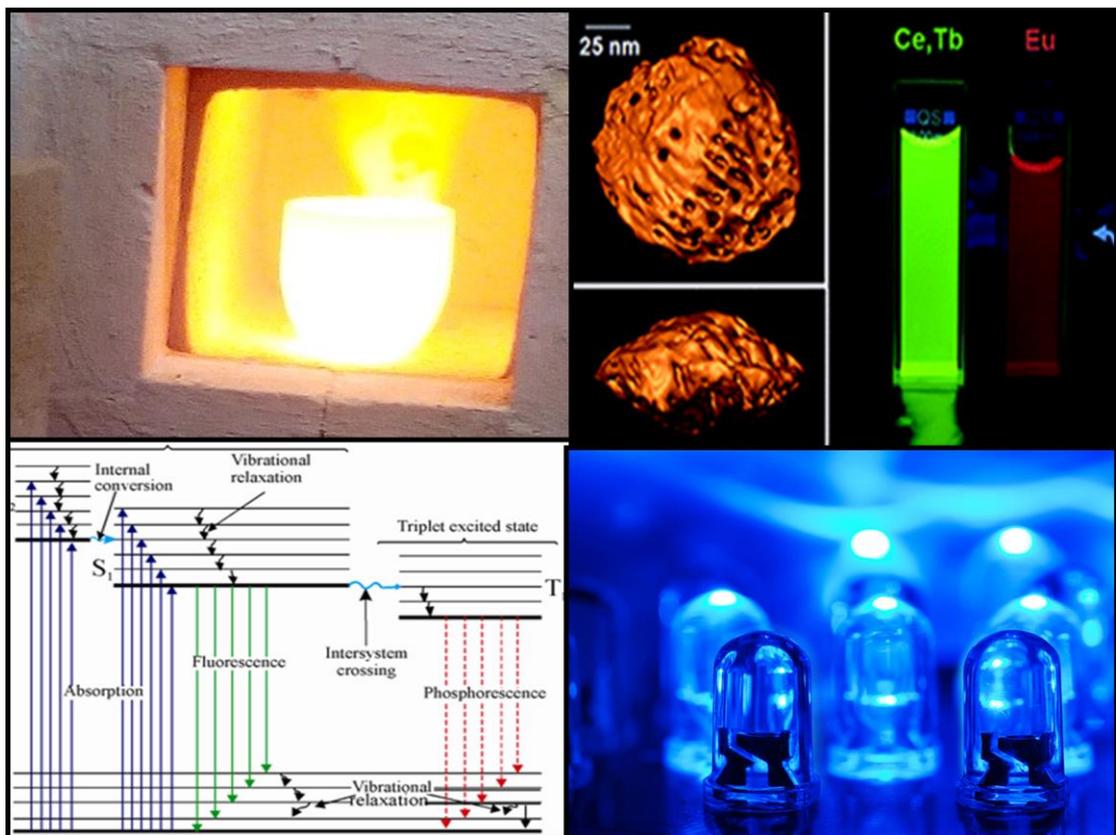


# Chapter 1

## Introduction



## 1.1 NANOMATERIALS

Materials have been the cornerstones of human development ever since man came into being. The importance of materials is increasing at an unprecedented pace from last few decades [1]. Nano-sized materials, which are of extremely minute size, have always existed in nature. In fact, such materials form the basic building blocks of life. Organic molecules, which are the foundations of living forms comes under the nano range. Nano phase materials such as particles of clay, oxides and hydroxides of metals such as iron, aluminium, silicon and the magnetite found in magneto-tactic bacteria are examples of naturally occurring nano particles. These were formed in nature because of extreme environmental circumstances; much earlier before man attempted to create them by simulating the natural conditions that lead to their formation.

The term nanotechnology refers to the designing, fabrication, and characterization of nano sized particles, which have at least one dimension in the nanometer scale ( $1 \text{ nm} = 10^{-9} \text{ m}$ ), and their application to structures, devices and systems. This is superfine scale, where these materials exhibit properties that are markedly different from those observed in the bulk phase of the same materials [2]. Although the term nanotechnology became popular in scientific parlance during the 1990s, the concept had provoked attention and come to be considered a subject of research in 1959 after the lecture of Nobel Laureate Richard Feynman, entitled “There are plenty of room at the bottom”, wherein he proposed the seemingly fantastic idea of writing the entire 24 volumes of Britannica on the head of a pin!” [3]. In his innovative presentation, Feynman projected an idea of crafting minute and complex electronic devices , which the manufacturing electronics industry is capable of doing, and introducing them into the human body to make them perform the biological function of cellular repair on a molecular level. He explained how such devices can be sized down to the atomic level [4]. Ever since these concepts were put forth, extensive studies are being conducted to investigate and to comprehend size-related behaviour of materials. Nanomaterials of different sizes and shapes, such as, nanowires, nanotubes, nanorods, and nanocomposites are currently being investigated for their potential to revolutionize technological applications [5, 6].

In 1974, the Japanese researcher Norio Taniguchi expounded how nanotechnology can be applied to engineer integrated circuits, mechanical devices, computer memory devices , and optoelectronic materials at the nanometre scale [7].

At the nanoscales, the properties of matter predominantly governed by surface-area effects; quantum confinement effects begin to dominate the properties of matter. The significance of quantum size effect becomes pronounced when the de-Broglie wavelength of the valence ion of a particle becomes comparable to the size of the nanoparticles itself [8]. In 1970s, electron beam lithography technique was popularly used to manufacture various nanostructures in the size range of 40–70 nm. Nanotechnology received a fillip in 1981 when Gerg Binnig and Heinrich Rohrer of IBM's Zurich research Laboratory developed a device, the scanning tunnelling microscope, device that made possible the study of solid surfaces at atomic scale resolutions. In 1986, K. Eric Drexler, in his book “Engines of Creation “outlined the potential of the technology for the future, particularly the creation of larger objects from the self-assembly of atomic and molecular components in an ordered and functional manner, in a ‘bottom-up’ approach [9]. Nanotechnology is fast advancing into various areas such as biology, chemistry, physics and material science, demonstrating its versatility and playing a vital role in the betterment of the society.

## **1.2 PHOSPHORS**

Phosphors are typically solid inorganic materials that efficiently emit light under photon excitation as when subjected to an electric field they have received considerable attention during the past few years due to their fundamental and practical applications for various novel high-performance displays and devices. Typically, nano size phosphor particles, having a spherical shape, are strongly desired extend their application to high resolution display devices and semiconductor quantum dots, rare earth doped inorganic luminescent materials, also called nanophosphors have different optical properties compare to those observed in bulk phosphors due to non-radiative relaxation and spatial confinement in nanophosphors [10]. However, as the particle size of phosphor materials was reduced to the nanoscale, the luminescence efficiency of nanophosphors decreased due to large surface area with many defects as compared to bulk phosphors [11].

In Greek, the word phosphor means “light bearer”. In Greek mythology, the term appears in the personification of Venus as the morning star [12]. The luminescence of phosphors is due to their ability to absorb energy and re-emit it in the form of visible light. The word phosphorescence, which means persisting light emission from a substance after the exciting source of radiation has been removed, is

derived from the word phosphor. As against phosphorescence, the word fluorescence refers to the property of a substance by which it emits light when exposed to exciting radiation.

Bulk-type phosphor materials and nano-sized phosphor particles show considerable difference in terms of electrical, optical, and structural characteristics. At nanometric sizes, quantum size effect assumes predominance because the band gap increases due to the decrease in the quantum-allowed state, and the high surface to volume ratio improves the surface and interface effects as shown in Fig.1.1. Consequently, nano-sized particles exhibit reduced scattering of the emitted light photons, which results in enhanced luminescence efficiency [13]. Inorganic materials that efficiently emit light under photon excitation as when subjected to an electric field. Generally, phosphors consist of two components: a host and an activator (also called the luminescent centre). The host is typically an insulator (oxide, sulphide and nitride) or a semiconductor. The host lattice embeds minute impurity ions (activators) included at controlled levels, which produce luminescence output. The activators are typically transition metals or ions of rare earth (RE) elements. RE ions are characterized by the partially filled 4f shell, which is well shielded by  $5s^2$  and  $5p^6$  electrons. This structure renders them particularly effective as luminescent centers in various inorganic host lattices and has been widely exploited to produce high quantum phosphors. The remarkable luminescent properties of RE-doped nanophosphors derive mainly from crystal field effects and spin-orbit coupling of 4f electrons, in addition to the large surface-to-volume ratio of the nanostructured material. All these factors collectively provide tools for probing the effects of reduced domain on the luminescent properties of RE doped nanophosphors. One of the most striking features of luminescent RE compounds is the sharp line-like emission they are capable of, which leads to high color purity of the emitted light [14].

