

REVIEW ON STRUCTURAL, MAGNETIC, OPTICAL AND ELECTRICAL PROPERTIES OF PURE AND DILUTE MAGNETIC II-VI SEMICONDUCTORS**Rekha R. S¹, Dr. Geeta Khoobchandani²**¹ Research Scholar, Department of Physics, Sri Satya Sai University of Technology & Medical Sciences, Sehore, M.P.² Research Guide, Department of Physics, Sri Satya Sai University of Technology & Medical Sciences, Sehore, M.P.**ABSTRACT:**

Nanoparticles of II-VI semiconductors have been the subject of investigations in recent years. The size dependent properties of II-VI semiconductors have stimulated an exponential development of nanochemistry and nanophysics. Quantum confinement and large surface to volume ratio have led to the study of optical, electrical and vibrational properties of these nanostructured materials. Among the most common II-VI semiconductor nanoparticles, Cadmium selenide (CdSe) and Cadmium telluride (CdTe) are the famous one which has very advantageous properties as compared to the other chalcogenides of cadmium due to their great mobility and photosensitivity. CdSe is a well-known II-VI semiconductor which exists in three crystalline forms viz. wurtzite (hexagonal), sphalerite (cubic) and rock-salt (cubic). The nanoparticles (NPs) of CdSe and CdTe provide excellent and unique properties which depend upon shape and size of nanostructures.

Keywords: Structural, Magnetic, Optical, Electrical, Semiconductors**INTRODUCTION:**

Semiconductors are crystalline or amorphous solids with distinct electrical characteristics. Resistance of semiconducting materials is intermediate that of metals and insulators. They have negative temperature coefficient of resistance in contrast with metals. Finally, their conducting properties may be altered in useful ways by the deliberate, controlled introduction of impurities ("doping") into the crystal structure. Homo junctions and hetero junctions are fabricated using modern fascinating experimental methods like molecular beam epitaxy (MBE), metal-organic chemical vapour deposition (MOCVD) etc. The behaviour of charge carriers which include electrons, ions and electron-holes at these junctions is the basis of diodes, transistors metal-oxide-semiconductor field-effect transistor (MOSFET) and all modern electronics and optoelectronic devices.

Nanoparticles are particles between 1 and 100 nanometers in size. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport properties. Nanoparticles are of great scientific interest as they are, in effect, a bridge between bulk materials and atomic or molecular structures. A bulk material should have constant physical properties regardless of its size, but at the nano-scale size-dependent properties are often observed. Thus, the properties of materials change as their size approaches the nanoscale and as the percentage of the surface in relation to the percentage of the volume of a material becomes significant. For bulk materials larger than one micrometer (or micron), the percentage of the surface is insignificant in relation to the volume in the bulk of the material. The interesting and sometimes unexpected properties of nanoparticles are therefore largely due to the large surface area of the material, which dominates the contributions made by the small bulk of the material. Nanoparticles often possess unexpected

optical properties as they are small enough to confine their electrons and produce the quantum effects. For example, gold nanoparticles appear deep-red to black in the solution. Nanoparticles of yellow gold and grey silicon are red in color [1-11]. Gold nanoparticles melt at much lower temperatures (~300 °C for 2.5 nm size) than the gold slabs (1064 °C) [12]. Other size dependent property changes include quantum confinement in semiconductor particles, surface Plasmon resonance [13] in some metal particles and super paramagnetism in magnetic materials. What would appear ironic is that the changes in physical properties are not always desirable. Ferromagnetic materials smaller than 10 nm can switch their magnetisation direction using room temperature thermal energy, thus making them unsuitable for memory storage [14]. There are several methods for creating nanoparticles, including attrition, pyrolysis and hydrothermal synthesis. In attrition, macro or micro-scale particles are ground in a ball mill, a planetary ball mill, or other size-reducing mechanism. The resulting particles are air classified to recover nanoparticles. In pyrolysis, a vaporous precursor (liquid or gas) is forced through an orifice at high pressure and burned. The resulting solid (a version of soot) is air classified to recover oxide particles from by-product gases. Traditional pyrolysis often results in aggregates and agglomerates rather than single primary particles. Ultrasonic nozzle spray pyrolysis (USP) on the other hand aids in preventing agglomerates from forming. The sol-gel process is a wet-chemical technique (also known as chemical solution deposition) widely used recently in the fields of materials science and ceramic engineering. Such methods are used primarily for the fabrication of materials (typically a metal oxide) starting from a chemical solution (*sol*, short for solution), which acts as the precursor for an integrated network (or *gel*) of either discrete particles or network polymers [15].

