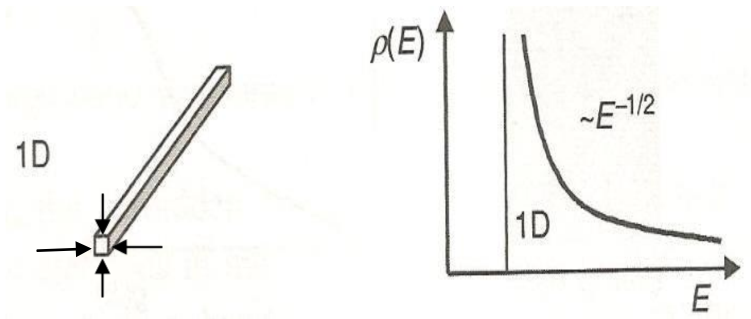
I. Quantum Wire

If the thickness as well as width of any structure is comparable to de- Broglie's wavelength of electron at Fermi energy, and the electronic motion is restricted along both, thickness and width, the structure is called **quantum wire[2].**

As the structure is one dimensional (1D), motion of charge carriers are allowed only in one direction, other two directions Y and Z are confined. The density of states in this case can be expressed as[2]:

$$\rho(E)_{1D} = \frac{1}{\pi}\left(\frac{2m^*}{\hbar^2}\right)^{1/2} \sum_i \left(\frac{n_i H(E - E_i)}{(E - E_i)^{1/2}}\right)$$

Here also, $H(E\text{-}E_i)$ is the Heavy side function and n_i is the degeneracy factor.



(a) Degrees of freedom (b) Density of states

Figure:1.4 (a) Electrons moving in one dimension (b) DOS variation of the 1Dsystem as a function of energy.

Here carriers are confined in both directions (say Y & Z) of small dimension, 't'. and allowed to move freely along the length of X-axis [2] . In this case, the wave function is

$$\psi_{nn}(x, y, z) = \left(\frac{2}{t}\right) \sin\left(\frac{n_y \pi y}{t}\right) \sin\left(\frac{n_z \pi z}{t}\right) e^{ik_x x}$$

TECHNOLOGY IMPORTANE OF QUANTUM DOTS:

The road map of so called Semiconductors Industries Association(SIA) for Silicon Technology has now been established. According to it, the minimum design rule, which was 0.35 m in 1995 will be multiplied by 0.7 every 3 years. In 2010 it would have been possible to create 64 GB DRAM with average area of 'FET' being 1.1 m. But this conventional technology has some serious constraints[8] which are completely absent in semiconductor quantum dots as discussed below:

i). In conventional devices, as the gate length shrinks to 0.1 m or less, some of physical effects like (a) Hot electron effects (b) Oxide tunnelling (c) Silicon Tunnelling (d) Drain induced barrier lowering etc. comprise to make successful 'CMOS' operation difficult. In quantum dot devices, the above said physical effects are absent.

ii) In silicon technology, when the device size shrinks, the capacitances of their interconnections connections become increasingly important. If very small conductors are used, the capacitances of their inter connections becomes the limiting factor in circuit speed.

LITERATURE SURVEY

Beginning of any research work starts with literature survey. To set the aimand objective of the research work, it is pertinent for any scholar to go through the different research publications on the particular area to understand its importance, growth, development and directions. Drawing information from literature review, one can understand the ongoing research activity on the particular topic of the subject and then one can fix the aim, objective and methodology to carry out the study. Thus, literature survey provides us following information:

1. Review of literature provides the information about the existing similar kinds of problems on which research work was and is carried out. It gives an idea forfixing research problem along with methodology for further development.
2. It provides the idea about the availability of required tools and techniques for the research work.
3. It helps to frame and develop the research work.

4. It provides the idea to formulate, analyze and solve the problem.

NANO PARTICLES PREPARATION(SYNTHESIS):

The synthesis process that have been tried by researchers have made availablenano structured materials in wide variety of compositions, consequently exceptional changes in chemical, electronic and opto-electronic property have been observed .Changhua *et. al.* show solution – phase synthesis of mono dispersed SnTe nano crystallites at room temperature[1]. Jacobsohn *et. al*. synthesize CdSe nano crystals by a solution-phase pyrolytic reaction of organo metallic precursors[2]. Kommell *et. al.* prepare CdSe quantum dots on ZnSe substrate by MBE growth technique[3]. Banerjee *et. al.* report the deposition of p-$CuAlO_2$ nano particles by low temperature DC sputtering technique[4]. Kouklin *et. al.* fabricate CdS nano particles on conducting matrix by MOCVD technique[10]. Nanda Kumar *et. al.* prepare PbS quantum dots in Nafion through Pb^{++} ion exchange reaction followed by H_2S treatment (it is a chemical method)[6].

Tin dioxide (SnO_2) is an n-type wide band-gap transparent material which has numerous applications in electronic devices such as window layer of solar cells, electroluminescent devices, flat panel display gas sensors, etc. In order to improve its properties Tin dioxide (SnO_2) films are doped with several dopants. One of it is "synthesis of nano-crystalline fluorine -doped tin dioxide (SnO_2 : F) thin film by Sol- gel-dip coating process" reported by Banerjee group of Jadavpur University[7, 8,9]. Ghosh, *et. al.* report the synthesis of ZnS nanorods by RF magnetron sputtering technique[9]. Biswas *et. al.* synthesize ZnS nano particles and nanorods by Solvo Thermal process [12]. Nath *et.al.* report the preparation of ZnS quantum dots by simple chemical method. Different research groups[5, 13-15] synthesize the nanostructures by various techniques like Sputtering, MBE, Chemical rout, MOCVD etc.

CONCLUSION:

SnO_2, ZnS and CdS quantum dots have been synthesized on two matrices namely PAV and SBR latex by chemical route. The method is simple, easy and do not need sophisticated instruments. Sizes of quantum dots are estimated by three techniques namely UV/VIS optical absorbance spectroscopy, XRD and HRTEM. For all the samples, the sizes assessed from the three studies are well matching with each other. The characterization techniques infer that the prepared quantum dots are within 15 nm . The shape of quantum dots are mostly spherical and elliptical. Furthermore, the traps (like surface states, vacancies etc) are detected by luminescence studies. It has been revealed that oxygen vacancy(O^{+2}) in SnO_2 , Zinc vacancy(Zn^{+2}) in ZnS and CdO phase in CdS are responsible for photoluminescence[20, 21, 25,28,29, 30]. It is further notedthat SnO_2 and ZnS quantum dots show luminescence in yellow /orange region while CdS quantum dots show photoluminescence in red region.

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