Recently, researches focus on enhancing the usefulness of phosphor-converted white light emitting diodes (pc-LED) for much longer lifetimes, high efficiency and lower power consumptions in comparison to conventional illumination sources. The total efficiency of phosphor converted LEDs is determined by various factors:  $\eta_{pcLED}$ , the total pcLED efficiency, which depends on the efficiency of the particular LED source;  $\eta_{LED}$ , the stokes conversion efficiency;  $\eta_s$ , the ratio of the average emission wavelengths of the LED and the phosphor;  $\eta_{phosphor}$ , the phosphor

quantum efficiency, which indicates the ratio of the photons out to photons when the phosphors are excited from external sources; and  $\eta_{\text{package}}$ , the package efficiency, which is the efficiency of light extraction of LED and phosphor-emitted photons from the LED device package [15]. Each of these parameters must be optimized to obtain the highest overall efficiency. In exploring the possibility of improving the emission efficiency of white LEDs by using the nanoscale phosphors, it has been found that some of the optical and structural properties, such as a broad absorption spectrum, high concentration quenching limit, low coupling to phonons, dopant on a single crystallographic site, and regular particle morphology are cardinal factors that determine the emission efficiency of white LEDs [16]. In general, nanoparticles must have narrow particle size distribution and good crystallinity so that they have the level of photoluminescence that qualify them for commercial applications.

### **1.3 PHYSICS OF NANOPARTICLES**

The extremely small size of nanomaterials has the following two characteristic effects: the size effect and the surface induced effect. Size effect refers to the effects of the continuous energy levels (density of states) of bulk matter (extended periodicity of lattice) being replaced by a set of discrete energy levels as shown in Fig.1.1 (also termed quantum confinement effects) . The surface or interface induced effect can be ascribed to the fact that, as the size decreases, there is an enormous increase in the surface to volume ratio which in turn, means that a much larger number of atoms will be sitting on the surface than in the bulk-structure .

The size effect primarily manifests in the physical properties while the surface effect impacts chemical, optical, and mechanical behaviour [17-21]. Although the general assumption is that semiconductor nanoparticles or quantum dots (QD) have a size of zero dimension, for electrons in the QD this dimension is still an infinite 3- dimensional well. The potential energy is zero within the well, but infinite at the wall (boundary) of dots.

An electron-hole pair can be created in a quantum dot either by photo-excitation or by charge injection processes (by electric field). The minimum energy required to create an electron-hole pair in a quantum dot depends on these factors: the bulk energy gap ( $E_g$ ), charge carrier confinement energy ( $E_{\text{conf}}$ ) and coulomb interaction energy ( $E_{\text{coul}}$ ).

Table 1.1 Various phosphors emitted color with their applications

Phosphors	Transitions	Emission color	Applications
<b>Lamp phosphors</b> $\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}):\text{Sb}^{3+}, \text{Mn}^{2+}$ $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$ $\text{Gd}_2\text{O}_3:\text{Eu}^{3+}$ $\text{Gd}_2\text{O}_2\text{S}:\text{Eu}^{3+}, \text{Ti}^{4+}, \text{Mg}^{2+}$ $(\text{Ce}, \text{Gd})\text{MgB}_5\text{O}_{10}:\text{Mn}^{2+}$ $\text{CeMgAl}_{11}\text{O}_{19}:\text{Tb}^{3+}$ $\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$	UV into Visible	white red red red red green blue	Fluorescent lamp
<b>Cathode-ray phosphors</b> $\text{Y}_2\text{SiO}_5:\text{Tb}^{3+}$ $\text{Y}_2\text{O}_2\text{S}:\text{Eu}^{3+}$ $\text{YVO}_4:\text{Eu}^{3+}$ $\text{KMgF}_3:\text{Mn}^{2+}$ $\text{Zn}_2\text{SiO}_4:\text{Mn}^{2+}$ $\text{ZnS}:\text{Cu}^+$ $(\text{Ca}, \text{Mg})\text{SiO}_3:\text{Ti}^{4+}$ $\text{ZnS}:\text{Ag}^+$	Electrons in to Visible	white red red orange green green blue blue	Oscilloscope and Radar tubes Monitor tubes Color television
<b>X-ray Phosphors</b> $\text{Gd}_2\text{O}_2\text{S}:\text{Tb}^{3+}$ $\text{LaOBr}:\text{Tb}^{3+}$ $\text{CaWO}_4$	X-rays in to Visible	green blue blue	Fluoroscopic screens, Storage panels, Computed tomography
<b><math>\gamma</math>-ray phosphors</b> $\text{CsI}:\text{Tl}^+$ $\text{NaI}:\text{Tl}^+$ $\text{Bi}_4\text{Ge}_3\text{O}_{12}$ $\text{ZnWO}_4$ $\text{Y}_3\text{Al}_5\text{O}_{12}$ $\text{Eu}^{3+}$ - Cryptates	$\gamma$ -rays in to Visible & UV into Visible	orange blue blue blue green red	Electromagnetic Calorimeters, Medical Diagnostics, Luminescence Immunoassay

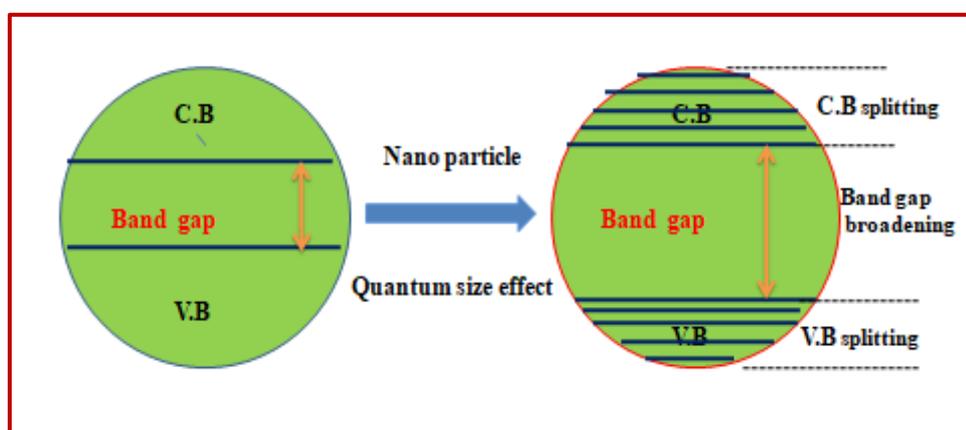


Figure.1.1 the quantum size effect: energy levels of nanoparticles & bulk.

By combining these three terms, the estimated size dependent-energy gap of quantum dot semiconductor particle can be derived to be given by:

$$\Delta E_g = \frac{h^2}{8a^2} \left( \frac{1}{m_e} + \frac{1}{m_h} \right) \dots \dots (1.1)$$

Where  $\Delta E_g' = (E_g^n - E_g^b)$ ; that is, the difference between the band gaps of nanoparticles ( $E_g^n$ ) and that of bulk ( $E_g^b$ ); 'h' is the Planck's constant; 'a'; diameter of the particle; and ' $m_e$ ' and ' $m_h$ ' the effective masses of electrons and holes respectively. The theoretically predicted variation in the energy gap of various semiconductor nanoparticles as a function of dot size is shown in Fig.1.2 [22].

Just as semiconductor QDs, metal nanoparticles also exhibit size-dependent optical properties, collectively referred to as surface plasma resonance (SPR) effect. This effect is mainly due to collective oscillations of conduction electrons. The effect is quite pronounced in the case of noble metal nanoparticles; like silver and gold [23]. When these particles are subjected excitation by light, the collective oscillations combines with electromagnetic radiations and causes substantial enhancement of the electromagnetic field in the metal nanoparticles. Consequently, the interaction of this reinforced internal field with any incident light leads to scattering and absorption of the incident light.