Nanomaterials have been unintentionally used by people throughout history. Feynman's well-known lecture *There's Plenty of Room at the Bottom* made modern nanotechnology prominent in academia. Since then, nanotechnology has advanced significantly and is continually encroaching into new industries. Nanomaterials are commonly defined as substances with a size between 1 and 100 nm. Two primary methods are used to make nanomaterials. One of the important methods is top-down processing, which includes a range of methods like mechanical milling, electrospinning, lithography, sputtering, arc discharge, and laser ablation. The second method makes use of bottom-up methods such as chemical vapour deposition, reverse micelle, solvothermal and hydrothermal, sol-gel, and solvothermal and hydrothermal processes (CVD). It has been shown that nanomaterials differ from their bulk counterparts in a number of different ways. Nanomaterials have several properties, including a large surface area, magnetism, quantum effects, antimicrobial activity, and high thermal and electrical conductivities. At the nanoscale, metal-based compounds show remarkably strong catalytic activity. It is conceivable to enhance these catalysts' dispersion and hence enhance the overall efficiency of metal-based catalysts by distributing them across 2D sheets of other nanomaterials. The family of nanoparticles includes nanoporous materials, core-shell materials, ultrathin 2-dimensional nanomaterials, carbon-based nanomaterials, and metal-based nanomaterials. The carbon-based nanomaterials, which include graphene, fullerenes, carbon nanotubes, carbon-based quantum dots, and carbon nanohorns, are an intriguing subset of these. Furthermore, carbon-based nanomaterial surfaces can be further functionalized to modify their properties for particular applications. CNTs and graphene are

well-known members of the family of carbon-based nanomaterials and have been carefully explored for a range of applications due to their huge surface areas, rapid charge transfer abilities, and remarkable mechanical strength. Carbon quantum dots have attracted a lot of attention in the fields of sensing, nanomedicine, and bioimaging. Since graphene was separated from graphite in 2004, ultrathin 2D materials have generated a lot of interest due to their various unique properties. As a result, numerous ultrathin nanomaterials have been characterised, including silicene, borophene, antimonene, MXenes, 2D MOF nanosheets, and boron nitride nanosheets. Ultrathin 2D materials are being explored quickly for use in practical applications, despite the fact that experimental evaluation of these materials is still in their early phases. A well-liked area of study is the creation of nano-catalysts employing a range of metal-based nanostructured materials. Nanoscale catalysts are characterised by huge surface areas, numerous binding sites, and complex surface textural aspects. All these features, together with the small size, favour the thermodynamics and kinetics of transport during heterogeneous processes. Layered metal-oxide-based compounds are being researched as electrode materials for energy conversion and storage devices. The ability of semiconductor metal oxide materials to catalyse water and produce sustainable energy is being improved through nanoscale changes. Much attention is being placed on developing nanomaterials with regulated morphologies and nanoscale dimensions as a result of well-organized nanostructures. Nanotechnology has already made several devices obtainable in the marketplace. When nanomaterials are incorporated into next-generation technologies to satisfy the high energy demands of the future and play a more active role in biosensors and nanomedicines to battle both known and undiscovered diseases, there will likely be much more advancement. Two examples of synthetic nanoparticles used in biomedical applications are Abraxane and Doxil. These nanoparticles are medically approved therapy. White paints must have submicron-sized TiO₂ particles as a key component. Titanium oxide and zinc oxide nanoparticles are found in commercial sunscreen products. Titanium is massively produced industrially every year. Commercial LCDs currently employ colour pigments with crystal sizes less than 40 nm to boost contrast, brightness, and colour purity for applications based on high-definition television. With a few notable exceptions, most nanomaterials are being created for lab-scale applications, and substantial work is required to bring them to the commercial market. Another key challenge associated with current nanotechnology is the need to find alternatives to the use of materials that are endangered or have limited resources in the production of nanomaterials. In the following years, 44 out of 118 components will have supply limits. Rare-earth elements, precious metals, and phosphorus are included in the list of necessary components. It is crucial to reduce dependency on fragile and significant resources. For instance, efforts are being made to replace vital lithium ions in batteries with more readily available metal ions. Due of the abundance of carbon sources, carbon-based nanomaterials are a fantastic choice for large-scale synthesis for a range of applications. The usage of core-shell based morphologies can reduce the utilisation of essential components in various applications. Nanotechnology can play a significant role in wastewater recycling and water purification. Future issues affecting our society can be solved with better knowledge and quick advances in nanotechnology.