Let us consider how particle size is a primary factor in determining the interaction between particles and incident light. For particles the surface to volume ratio is inversely proportional to the radius of nanoparticles (1/R). For example, in case of a cluster containing 13 atoms, the surface to volume ratio is close to 92.3 % [24]. The variation of theoretically predicted surface to volume ratio as a function of particle radius is plotted in Fig.1.3. It is evident that the surface to volume ratio increases rapidly with decreasing size of the cluster for sizes below 3 nm. The atoms that constitute the surface are unsaturated atoms, which are highly reactive. They play an important role in controlling most of the fundamental properties: from structural phase transition through light emission, to solubility. For explaining the states of these surface atoms, electronically, these states can be considered to create a set of discrete energy levels in the energy gap. For smaller particle size, these energy levels substantially mix up with intrinsic discrete states, such as the intrinsic discrete states of nanoparticles [25].

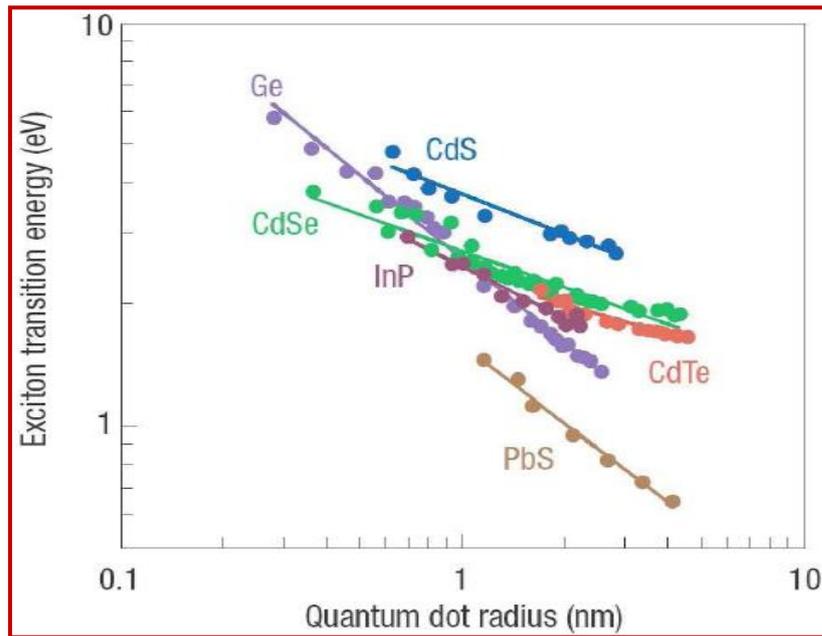


Figure.1.2 Size tuning of excitation for various semiconducting Nanocrystals [Nature Materials, 5, 920 (2006)].

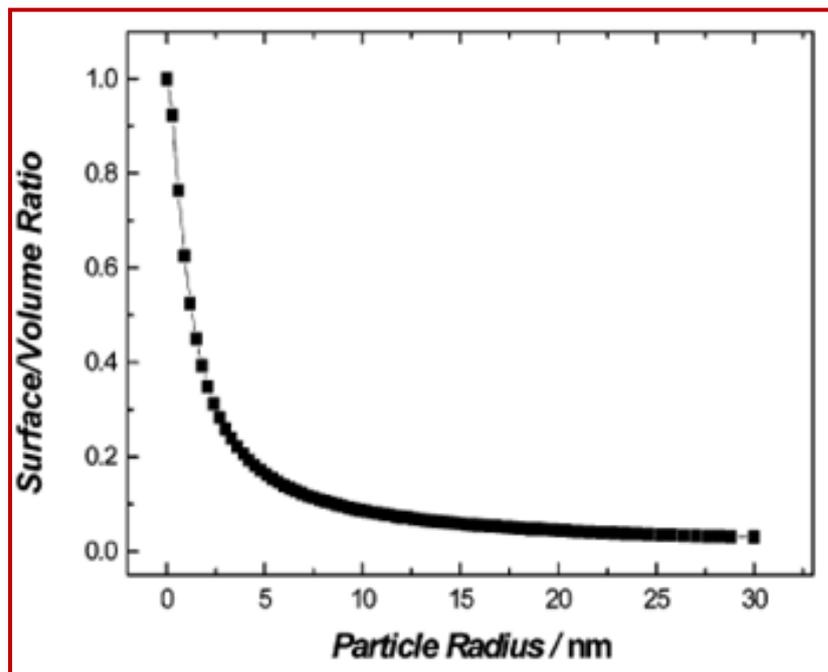


Figure.1.3 Surface/volume ratio as a function of the particle size.

## 1.4 SYNTHESIS OF NANOMATERIALS

The various methods for the synthesis of nanoparticles can be broadly classified into two categories, namely physical and chemical methods. The physical methods generally follow a ‘top-down’ approach; that is, they start from solid bulk material

and aim to reduce particle size methods that are based on this approach are: Ball milling, nanolithography etc. The chemical methods, on the other hand, mainly adopt a ‘bottom-up’ approach; that is they start from molecular system and aims to increase particle size, methods that are based on this approach are: hydrothermal technique [26, 27], co-precipitation technique [28, 29] spray pyrolysis [30, 31], microwave technique [32], sol-gel technique [33, 34] and solution combustion process [35, 36]. The feasibility of a method depends on the properties of product being sought and no method is truly universal. However, with different routes being discovered for manufacturing each product, the scalability, cost involved, and environmental hazard potential of various synthetic routes are being closely studied and evaluated, especially with the progress in the market for the demand for commercial phosphors and new avenues opening for commercializing nanophosphors. Some of the synthetic techniques are briefly described in the following sections.

#### **1.4.1 Hydrothermal synthesis**

The hydrothermal (HT) method employs pressure autogenously developed at temperatures above the boiling point of water for the synthesis of various ceramic oxide powders at relatively low temperatures (100-300 °C) without milling or calcinations [37]. The particle size and shape of the products are controlled by governing various processing parameters such as temperature, pH, and the addition of surfactants or mineralizers. Control over the reaction is achieved by dissolution and precipitation of reactants in an aqueous medium. The method involves dissolving stoichiometric amounts of precursors in nitric acid and evaporating to dryness. Subsequently, the residual mixture is transferred to a Teflon-lined stainless-steel autoclave with filling capacity of 40 % distilled water and allowed to crystallize at a low temperature for a few hours nanophosphors crystallize as a powder Finally, the phosphor powders are filtered, washed with distilled water, and then dried in an oven at 80-100 °C.

#### **1.4.2 Co-precipitation method**

The co-precipitation involves a technique that enables direct and clean reaction between the chosen starting materials and precipitating reagent in stoichiometric amounts without generating any by products other than water. The reaction is highly vigorous and exothermic in nature. Large precipitates are immediately at the reaction

site, which can be separated by centrifugation. The resulting precipitates are washed repeatedly by de-ionized water and collected in quartz boats. These are subjected to thermal treatment in a suitable atmosphere to produce phosphors, which show emission color under a UV source. In this technique, the morphology of particles is significantly influenced by the kind of flux employed [38]. Spherical particles around 300 nm were obtained on employing  $\text{H}_3\text{BO}_3$  as flux while when  $\text{Li}_2\text{CO}_3$  or  $\text{Li}_3\text{PO}_4$  or a combination of these was used as a double flux, uniform spherical or near spherical particles of 5  $\mu\text{m}$  were formed. Further sintering of these particles at high temperatures (1100 or 1200  $^\circ\text{C}$ ) in the presence of the double flux leads to the formation of smooth spherical particles.

#### **1.4.3 Spray pyrolysis**

This is an aerosol processing type technique that apparently holds good commercial potential, especially for the synthesis of multi-component oxides. In this method, an ultrasonic aerosol generator is employed to atomize the precursor solution and the droplets that are produced are carried into a hot furnace by the air spray. The particles formed are collected in a bag filter and subjected to post treatment for crystallization and for the activation of the activator. The morphology of particles prepared in this method is primarily dictated by the synthetic conditions created and the type of precursors used. The most remarkable merit of spray pyrolysis the unique particle formation mechanism it offers, which results in morphologically high-quality phosphor particles, with small size, uniformly spherical shape, small size, narrow size distribution, and non-agglomeration characteristics [39].