The foundation of nanoscience and nanotechnology is nanomaterials. For the past few years, there has been a lot of interest in the development of nanomaterials on a global scale. With

the discovery of carbon nanotubes in 1991, a new paradigm in nanomaterial research was established. Typically, particles in nanomaterials are described as being between 1 to 100 nanometers in size (nm). They are bigger than atoms on their own. One millionth of a millimetre is a nanometer. The diameter of a human hair is 100,000 times larger. The number of research teams operating in the pitch exploded after this finding. There are numerous exciting applications that are possible because nanoparticles' characteristics differ from those of "bulk" materials with the same composition. Quantum confinement is one of several uses for quantum phenomena at the nanoscale. Alternative energy, electronics, catalysis, biomedicine, batteries, water treatment, and material reinforcement are a few examples of applications for nanotechnology.

MAGNETIC PROPERTIES:

As charged particles make up all matter, magnetism is a property that all matter possesses and is brought about by the relative motion of these particles. Based on their reactions, magnetic materials can be separated into two groups: In contrast to paramagnetic materials, which are repelled by the magnetic field, diamagnetic materials are drawn to it. The most important charged particle that contributes to magnetism is a moving electron. Now, here is a brief explanation of how magnetism created by electrons works. Lenz's law states that diamagnetism always occurs anytime an external magnetic field tries to influence the electron's direction. Yet, the vast majority of the material exhibits an appallingly weak diamagnetic response.

A system's magnetic moment can be used to determine the strength and direction of its magnetism. Usually, the phrase itself is about the magnetic dipole moment. Any magnetic object, such as a bar magnet or an electric current loop, has a magnetic moment. A magnetic moment is a vector quantity since it has both a direction and a magnitude. An electron has a magnetic dipole moment because of its innate spin property, which makes it an electric charge in motion. There are various variations in magnetic behaviour, including paramagnetism, diamagnetism, and ferromagnetism. A fascinating attribute of transition metals is their ability to produce magnets. Metal complexes containing unpaired electrons are magnetic. The final electrons are in the d orbitals, thus this magnetism must be the result of having unpaired d electrons. The spin of the electron is negated when it is associated with another particle, but when it is unpaired, it generates a weak magnetic field. As there are more unpaired electrons, the paramagnetic effects intensify. A coordination complex causes a shift in the transition metal's (d-block) electron configuration as a result of the repelling interactions between the compound's electrons and those in the ligands. Depending on the strength of the ligand, the chemical may be diamagnetic or paramagnetic.

OPTICAL AND ELECTRICAL PROPERTIES:

Because to their simple manufacturing, colour tenability, and other advantages, conjugated polymers (CPs) are widely recognised as the most promising choice in the organic semiconductor industry. The very basic structure of the devices based on structure CPs consists of an emissive polymer sandwiched between a cathode with a low work function and an anode with a high work function. Because most CPs exhibit trap-limited electron transport, polymer LED devices are hole-dominated systems, which leads to the degradation of the polymer diode. Hence it is essential to accomplish balanced electron and hole transport in order to create a highly efficient polymer-based LED device. We have included the idea of

doping to obtain a balanced electron and hole transport. The term "doping" was first used to describe organic tiny compounds. These tiny molecules are deposited in thin films by thermal evaporation. The host is then coevaporated with a dopant molecule from a different source. This results in a uniform distribution of doping throughout the host. Conjugated polymers (CPs), however, are deposited using the solution technique. Processing of thin films from such a solution is impossible because adding a dopant to the solution easily causes charge transfer and aggregation in the solution already there. Hence, in this study, we explore the optical and electronic properties of conducting polymers and demonstrate how charge transfer from doping can modify the optical and electrical properties. A pi electron can be promoted from the lower energy state to the highest energy state in a tiny molecule with an isolated double bond by absorbing a photon with energy greater than the energy gap (E_g) between the two orbitals. However, a comparable molecule with conjugated double bonds will have an energy difference between its lowest unoccupied molecular orbital (LUMO) and its highest occupied molecular orbital (HOMO). The energy gap E_g can be even smaller in conjugated polymers because the orbital interactions led to a reduced energy gap, which can be further lowered by promoting a pi electron from HOMO to LUMO with a lower energy photon.

A semiconducting polymer can promote an electron from HOMO to LUMO, creating an exciton—an electron-hole pair that is electrostatically bound—when a sufficiently intense photon (γ) is absorbed by it. Until it relaxes as a result of some deactivation process, this excited state species can move from one place to another. Luminescence is one of the most practical methods for deactivating conjugated polymers (light emission). Depending on the spins of the electrons participating in radiative transitions, luminescence is divided into two categories: fluorescence and phosphorescence.

Phosphorescence is the term used to describe the emission of light when the excited state electrons share the same spin with the electrons in the matching ground state orbital. Fluorescence is the name for an emission when the excited electron has the opposite spin to the electron in the equivalent ground orbital. An electrical transition from a triplet excited state with an unpaired electron spin to a singlet ground state with a paired electron spin occurs during phosphorescence. The quantum mechanical selection rule technically forbids this transition, which happens far more slowly than fluorescence, which involves an allowed transition from a singlet excited state to a singlet ground state.