#### **1.4.4 Microwave synthesis**

Microwave processing is relatively an advanced technique for preparing various phosphors. This distinguishing characteristic of this method is that it involves substantially accelerated reaction kinetics in the participant material systems if the reacting constituents are properly selected. The typical feature of microwave heating is volumetric heating, which is quite different from conventional heating where the heat must diffuse in from the surface of the material. Volumetric heating refers to materials absorbing microwave energy directly and internally and finally converting it to heat. It is this process of heating that is employed in microwave ovens and heaters, which are widely being used to process materials [40]. In microwave processing,

electrical energy in the form of low-voltage alternating current and high-voltage direct current, is transformed and converted into direct current. The temperature of the processing ambience is controlled by monitoring the input power. As part of microwave processing, the samples being treated are rotated horizontally about the axis, which causes them to get heated up uniformly, and are maintained at specific temperatures typically for 10 to 20 minutes.

#### **1.4.5 Sol-Gel method**

The sol-gel process presents a viable alternative approach for the preparation of glasses and ceramics at considerably lower temperatures. The method has been fine tuned over the past forty years and is widely employed in the field of materials science and ceramics engineering as a low cost and closely manageable process. This is basically a wet synthesis technique, in which the initial components interact in the solution state triggering various polymerization and poly condensation processes that lead to the gradual formation of the solid phase network. The resulting sol is first subjected to sequential operations which include gelling, drying, pressing, and casting, during the course of which, various structural and phase transformations occur. These transformations lead to the formation of powders, fibers, bulk monolithic products, coatings, and so on, all having the same initial composition [41].

#### **1.4.6 Solution combustion synthesis (LCS)**

In the solution combustion process, the raw materials for starting the process are dissolved in stoichiometric amounts in the minimum amount of deionized water. The solution is placed in a muffle furnace maintained at required temperature as depicted in Fig.1.4. A hot plate can also be used in place of a muffle furnace. The initial combustion reaction occurs at a temperature that is below the phase transition temperature of the desired product. The solution boils and ignites to burn with a flame or sometimes only smouldering is noticed yielding a voluminous foamy powder within 3-5 minutes. A striking feature of this technique is that the heat required to force the synthesis is supplied by an exothermal reaction occurring among the reagents. The energy released during this process rapidly heats the system to high temperatures without any external heat source. Thus, in this process, the amount of heat energy required to be supplied by an external source for the formation and crystallization of phosphors is low, which qualifies this as a low-temperature process.

Although, metal nitrates can also be decomposed into metal oxides by simple calcination, upon subsequent heating to or above their decomposition temperature, these oxides can further react to produce new substances. In contrast, in the solution combustion synthesis (LCS) process, the combination of nitrates with a sacrificial fuel such as urea, carbonylhydrazide, oxalyl dihydrazide, glycine, diformyl hydrazine etc ignites the precursor mixtures at a rather low temperature and well in advance of the exothermal reaction that provides itself the required heat for the synthesis [42].

#### **1.4.6.1 Advantage of the combustion synthesis method**

LCS method has distinguished itself as an effective, rapid, single-step technique for the synthesis of high purity, homogeneous and crystalline nano-sized phosphor powders. This approach allows uniform doping of trace amounts of rare-earth ions at significantly lower temperature in comparison to conventional methods. This is because, in this method, the starting raw materials that are homogeneously mixed in liquid phase react instantly, generating exothermic radiations that can volatilize low boiling point impurities [42, 43].

The synthesis of nano-crystalline phosphors through LCS is currently being studied extensively as a major subject in the field of material science. Recent breakthrough is that a variety of nanophosphors such as oxides [44] aluminates [45], phosphates [46], zirconates [47] vandates [48] and indates [49], all of which have high commercial potential have been prepared using this approach. With this, the importance of this process as a versatile, simple and rapid for the effective synthesis of nano-size materials has been widely acknowledged.

Besides, it has been found that the process can be used for a range of products because the characteristics of the resulting powders including whether they have crystalline or amorphous structure, the crystallite size, purity, surface area, particle clustering, agglomeration, and so on are depends on the type the precursors as well as on the conditions employed for the process of organization [50], both of which can be controlled as required. The combustion synthesis technique proves to be a much better method than the other conventional methods for synthesizing highly crystalline and homogenous nanophosphors at low firing temperature. In the present investigation, we prepared  $GdAlO_3$  nanoparticles using solution combustion method and the findings are discussed in detailed in a later part of this thesis.



Figure.1.4 Muffle furnace maintained at  $400 \pm 10^{\circ}\text{C}$  temperature

## 1.5 LUMINESCENCE

Luminescence is defined as a *phenomenon of emission of electromagnetic radiations in excess of thermal radiations*. The electromagnetic spectrum of light is generally classified according to wavelength into  $\gamma$  rays, X- rays, ultraviolet rays (UV), visible rays, infra-red, microwaves, and radio waves as shown in Fig.1.5. The word *Luminescence* derived from the Latin word lumen, which means light. The word was first used by Eilhardt Wiedemann, a German physicist, in 1888. Studies have revealed that the origin of luminescence lies in the *radiative transitions* between two electronic states of atoms, molecules or extended molecular systems. The term radiative transition implies a transition in which some kind of external energy is released in the form of photons. Radiative emission can take place between two states of the same multiplicity or of different multiplicity. Luminescence from electronically excited singlet ( $S_1$ ) to ground state is termed as “fluorescence,” while emission from triplet ( $T_1$ ) to singlet ( $S_1$ ) state termed “phosphorescence”. The excited species can return to the ground state by losing all of its excess energy following any one of the paths as depicted in Fig. 1.6, in the representation known as the Jablonki diagram.

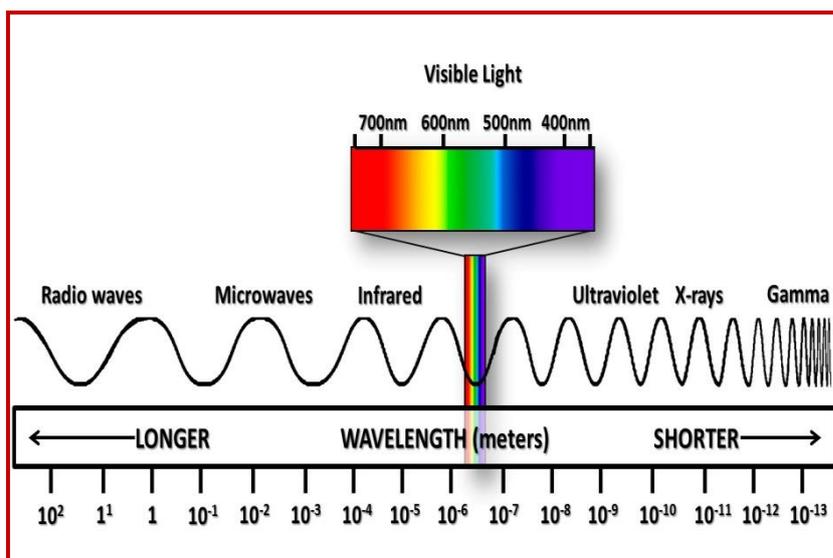


Figure.1.5. Electromagnetic Spectrum

In the process of luminescence, the first step involves photon absorption; that is, the excitation of an electron after the absorption of energy in the form of photons of light radiations. This photon absorption process is extremely fast, occurring in  $10^{-14}$  to  $10^{-15}$  seconds. An electron reverting to the ground state from the excited state traverses several process paths:

- i) Internal conversion (IC): Non-radiative transition from a higher singlet state to the lowest excited singlet state S1. It is a very fast process and occurs in less than about  $10^{-11}$  seconds.
- ii) Fluorescence: Spin-allowed ( $\Delta S=0$ ) radiative transition from the lowest excited singlet state S1 to the ground state. It occurs  $10^{-5}$  to  $10^{-10}$  seconds after the absorption and manifests as the emission from a substance only in the presence of an exciting radiation, which is termed fluorescence. Some examples of substances exhibiting the phenomenon of fluorescence are fluorite ( $\text{CaF}_2$ ); organic dyes such as eosin; fluoresce in, vapour of sodium, mercury, and iodine; and certain inorganic compounds such as uranyl sulphate ( $\text{UO}_2\text{SO}_4$ ).
- iii) Inter system crossing (ISC): Radiation less transition from the first excited state to the first excited state; but between states of different multiplicity (S1 to T1). Such transitions are normally forbidden but whenever they occur, their rate is very slow.
- iv) Phosphorescence: Spin-forbidden transitions ( $\Delta S=1$ ) radiative transition from the excited triplet state T to the ground state. It is a slow process ( $10^{-4}$  to 10 seconds) as the process is spin forbidden and persists even after the removal of absorbed radiation and manifests as phosphorescence. Zinc sulphide and sulphides of the alkaline earth metals are well-known examples of materials exhibiting phosphorescence includes.

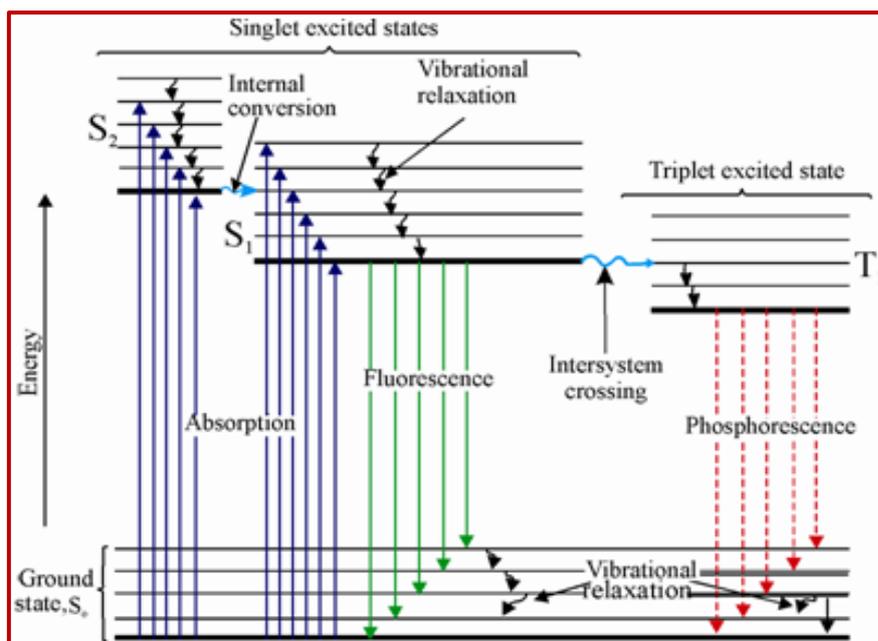


Figure 1.6. Jablonski diagram showing electronic transitions of photoluminescent molecules in its different energy states

### 1.5.1 Mechanism of luminescence

Nanophosphors are luminescent, high-purity, inorganic nanomaterials that emit light when exposed to various excitation sources. In general, nanophosphors comprise two components: a host and an activator. In a crystalline host or a matrix, a relatively small amount of certain impurities called activators are intentionally added; the process being called doping. The host materials constitute the bulk share of the phosphor while activators or dopants, although present in small amounts, are primarily responsible for the characteristic property of luminescence possessed by nanophosphors. An activator is a deliberately introduced dopant ion that serves as a luminescent centre when introduced into a host lattice and ensures that the required emission occurs after absorption of the excitation energy. Usually, the color of the emission is decided by the activator ion used and not by the host lattice in which the impurity ions are incorporated. Quite often, activator ions such as RE ions show emission band patterns at specific spectral positions, regardless of their chemical environment. If the absorption capability of the activator ions too weak for effective absorption, a second variety of foreign ions called sensitizers are incorporated. Sensitizers efficiently absorb the excitation energy and transfer the absorbed energy to the activator, thus affecting the characteristic luminescence. Fig.1.7 illustrates the roles played by activators and sensitizers.

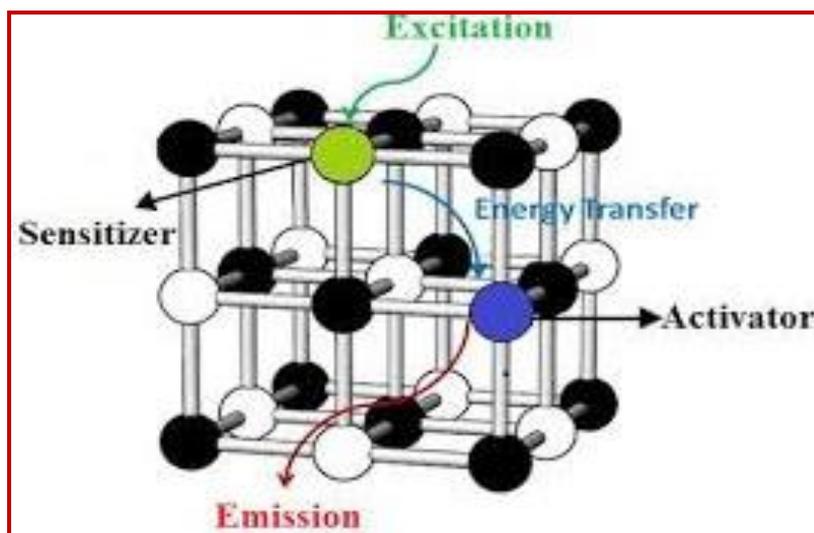


Figure.1.7. Diagrammatic representing role of sensitizer and its relationship with activator in the luminescence process

In some cases, the host material itself acts as the sensitizer. An example is self-luminescent  $MWO_4: Sm^{3+}$  ( $M = Ca, Sr, Ba$ ) Tungstate phosphors in which  $WO_4^{2-}$  absorbs a UV photon by virtue of charge transfer from oxygen to tungsten and effectively transfer its energy to the samarium ions, resulting in red emission[51].

## 1.6 TYPES OF LUMINESCENCE:

On the basis of nature of excitation, luminescence can be classified into the categories explained in the following sections.

### 1.6.1 Chemiluminescence

In chemiluminescence, the emission of light takes place as the result of a chemical reaction. Some evolution of heat might also occur. Chemical reactions, especially those involving oxidation-reduction mechanisms, are typical examples of chemiluminescence [52].

### 1.6.2 Bioluminescence

When Bioluminescence takes place in living organisms, the phenomenon is termed bioluminescence. It plays a crucial role in the direct studies of cellular and biochemical processes. Lucifer in producing creatures such as fireflies and anglerfish are well known examples in which Lucifer in react with oxygen to emit light [53].

### 1.6.3 Triboluminescence

Luminescence in which emission of light takes place because of the breaking of chemical bonds in a material when it is pulled apart, ripped, scratched, crushed, or

rubbed is known as triboluminescence. This phenomenon is attributed to the separation and reunification of electrical charges. .

#### **1.6.4 Radioluminescence**

Radioluminescence is luminescence in which emission of light from a substance takes place because of bombardment with ionizing radiations such as alpha or beta particles. Radioluminescence was first observed and reported by Nobel Laureate Pierre and Marie Curie. Radioluminescence is employed in making the radium-dials of watches and clocks and in “continuous” phosphorescent devices, which are used to serve as source of light for long hours in the absence of any external energy sources [54].

#### **1.6.5 Sonoluminescence**

Sonoluminescence is caused by the emission of light when a sound wave of sufficient intensity induces a gaseous cavity located within a liquid to collapse abruptly. The cavity can be a pre-existing bubble, or can be one generated through a process known as cavitation [55].

#### **1.6.6 Cathodoluminescence**

In this type of luminescence, the material emits light because of electrons impacting the material. This process is widely used in cathode-ray tubes, display screens, and TV sets. This kind of luminescence is particularly useful in the study of minerals in rocks, where the presence of even traces of transition metals elements can cause the mineral to emit light of a distinctive colour, that reveals the identity of the trace metals [56, ].

#### **1.6.7 Crystalloluminescence**

In which emission of light by a substance occurs during the process of crystallization is termed Crystalloluminescence. This property is employed in determining the critical size of crystal nuclei.

#### **1.6.8 Thermoluminescence**

It involves the emission (or rather, re-emission) of light by a substance that contains previously absorbed energy from electromagnetic radiations under heating.