Chemical flaws, kinks, twists, and conjugation breakdowns make conjugated polymeric structures less than ideal. As a result, band-to-band transport is currently invalid, and charge transport is controlled via hopping. With inorganic semiconductors, the charge transport is not easily visible. There hasn't been a consistent method up to this point, and numerous models have been created to characterise movement. The mobility is found to be influenced by charge carrier density, electric field, and temperature in the majority of the models.

A theory of the quenching of exciton in doped disordered semiconductors was put forth by Arkhipov and his team. They suggested that if a deep trap (often for electrons) is situated near to a molecule or segment visited by the exciton during its energy relaxation, the exciton can dissociate into a geminate pair of charge carriers. The probability that an exciton will come into contact with a charge transfer centre is entirely dependent on the number of sites that this exciton visits because the spatial distribution of traps is random and does not

correspond with energies of the host molecules. Unless the majority of excitons were produced within the deep tail of EDOS, they hypothesised that the prospect of thermally assisted jumps of excitons to sites of higher energies is neglected, meaning that the time scale of energy relaxation is larger than the exciton lifetime.

Doping has an impact on the electrical characteristics of organic semiconductors, such as carrier mobility, drift velocity, and so forth. When we perform n -type doping, the electron bypasses the shallow level and moves straight from the host level to the dopant molecule. Similar to doping, which makes electrons in the donor level inactive by causing them to fall into electron traps (empty defect levels), is the case with doping. As a result, doping increases the density of hole and electron carriers, and the mobility ratio also changes.

REVIEW OF LITERATURE:

CdSe and CdTe nanomaterials are one of the most popular II-VI semiconductors for their various applications. In this section we must have a look on the previous work on transition material doped and/or undoped II-VI semiconductor nanomaterials mainly on Fe, Co and Ni doped CdSe/CdTe nanomaterials.

Stuckes et al. studied the electrical and thermal properties of alloys of CdTe and CdSe [16]. Klein et al. studied the size dependence of electron-phonon coupling in semiconductor nanospheres for CdSe [17]. Trindade et al. synthesised the CdS and CdSe nanoparticles by thermolysis of diethyldithio or diethyldiseleno-carbamates of cadmium [18]. Grieve et al. studied the synthesis and electronic properties of semiconductor nanoparticles/quantum dots [19]. Talapin et al. established a new approach to crystallization of CdSe nanoparticles into ordered three-dimensional superlattices [20]. Khalid et al. explained the magnetic ordering in doped $\text{Cd}_{1-x}\text{Co}_x\text{Se}$ diluted magnetic quantum dots [21]. Drimtin et al. studied the synthesis and surface modification of amino-stabilized CdSe, CdTe and InP nanocrystals [22]. Kim et al. explained the synthesis and characterization of Co/CdSe Core/Shell nanocomposites: bifunctional magnetic-optical nanocrystals [23]. Liu et al. compared the water-soluble CdTe nanoparticles synthesized in air and in nitrogen [24]. Robel et al. studied the size-dependent electron injection from excited CdSe quantum dots into TiO_2 nanoparticles [25]. Han et al. synthesised the high quality zinc-blende CdSe nanocrystals and their application in hybrid solar cells [26]. Singh et al. substituted iron in CdSe nanoparticles and studied the magnetic and optical properties [27]. Jaspal et al. studied the synthesis and characterization of Fe-doped CdSe nanoparticles as dilute magnetic semiconductor [28]. Giribabu et al. explained the structural, optical and magnetic properties of Co doped CdS nanoparticles [29]. Cirillo et al. studied the flash synthesis of CdSe/CdS core-shell quantum dots [30]. Michel et al. synthesized the gradient CdSe/CdS quantum dots with room temperature biexciton unity quantum yield [31].

Though a lot of researches on CdSe and CdTe nanomaterials have been done but there is no report on systemic study of dielectric properties of pure and doped CdSe/CdTe nanomaterials.

CONCLUSION:

In recent years dilute magnetic semiconductors (DMS) have attracted the scientific fraternity in exploiting their properties at bulk as well as nanoscale. They are doped with external impurity elements to give improved the optical and magnetic properties. The astonishing changes in the nanoscale DMS are due to their quantum confinement effects. There has been

much interest in magnetic semiconductors which exploit both the spin and the charge of the carriers.

DMS refer to semiconductor alloys in which magnetic elements are randomly distributed in the lattice and it is designed by introducing magnetic dopant ion in the host semiconductor material. These types of ion have partially filled *d* and *f* shells, which give rise to unpaired electrons. The presence of the paramagnetic ions leads to an exchange interaction between *d*-electrons of the paramagnetic ions and the *sp*³ band electrons [32-34].

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