### **1.6.9 Electroluminescence**

It involves the emission of light by a substance occurring during electrochemical reactions in solutions. The different mechanisms of electroluminescence are followed in inorganic and organic semiconductors. Emission of light in inorganic semiconductors occurs through a process involving recombination of electrons and holes that meet together in an emitting layer or on a border between n- and p-type semiconductors (called a p-n junction). On the other hand, in organic semiconductors, electroluminescence is caused by the formation of excited molecules (excitons) and their subsequent re combination. This recombination might result in either light or heat emission (vibrational or thermal dissipation). Electroluminescence can cause either fluorescence or phosphorescence or both as explained by the mechanism by which it happens [57].

### **1.6.10 Photoluminescence**

Photoluminescence refers to the emission of light that takes place in the presence of light. It can manifest either as fluorescence or as phosphorescence mechanisms, as explained by Stokes rule (which however, does not address the mechanism of “delayed fluorescence”). Common examples of applications involving photoluminescence are fluorescent dyes used in the manufacture of bright textile; traffic signals and to luminescence refers to the emission of light [58].

## **1.7 PHYSICAL ASPECTS OF PHOTOLUMINESCENCE**

The process of luminescence when excited by light is called photoluminescence (PL). The phenomenon of PL finds ready application in PL spectroscopy, a technique to obtain the relation between the intensity and the wavelength of the luminescence, has become one of the most versatile techniques for the comprehensive and non-destructive assessment of many materials. PL spectroscopy can be used to garner a large amount of information about the electronic structure of the materials under study. A schematic representation of the basic mechanism involved in PL is shown in Fig.1.8. PL falls under two categories: intrinsic luminescence and extrinsic luminescence.

**1.7.1 Intrinsic luminescence:** As the name suggests, intrinsic luminescence refers to luminescence that originates from within a pure material or crystal. It can be of three types:

- a) **Band-to-band luminescence:** This kind of luminescence occurs when there is a combination of an electron in the conduction band with a hole in the valence band, producing a band-to-band transition. Luminescence of this kind is typically limited to very pure materials at relatively high temperatures. The phenomenon when occurring at lower temperatures qualifies more as excitation luminescence rather than band-to-band photoluminescence. Examples of materials that exhibit band-to-band photoluminescence are Si, Ge and some IIIb–Vb compounds such as GaAs [59].
- b) **Exciton luminescence:** An exciton is a bound electron-hole pair in which an excited electron interacts with a hole. As it traverses the crystal, the exciton carries some energy and the electron and hole recombine, which causes the luminescence to occur. There are two kinds of excitons: the Wannier exciton, and the Frenkel exciton. The Wannier exciton comprises an electron in the conduction band and a hole in the valence band bound together by the coulomb interaction and is found primarily in IIIb–Vb and IIb–VIb inorganic semiconductors. The Frenkel exciton is the one formed when the expose of the electron and the hole wave function is smaller than the lattice constant. It is observed in organic molecular crystals such as anthracene, inorganic complex salts such as tungstates and vanadates, and in uranyl salts [4].
- c) **Cross-luminescence:** Cross-luminescence occurs when an electron in the valence band recombines with a hole created in the outermost core band. This kind of luminescence is typically observed in alkali and alkaline-earth halides and double halides.

**1.7.2 Extrinsic Luminescence:** Extrinsic luminescence refers to luminescence caused by intentional incorporation of impurities or defects into a phosphor lattice. In ionic crystals and semiconductors, the luminescence observed can be either unlocalized or localized. It is unlocalized if the free electrons in the conduction band and free holes in the valence band of the host lattice also participate in the luminescence. The localized type of luminescence occurs when the excitation and emission process of the luminescence are constrained within a localized luminescent centre.

## 1.8 POTENTIAL APPLICATIONS OF NANOPHOSPHOR

Nanophosphors doped with RE ions are technologically versatile materials that find wide applications in devices such as energy saving fluorescent lamps, plasma display panels, field emission displays, solid-state lasers, X-ray detectors, and biomedical diagnosis, and in the development of white light emitting diodes, which are revolutionizing the lighting industry. Hence, it is quite opportune to explore the full potential of nanophosphor materials [60, 61]. Currently, one factor that primarily drives the development of nanophosphors is the production of white light emitting

diodes (LEDs), which are in high demand for solid-state lighting (SSL) and back-light units (BLU) in displays [62].

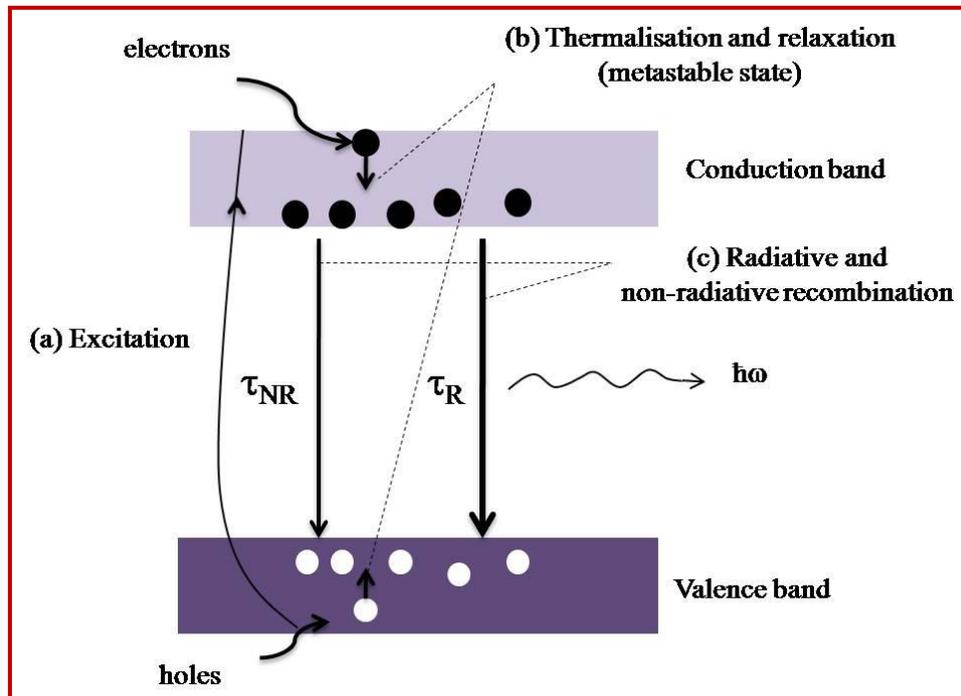


Figure.1.8: Schematic diagram of the general process of luminescence

### 1.8.1 Fluorescent lamps

Fluorescent lamps are low- pressure mercury vapour gas discharge lamps that emit light upon ultraviolet irradiation (85 % of this radiation consists of 254 nm radiation). White emission was obtained by the addition of small amounts of magnesium tungstate, which accentuated the blue part of the spectrum. However, the toxicity of beryllium caused halo phosphate based phosphors to replace beryllium in the manufacture of fluorescent lighting products. Fluorescent lamps are of various kinds, depending on the chromaticity coordinates and color rendering index. In the last few decades, the introduction of divalent europium, trivalent cerium, gadolinium, terbium, yttrium, and europium in phosphors has drastically improved the light output and the color rendering index of fluorescent lamps. Some examples of RE-doped nanophosphors which can be used in making high-quality fluorescent lamps are: color tunable Eu/Tb co-doped  $Y_2O_3$ ; Eu/Dy co-doped  $Y_2O_3$  [63];  $Eu^{2+}$  doped  $Ba_{0.64}Al_{12}O_{18-64}$ ;  $BaMgAl_{10}O_{17}$  and  $BaMg_2Al_{16}O_{27}$ ; Tb doped  $Ce_{0.67}MgAl_{11}O_{19}$ ;  $Eu^{2+}$  and  $Mn^{2+}$  doped  $BaMgAl_{10}O_{17}$  [64]; and Eu/Tb doped  $YGdBO_3$  [65].

### **1.8.2 Plasma display panels**

Plasma display panels (PDP) can be described as flat, panel information display devices in which the display is brought about by pixels composed of small gas-discharge cells that radiate visible luminescence directly or radiate the luminescence generated by the phosphors. In practical PDPs, a discharge cell is employed [66], which can stimulate a type of display cell in these panels [67]. In manufacturing high-definition televisions (HDTVs) and personal computers of affordable prices, the cost involved in making these displays is reduced by employing nanophosphors. It has been found that the resolution of these display devices can be significantly enhanced and their manufacturing costs reduced by using synthesized nanocrystalline phosphors. Another salutary advantage of using nanophosphors is that because of the improved electrical, chemical, and electronic properties of materials in the nanophase, the flat-panel displays made from nanomaterials exhibit higher levels of brightness and contrast than the conventional devices. Nanophosphors are widely explored in electroluminescent (EL) displays because they help achieve higher resolutions, lower power consumption and low voltage operation (~10V). Nanoparticles when capped with the biocompatible histidine molecule, show remarkable enhancement in the luminescence efficiency as evident in histidine coated ZnS: Mn nanoparticles which are effectively employed as the phosphors in display applications [68]. KLaF<sub>4</sub>:Eu<sup>3+</sup> nanophosphors emit strong red light and have long emission lifetimes, which make them highly suitable for use in display panels [69]. Layers of lanthanide nanophosphors are widely utilized to form plasma display panels [70].

### **1.8.3 Field emission displays**

Field emission displays (FEDs) offer several desirable features including high brightness, good contrast ratio, wide horizontal and vertical view angle coverage, low power consumption, and short response times. The only reported demerit is perhaps the shorter operating time as against in other technologies. FEDs can realize high levels of brightness (3000 cd/m<sup>2</sup>) and have high efficiency, around 2W/10.4. Current studies sharply focus on investigating the application of nanosized and eventually submicron-sized phosphors particles in FEDs as such particles seem to be considerably suitable for low-voltage FED applications [71, 72]. Rare-earth-doped nanocrystalline oxides such as Y<sub>2</sub>O<sub>3</sub> and SnO<sub>2</sub> or garnets Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub> (YAG), GdAlO<sub>3</sub>

(GAG) seem to be specifically potential candidates for FED phosphor applications [73].

#### **1.8.4 Solar state lasers**

To improve the efficiency of Si solar cells, up-converting and down-converting phosphors with particle size in the nanometric range have been widely explored [74]. The nanophosphor coating increases the amount of light energy being converted, which enhances the energy production while also reducing damage to the solar cell from the UV light. The luminescence output of solar cells can be significantly improved by coating nanoparticles on the solar cells or modules.

#### **1.8.5 Biomedical Diagnostics**

RE doped inorganic nanophosphors find various applications in biomedical diagnostics [75]. Different types of radiations such as X-rays, THz-radiations, and microwaves are emitted by bio labels and nanophosphors. Hence, they can be used as potential probes in imaging, bio sensing, as well as in treatment and drug-delivery applications, and in characterizing various biological processes occurring in living organisms. Bacteria-mediated delivery of nanophosphors and cargo into cells of live animals has been reported by Akin et al. [76].  $\text{GdVO}_4:\text{Eu}^{3+}$  red light-emitting bifunctional nanophosphors, which have both luminescent and paramagnetic properties, are well suited for various biomedical applications such as for bioimaging applications with tracking capabilities [77]

#### **1.8.6 X-ray and Ionizing detection**

The procedure involves the application of RE based nanophosphors in X-ray intensifying screens, X-ray fluorescent screens, luminescent security inks, and authentication, scintillators and so on. In radiological diagnosis through X-ray intensifying screens of phosphors, the amount of unintentional radiation exposure risk to patients has been significantly reduced. In industrial applications, the testing time for non-destructive testing is considerably shortened [78]. Rare earth phosphors based scintillators are widely applied from medical imaging (PET and CT), industrial inspections and security applications. High class scintillators possess a high quantum efficiency, linearity of the spectral emission with respect to the incident energy, high density, fast decay time, minimal self-absorption and a high effective Z number. Rutgers University has patented a unique synthesizing method to prepare nano-sized

rare earth phosphors that can up-convert energy from IR wavelengths to emit higher energy in the visible spectrum. This technique is used in making scintillators with improved properties at a much-reduced cost, which are widely used in diagnostic testing.

### 1.8.7 White light emitting diodes (WLEDs)

In view of their potential for higher efficiency, longer life times, and lower energy consumption in comparison to conventional light sources, the use of white light emitting diodes, a creation of solid state lighting technology, has revolutionized the lighting industry. Lighting technology's recent designs include the UV-LED with tricolor RGB phosphors that produce single-phased white light emitting phosphors. Numerous UV-LED excited phosphors such as  $\text{Eu}^{2+}/\text{Sm}^{3+}$ -co-doped  $\text{SrSiO}_3$  [79], color tunable  $\text{Eu}^{3+}$  doped  $\text{BaLn}_2\text{ZnO}_5$  ( $\text{Ln} = \text{La, Gd or Y}$ ) [80], europium doped  $\text{CaLa}_2\text{ZnO}_5$  [81] and soon have been developed worldwide to meet the requirements of advanced lighting systems and the generally sought-after features of low electric energy consumption, high brightness, long life times, and environmental friendly characteristics.

## 1.9 REVIEW OF LITERATURE

Seeta Rama Raju et al [82] reported various concentrations of  $\text{Dy}^{3+}:\text{GdAlO}_3$  nanophosphor samples were prepared by solvothermal process. In his report XRD pattern confirms its orthorhombic structure, luminescence studies on these compounds have been carried out on the emission and excitation, along with lifetime measurements. The emission spectra show two strong bands in the blue ( ${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{15/2}$ ) and yellow ( ${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{13/2}$ ) regions. Tamrakar et al [83] structural characterization and luminescence spectra of  $\text{Yb}^{3+}$  doped  $\text{GdAlO}_3$  phosphors have been discussed. These compounds are prepared by combustion method using urea as a fuel emission peaks are due to transition between  ${}^2\text{F}_{7/2}$  to  ${}^2\text{F}_{5/2}$  states of  $\text{Yb}^{3+}$  ion. The emission spectra were recorded as a function of  $\text{Yb}^{3+}$  ion concentration. Intensity of the emission spectra is high at 5 mol %  $\text{Yb}^{3+}$  concentration. CIE coordinates indicates the phosphors emitters green colour in the visible region.

Matose et al [84] explained about GAP doped with europium synthesised by the non hydrolytic sol-gel route. Different phases such as GAP,  $\text{Gd}_3\text{Al}_5\text{O}_{12}$  (GAG), and  $\text{Gd}_4\text{Al}_2\text{O}_9$  (GAM) were obtained at lower temperatures. The charge transfer

bands depend on the symmetry of the  $\text{Eu}^{3+}$  ion site which was showed by excitation spectra. In PL measurements observed that  $\text{Eu}^{3+}$  was red emission. Sinha et al [85] investigated phase evolution and electrical conductivity of barium doped GAP nanophosphors. Which was prepared through citrate gel process. In phase analysis a second phase ( $\text{BaAl}_2\text{O}_4$ ) observed from above 0.04mol% of Ba doped composition which is due to less solubility limit of barium in GAP. The total electrical conductivity of Ba-doped GAP increased with increasing amounts of barium up to 2 mol % doping. The sintered density of the Ba doped GAP was quite low than Ca doped GAP.

Dotsenko et al [86] reported Yttrium-gadolinium aluminum garnets (YGdAG) doped with  $\text{Ce}^{3+}$  ions prepared by the co-precipitation method. At room temperature the  $\text{Ce}^{3+}$  ions in GdAG exhibit the maximum broadband emission at 583 nm. the crystal field splitting of the  $\text{Ce}^{3+}$  5d configuration and Stokes shift of the emission increases causing red shift of this emission with the respect to that of  $\text{Ce}^{3+}$  ions in YAG. The excitation spectrum for the  $\text{Ce}^{3+}$  emission in GdAG contains an intense 4f  $\rightarrow$ 5d excitation band at 186 nm (6.67 eV) was maximum due to the  $\text{Ce}^{3+}$  bound exciton absorption. Deng et al [87] studied  $\text{GdAlO}_3:1.5\%\text{Er}^{3+}, 8\%\text{Yb}^{3+}$  precursor was prepared by a co precipitation method by calcining the precipitate precursor at different temperatures. In their study its reported increasing calcinations temperature, the crystallinity of the phosphor improved accompanied by both the increased particle size and the decreased concentration of residual  $\text{OH}^-$  in the phosphor. The improved crystallinity and morphology enhanced the light absorption at 980 nm, while, the reduced concentration of residual OH species inhibited the non-radiative relaxation from the green emitting levels.

Kesavulu et.al [88] discussed  $\text{Tb}^{3+}$  doped gadolinium calcium silicoborate (BSGdCaTb) glasses prepared by conventional melt quenching technique. In their results given about the strongest excitation at 275 nm for  $\text{Gd}^{3+}$  ions and it generates the emissions of  $\text{Tb}^{3+}$  ions through energy transfer from host matrix to activator. In emission spectra showed strong green emission at 543 nm corresponding to  $^5\text{D}_4 \rightarrow ^7\text{F}_5$  transition with high experimental branching ratio of 59.7 %, CCT of 6036 K and high color purity of 78 % compared to other  $\text{Tb}^{3+}$  doped BSGdCaTb glasses. Oliveira et.al [89] reported the  $\text{GdAlO}_3:\text{RE}^{3+}$  perovskites by the Pechini method at 700, 900 and 1100 °C. In their report observed in excitation spectra there is an energy transfer from

Gd<sup>3+</sup> to RE<sup>3+</sup>. The RE<sup>3+</sup> ions occupy minimum one site without center of symmetry. In photoluminescence measurements characteristic red emission of Eu<sup>3+</sup> and the blue/green emission of Tb<sup>3+</sup> were observed and the blue green emission composition color of Tb<sup>3+</sup> samples can be tuned by amount doping.

Saji et.al [90] investigated GdAlO<sub>3</sub> perovskite ceramic materials were synthesized by auto combustion process, via citrate-nitrate method. In their studies reveal that phase pure GdAlO<sub>3</sub> nanocrystals form after calcinations at 1000 °C for 2 h. The UV -Vis spectra analysis reported that the material has a wide band gap, E<sub>g</sub> = 3.4 eV at room temperature which makes the material suitable for UV shielding and transparent conducting oxide films for window layers on solar cells. Teng et.al [91] reported Tb doped GAP garnet (Gd<sub>1-x</sub>Tb<sub>x</sub>) AG (x=0.07-0.15) phosphors have been obtained by calcining their precursors synthesized through carbonate co-precipitation at 1500 °C. In their analysis (Gd<sub>1-x</sub>Tb<sub>x</sub>) AG powders have good dispersion and fairly uniform particle morphologies shows strong green emission at ~544 nm. The emission intensity and quantum yield of (Gd<sub>0.9</sub>Tb<sub>0.1</sub>)AG under 277 nm excitation were both higher than (Y<sub>0.9</sub>Tb<sub>0.1</sub>)AG and (Lu<sub>0.9</sub>Tb<sub>0.1</sub>)AG garnets due to the Gd<sup>3+</sup>-Tb<sup>3+</sup> efficient energy transfer. Upadhyay et al [92] GdAlO<sub>3</sub>:Eu<sup>3+</sup> doped phosphor synthesized by solid state synthesis method. The PL emission was observed in the range 400- 650 nm ranges with intense red emission centred at 613 nm peak for the GAP phosphor doped with Eu<sup>3+</sup>. Excitation spectrum found at 266nm. Broad intense peaks found around 594 and 613 with high intensity. The results indicate that GdAlO<sub>3</sub>:Eu<sup>3+</sup> (5%) phosphors can be selected as a potential candidate for FL (Fluorescent Lamp) and Compact Fluorescent Lamp (CFL).

Shilpa et.al [93] reported GdAlO<sub>3</sub>, GdAlO<sub>3</sub>:Eu<sup>3+</sup> and GdAlO<sub>3</sub>:Eu<sup>3+</sup>:Bi<sup>3+</sup> nanophosphors were synthesised by solution combustion technique and obtained pure orthorhombic phase as confirmed by powder X-ray diffraction (PXRD) studies. The average crystallite size for GdAlO<sub>3</sub>, GdAlO<sub>3</sub>:Eu<sup>3+</sup>, GdAlO<sub>3</sub>:Eu<sup>3+</sup>: Bi<sup>3+</sup> was found to be 38, 34 and 26 nm respectively. In PL the highest emission peak at 612 nm was observed in the Eu<sup>3+</sup> electric dipole transition of <sup>5</sup>D<sub>0</sub>→<sup>7</sup>F<sub>2</sub>. The weak emission peaks around 590, 654, 700 and 780 nm were due to the transition of Eu<sup>3+</sup> ions from <sup>5</sup>D<sub>0</sub>→<sup>7</sup>F<sub>1</sub>, 2, 4, and 5. The critical transfer distance (R<sub>c</sub>) of Eu<sup>3+</sup> ions was calculated to be 11.22 Å. The CIE chromaticity co-ordinates show orange red color of Eu doped phosphors. Whereas, deep red color show in addition of Bi in GdAlO<sub>3</sub>:Eu<sup>3+</sup>. V.

Lojpur et.al [94] was investigated for application in luminescence thermometry  $\text{Eu}^{3+}$  doped GAP powder synthesized by solid state reaction. Fluorescence intensity ratio and lifetime methods were used for monitoring luminescence changes. Maximum value of relative sensitivity was  $2.96 \% \text{ K}^{-1}$  at 293 K with fluorescence intensity ratio whereas lifetime method obtained and relative sensitivity is  $2.28 \% \text{ K}^{-1}$  at 793 K. From the obtained results it can be summarised that  $\text{GdAlO}_3$  doped with  $\text{Eu}^{3+}$  ion can be used as material for luminescence temperature measuring for temperatures up to 793 K.

### **1.10 SCOPE OF THE PRESENT WORK**

In the last two decades considerable interest has been directed towards the synthesis and characterization of economical and efficient rare earth doped phosphors using different hosts has been developed for various applications. For example, the red emission of  $\text{Eu}^{3+}$  and green emission of  $\text{Tb}^{3+}$  is usually used in these phosphors. These phosphors find applications in fluorescent lamps, color TV screen, cathode ray tubes, Plasma Display Panels, discharge lamps etc. These phosphors are not commercially synthesized in India, and are imported. Also, no systematic efforts were made towards studying the use of indigenous chemicals for the synthesis of these phosphors.

The current generation need high productive phosphors with ecofriendly route having longer life time. Therefore leading requirement for better future environment are mercury free lamps phosphors more efficiency under excitation with ultraviolet radiation and high quality physical and chemical stability.  $\text{ABO}_3$  type perovskites are having remarkable application in diverse field such as phosphor, scintillator, dielectric resonator etc [82]. Among the perovskite class of materials, GAP ( $\text{GdAlO}_3$ ) are currently under development candidate material for neutron absorption, solar cells, sensors, dielectric materials, photocatalysts, luminescent and in control rod applications. The possibility of developing a novel compound that offer due to remarkable properties such as high density, chemical stability, low thermal expansion ,spectroscopic properties as colour purity, high luminous yield,  $\text{Gd}^{3+} \rightarrow \text{RE}^{3+}$  energy transfer and minimum environmental impact continues to be the subject of research interest in the recent years [83]. Comprehensive and in-depth understanding of the structural changes that occur when the particle size is reduced can be helpful in developing specific applications that use nanocrystalline materials.

The work presented in this thesis summarizes the experimental results of the GdAlO<sub>3</sub> phosphors synthesized using solution combustion technique using homemade fuel ODH. The phosphors presented in this thesis were selected in view of their application potential. These phosphors doped with different concentrations of Eu<sup>3+</sup>, Dy<sup>3+</sup>, Tb<sup>3+</sup>, and Co<sup>2+</sup> formed the subjects for the study. Because the production of white light emitting diodes (WLEDs) is currently a primary requirement for the present-day energy saving lamps which are becoming popular globally, phosphor synthesis will help the local industry by enabling them to use in digenously developed phosphor materials. The phosphors GdAlO<sub>3</sub> doped with the above-mentioned RE materials were synthesized, their structure and photoluminescence properties are systematically studied. The conductivity properties of GdAlO<sub>3</sub> doped with Eu<sup>3+</sup> and CO<sup>2+</sup> were also extensively analysed.

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